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CENTRAL AMERICA REGIONAL PROGRAMMATIC STUDY FOR THE ENERGY SECTOR

MANAGING AN ELECTRICITY SHORTFALL

A Guide for Policymakers

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Energy Cluster

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Energy Sector Management Assistance Programme

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank and assists low- and middle-income countries to increase know-how and institutional capability to achieve environmentally sustainable energy solutions for poverty reduction and economic growth.

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Abbreviations and Acronyms

AMI	Advanced metering infrastructure
AMR	Automatic meter reading
CC	Combined cycle
CCGT	Combined cycle gas turbine
CFL	Compact fluorescent lamp
CPC	Confederación de la Producción y del Comercio de Chile
CTP	Critical peak pricing
DSM	Demand side management
EPC	Engineer procure and construct
ERNC	Energías renovables no convencionales
GDP	Gross domestic product
GT	Gas turbine
GW	Gigawatt
GWh	Gigawatt hour
HFO	Heavy fuel oil
HVAC	Heating, Ventilation, Air Conditioning
ICE	Instituto Costarricense de Electricidad
IEA	International Energy Agency
IPP	Independent power producer
kW	Kilowatt
kWh	Kilowatt hour
LDO	Light distillate oil
LFO	Light fuel oil
MVAR	Mega Volt Ampere reactive
MW	Megawatt
MWh	Megawatt hour
O&M	Operation and maintenance
OCGT	Open Cycle Gas Turbines
PPA	Power Purchasing Agreement
RTP	Real time pricing
SC	Single cycle
SIEPAC	Sistema de Interconexion Electrica para America Central
SOE	State owned enterprise
TOU	Time of use
VOLL	Value of lost load
W	Watt

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PREFACE

Economic growth in Central America has rapidly increased over the past twenty years. Currently, the GDP per capita for the six Central American countries of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama averages approximately US$3,600. However, masked behind this average figure is a sub-region of 40 million with a wide variety of income and where more than half of the population lives in poverty.

Energy in general and electricity specifically are critical for economic development. Electricity is needed to power the machinery that supports income generating opportunities. Capital (both domestic and foreign) is attracted to countries that are able to offer an affordable, reliable source of electricity for businesses. Investment in secure, reliable and reasonably priced sources of energy that promote efficient consumption is necessary for sustained economic growth.

Although the individual electricity markets of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama are not large, together the six countries collectively generated nearly 38 TWh of power -- equivalent to around 70 percent of the annual electricity supply of a medium-sized country in Latin America. However, individual electricity markets in this sub-region are very different, ranging from vertically integrated to totally unbundled systems. Electricity markets also vary significantly in their quality of service, and in their efficiency in production and delivery. In addition, the fragmentation of the sub-region's electricity market into small units has presented challenges to meet a growing demand and has raised supply costs.

The SIEPAC Electrical Interconnection System, which will link the six countries in 2010, could bring a number of associated benefits such as the improvement of energy security through increased reserve margins, as well as efficiency gains and lower costs through economies of scale. Integration is necessary, but not sufficient, to meet the sub-region's electricity needs and there remain a number of steps to be taken in both the short and long term to be able to fully exploit the benefits of integration. These include addressing physical, regulatory, institutional and political issues on both national and regional levels as part of an effective integration plan.

The World Bank has undertaken a series of studies to better understand the energy challenges facing these six countries of Central America that are to be joined by SIEPAC and to identify actions to promote the sound development of the sector. These studies have been prepared by a team of policy experts, engineers, and economists as part of an integrated series entitled the Central America Programmatic Energy Studies, with a primary focus on the electricity sub-sector. The initial phase of this programmatic series includes three modules. An overview module sets the stage for further analysis by systematically examining the electricity sub-sector and identifying major challenges both at the individual country and regional levels. The managing electricity shortfalls module evaluates the effectiveness of supply side and demand side actions to address actual or looming shortages. For longer-term sustainability, the regional regulatory module identifies barriers to electricity integration and proposes actions to overcome them. The

World Bank is also proposing additional modules, including on the potential for further development of geothermal energy in the sub-region.

It is our hope that this series of studies will help policy makers and other stakeholders in these six countries to address the issues necessary to create a reliable and efficient energy system that serves as a solid foundation for economic growth in the sub-region.

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EXECUTIVE SUMMARY

I. Introduction

1. Supply-demand tension has taken its toll in various countries around the world over the last several years. Governments and utilities have faced gaps between electricity supply and demand, which has led to blackouts and load shedding and translated into electricity shortfalls. While countries look to avoid the prospects of supply shortages by, inter alia, strengthening their planning capacity and working to achieve a sounder and more sustainable electricity sector, the possibility of shortages in the future remains.

2. This document summarizes the framework for action and a broad menu of options available to policymakers to bridge a supply-demand gap in the short- to medium-term. These topics are covered more extensively in the report "Managing an Electricity Shortfall: A Guide for Policymakers." It is our hope that the information in this note will provide valuable insights for energy policymakers around the world.

II. Elements of a Program to Manage an Electricity Crisis

3. While it may not be known when or why, it is certain that there will be future electricity crises and that they are likely to occur in both industrialized and developing countries.

An electricity crisis is characterized by an occurrence of electricity shortages which can find their origin in:

- **Capacity constraints:** the available capacity (generation and/or transmission) is insufficient to meet peak demand; or
- **Energy constraints:** the desired electricity consumption of all end-users, over an extended period of time, exceeds the production levels (e.g., as a result of insufficient fuel availability, such as water resources or fossil fuels or a surge in energy demand).

4. Elements of a tailored response to an electricity crisis will depend on: (i) the origin of the supply-demand gap, (ii) the expected duration of the shortfall (and the lead time available), (iii) the identification and evaluation of measures that can realistically be implemented (from both the supply and demand side) and, (iv) the institutional

organization of the sector. There is no one-size-fits-all solution to an electricity crisis. Policymakers should design a tailored response on the basis of these four factors.

5. **One of the most important elements of an electricity emergency response program is anticipating and preparing for the possibility of a crisis.**

A. Emergency Response Actions:

6. **Managing an electricity crisis involves actions to alleviate the capacity or energy constraints through a combination of measures affecting either the demand for electricity or the supply.** International experience shows that successful management of an electricity crisis requires the implementation of a range of measures including strong energy conservation campaigns, actions to reduce end-use consumption, efforts to reduce energy production losses and remove transmission bottlenecks, and measures to increase supply.

B. Demand side measures:

7. **Demand side measures are an essential dimension to mitigate electricity crises.** Demand side measures focus on reducing the quantity of electricity consumed such as through modifying tariffs, increasing energy efficiency, or affecting consumption behavior. Because the demand for electricity is a derived demand for lighting, cooling, heating, power for commercial and industrial processes, and other electricity uses, demand side measures will seek to affect end-uses. International experience indicates that successfully dealing with electricity crises entails using demand side instruments to limit the quantity of electricity consumed. The optimal mix of instruments will depend on the timing and nature of the crisis.

8. **Demand side adjustments act through direct or indirect price signals and through quantity restrictions.** Direct price signals – increases in the price of electricity – create incentives for users to save electricity (through the price elasticity mechanism). Indirect signals include, for example, subsidies for the purchase of more energy-efficient appliances. Quantity restrictions – or rationing – are an alternative way of ensuring that demand and supply balance in the short run. Rationing can be specific or general. Specific rationing takes the form of an administrative rule determining which users will cut back, when, and by how much. A general rationing rule will be based on geographical area or economic activity (such as a neighborhood or an industry) or type of users (such as consumers with an electricity load exceeding 1 MW).

9. **Electricity tariffs are one of the key elements in determining the rational use of energy.** There are two important caveats, however, to keep in mind when considering the effectiveness of tariffs. First, for many small users there is a time lag between when

electricity is consumed and when the electricity bill is paid. For a short-term crisis, this delay could limit the impact of a tariff adjustment. Secondly, the effectiveness of tariffs will depend on the nature of the crisis. For example, capacity constraints require a reduction in peak demand which occurs at specific times during the day and varies according to seasons. Unless the tariff structure includes time-of-day or seasonal pricing, rather than the typical structure based on the overall volume of consumption, a general tariff increase will not ameliorate a capacity-constrained crisis.

10. **Table 1 provides a list of demand side options available for managing an electricity crisis, covering adjustments in electricity prices, behavioral changes, and the introduction of more efficient technologies.**

Table 1. Menu of Demand Side Options for Managing Electricity Crises						
Measure	**Main characteristics**	**Time Frame**	**Est Cost US$/KWh**	**Prerequisites**	**Best Practice**	**Comments**
Increase electricity prices						
Increase Industrial Tariffs	Signal through price mechanisms crisis intensity; decentralize savings decisions.	Short Term	(Varied)	Need smart meters in place; use of wire transfers available; existence of long-term contracts, ability to resell contracted energy.		Powerful signal to induce desired changes in behavior acting on both supply and demand. Efficient structure will signal advantage to consume or shut down an sell power to the market.
Increase Residential Tariffs	Signal scarcity to residential users.	Short and Medium Term	(Varied)	Need ata on residential consumption (load curve and elasticities), political willingness, able to wait for delayed response.	Chile 2007-08 Electricity Crisis Management	Best suited for energy crisis as residential consumers have no time of use meters. Complement of media campaign rather than substitute.
Induce Changes in Behavior						
Launch a Mass Media Campaign	Involves communicating to consumers about electricity crisis information and proposed measures for saving energy.	Short Term	(Varied)	Need to identify channels and choose message content to use; ability to sustain media campaign over time.	South Africa Power Alert	This is a key element of a crisis strategy, but often needs to be complemented by other measures. Users need to understand that their actions affect the outcome of the crisis.
Mandate/Encourage Public Sector Energy Conservation	Re-allocating public sector uses of energy to more socially responsible purposes that conserve electricity.	Short and Medium Term	(Varied)	Need to conduct energy audits and assess data on energy consumption.	Chile Energy Efficiency Policies for Public Sector	High visibility of government actions signals strong commitment and increase likely response by public. Increasing public service uses of energy can have large impact (water pumping).
Encourage Voluntary Rationing	Involves voluntarily reducing electricity consumption	Short Term		Need appropriate data to implement efficient partial rationing	Government voluntary rationing: Brazil, Ontario, and Tokyo	Often the government is the first to engage in voluntary rationing, with hopes that industry and residential consumers will follow by example.
Mandate Compulsory Rationing	Consumers are given restricted electricity usage by mandate.	Short Term		Need data to implement efficient partial rationing; ability to compensate for or justify the social and economic disruption costs.	Norway "10 for 10" Campaign	Involuntary rationing should be used only as a last resort to preserve the integrity of the electricity system in the immediate term.
Introduce More Energy-Efficient Technologies						
Launch CFL Replacement Program	light bulb efficiency, including public lighting (traffic lights, street lights).	Medium Term	0.023	Need an in-place distribution channel and mechanism; a mechanism for ensuring destruction of old bulbs.	Cuba CFL Replacement Program	Introduction of efficient lightning through the distribution of CFLs is the most cost effective measure to reduce demand.
Launch Appliance Replacement Program	Replacement of inefficient appliances for residential & industrial users.	Medium Term	0.150	Need an in-place distribution channel and mechanism; a process for ensuring destruction of refrigerators.	Cuba Appliance Replacement Program	Need detailed information on existing stocks and use habits to design efficient campaign.
Short Term: Within 6 months; Medium Term: Within 24 months.						

C. Supply Side Measures:

11. **Supply side responses to electricity crises primarily involve increasing generation capacity and its availability.** In addition to a country's long-term electricity expansion plan, there are short- and medium-term opportunities to improve the performance of currently installed equipment which can be the most expeditious means to increase effective generating capacity. This can include increasing the availability of generating capacity (such as by improving maintenance), or by reducing losses in transmission or distribution. Any measures which involve investments in capital equipment are unlikely to be effective in relieving a short-term electricity crisis. However, if the crisis is longer than a few months, such measures may become feasible.

12. **Although many countries perceive diesel fuel based power generation as the most effective way to increase generating capacity, this may not always, or even generally, be the case.** Most countries have implemented emergency generation plans that include reciprocating high speed engines using diesel fuel or medium speed engines using heavy fuel oil (HFO). However, diesel fuel is a high-cost option and also suffers from price volatility. In addition, time can still be a constraint to implementing petroleum-based generation capacity. Medium speed engines may take as long as 24 to 30 months to engineer, procure, and construct. The rehabilitation of existing facilities, repowering, and the mobilization of back-up generation are typically quicker and more efficient ways to increase the supply of electricity.

13. **To manage electricity crises, the authorities in several countries have resorted to leasing temporary mobile generating stations** and implemented other measures focusing largely on increasing electricity supply. This is often a costly and suboptimal solution.

14. **Deciding which technology or solution to implement will depend on the particular circumstances of the country.** The costs of bringing in new capacity quickly should be analyzed against slower measures that are cheaper. Also, every solution will have implementation costs such as for incentive payments, expediting costs, spare parts, and additional capital, which should also be assessed on a case-by-case basis.

Table 2 provides a menu of supply side options for managing electricity crises.

Table 2. Menu of Supply Side Options for Managing Electricity Crises						
Measure	**Main characteristics**	**Time Frame**	**Est Cost US$/KWh**	**Prerequisites**	**Best Practice**	**Comments**
Improve Generation and Transmission Outputs (Increase Availability)	Allows improvements in the output of existing assets in the sector; valid for generation and transmission assets.	Medium Term	(Varied)	Data on availability limitations needs to be readily available.	Philippines Overhaul of Diesel Plant	For SOE, decisions are within the company and can be implemented quickly. In competitive markets, price signals should induce efficient levels of effort. Envoronmental restrictions can be binding constraint.
Rehabilitate/Repower Existing Equipment (Increase Capacity)	This increases capacity by Improving the operation of existing equipment, repowering existing equipment or rehabilitating retired or de-rated units.	Medium Term	(Varied)	Data on capacity limitations needs to be readily available.	Philippines Overhaul of Diesel Plant	It is important to assess the costs of parts for corrective maintenance or rehabilitation as these can be costly.
Expedite Completion of Plants Under Construction	Start with plants and transmission lines within Expansion Plans and advance the completion date to prevent schedule slippages.	Medium Term	(Varied)	Cost of expediting efforts or incentives to contractors and owners to adhere to reduced schedule; need to determine effectiveness of expediting the schedule		Advancing project implementation schedules is often effective to keep overall project completion on target.
Offer PPAs on a short term basis	Integrate backup generation into the dispatch pool for peaking by offering PPAs to make use of existing operating equipment.	Short Term	(Varied)	Need to create PPAs with appropriately lined and priced incentives to effectively target backup generation options.		Prevents blackouts.
Increase availability of bagasse fueled plants	Bagasse fueled plants are often used by sugar cane mills only during the sugar cane harvest -- use for alternative fuels after harvest.	Short Term	0.147	Need to assess data on existing on-site generation available plants. Rules and tariffs for use of wires and standardized PPA needed.		Buying power from existing generators can provide energy at reasonable cost in a short period of time. However, one needs agreement from owners and could face high priced fuel and capacity charges under PPA.
Add Capacitor Banks to Reduce Transmission Losses	Add capacitor banks at sites which reduce transmission system losses and can increase the operating MW capacity of existing generators.	Medium Term	$4.5 million for 90 MVAR at 230 kV	Need to cover cost of capacitor installations; need to update transmission system data.		Reduces transmission system losses and can increase MW capacity of existing generators, avoiding costs of installing new generation facilities.
Install Advanced Metering Systems to Reduce Losses	Reducing technical and non-technical losses cthrough installing new metering technologies	Medium Term	(Varied)	Data on sources of losses (technical, commercial); social and political feasibility; public acceptance of new metering technologies.	Colombia Integrated Power System (Cartagena)	Different metering technologies are available to help reduce technical and non-technical losses. Prepaid meters and integrated power systems can have substantive impact on losses.
Install High Speed Reciprocating Engines	Install high speed reciprocating engines to operate on a temporary basis.	Short/Medium Term	0.151	Need to obtain pricing data; need to be able to pay for high fuel costs and rental fees.		Fast to install, but very high fuel costs. Plants typically available for lease for short periods in containers which allow different plant sizes.
Lease Power Generation Barges, or Fixed Gas Turbine, Simple Cycle	Install leased power generation barges equipped with reciprocating engines or combustion turbines.	Short/Medium Term	$700/ kw for used barges; $650/kw to $850/kw for simple cycle	Need to obtain pricing and other available data, and be able to pay high cost fuel and rental fees or purchase costs, cost to prepare waterfront site, or land site.		Relatively large capacity additons possible in short time frame.
Lease or Purchase Used Power Plant Equipment	Lease or purchase used power plant equipment with a warranty less than for new equipment.	Short/Medium Term	(Varied), with high risk due to limited warranty	Need a defined schedule to implement usedpower plant equipment as soon as possible to minimize warranty risks		Large capacity additions possible, reduction of construction and operating risk
Short Term: Within 6 months; Medium Term: Within 24 months.						

III. Crafting an Emergency Response Program: Evaluating the Options and Choosing a Plan of Action

15. **The selection of measures will depend on an evaluation of the options given the nature of the crisis and other key factors.** The choice of measures will depend on how rapidly the impacts need to be felt. For any system there will be multiple combinations of options to increase supply and reduce demand. In the short run (less than six months) there are generally very limited opportunities to increase generation capacity. Some supply side measures targeting the availability of existing plants and/or purchases from captive generators can be effective in this time period. This means that in the short run the burden of adjustment will generally lie on the demand side.

16. **The impacts of measures can be classified according to the time period in which they take effect:**

- ***Very short run (a few weeks):*** No supply response is easily available. Demand responses are limited to changes in behavior given existing technology (such as switching off lights, air conditioning, hot-water heaters, and other non-essential equipment) that are normally induced voluntarily or through quantity restrictions (general rationing).
- ***Short run (within six months):*** Little supply response is easily available. A wider range of demand responses is available, including some minor technical changes which involve capital expenditure to replace existing appliances (such as CFLs). A wider range of price (changes in tariffs) and quantity incentives (specific rationing) can also be used.
- ***Medium run (up to 24 months):*** Some supply responses are likely to be available (such as increasing the availability of existing plants, co-generation from existing capacity, and speeding up projects under construction). Demand responses include making 'easy' switches in technology. A full set of price and quantity incentives are available.
- ***Long run (years):*** The full range of supply and demand responses is possible.

17. **Lessons from a wide range of international experience show that successful crisis management depends on implementing an emergency response package** composed of a variety of complementary measures. Those measures will depend on the cause and nature of the crisis, the institutional capacity of the country to rapidly deploy short-term measures, and the cost and benefits of those measures as well as their public acceptance.

18. **Identifying emergency responses will require a thorough examination of the effectiveness of individual measures, and of combining measures, to achieve the desired results.** For example, in some cases, price and rationing mechanisms can be used simultaneously. A useful principle is to assign each customer with a quota of electricity. If their consumption exceeds that quota, they face a financial penalty. If they save in relation to the given quota they receive a financial bonus. To be efficient and cost effective, rationing should be designed in such a way that it provides an incentive for consumers to reduce their lowest-value consumption. When the crisis arises from a capacity constraint, energy savings are needed during peak consumption. In many cases the metering equipment in place does not measure the time of consumption and thus cannot send an appropriate price signal to mitigate the crisis. Only a few countries use peak-load tariffs for large electricity consumers, which can reward off-peak and penalize on-peak consumption. Residential users typically pay energy-only tariffs and have meters which only record total electricity usage.

19. **Measures to mitigate the social impacts of the crisis are needed and should be well targeted.** In a market-based system, there is always a danger that a severe supply-demand gap could result in a price spike. If shortages last for more than a few days, price increases to final consumers are sometimes necessary. This in turn, can generate affordability problems, especially for low income consumers. However, responding to an increase in electricity prices with direct or indirect subsidies could exacerbate the energy crisis if there is no incentive for consumers to reduce their electricity consumption. Large-scale subsidies could also create a fiscal crisis. Market-based pricing and rationing schemes should be used to reduce electricity demand, while direct or indirect subsidies should be used to guarantee minimum electricity supplies for the poor.

20. **Regulatory constraints can affect the range of options available and the impact on different stakeholders.** Legal or administrative restrictions often prevent the use of certain instruments. For example, tariff changes may have to be approved through a pre-defined administrative process that involves public hearings, which means that increasing tariffs may not be a possible solution in the short term. The regulatory regime can also affect the impact of emergency response measures on different stakeholders. For example, a demand reduction can negatively affect the financial situation of a distribution company working under a price cap, even if the crisis originated in the generation sector.

21. **Taking into account possible negative effects on stakeholders is therefore critical.** The challenge facing decision makers is to find the optimal combination of demand and supply measures which will impose the least cost on the economy in terms of reduced output, employment, and social disruption. In addition, demand-side management, as a general proposition, has a smaller environmental footprint (for both

local and global pollutants) than supply-side interventions involving increased generation.

IV. Steps to Formulate an Emergency Response Program

22. **When formulating an emergency response to an electricity crisis the following steps should be taken:**

- **Identify the nature of the problem, including:**
  - **The nature of the electricity shortfall.** Every crisis is unique and the shortfall could be in peak capacity or in energy.
  - **The probable duration of the shortfall.** Appropriate responses will depend on the estimated duration of the shortfall.
  - **The breakdown of energy consumption by end-uses during the shortfall period to understand potential crisis impacts and to better define mitigation measures.** The most reliable approach is to build on existing detailed customer surveys, provided these include end-use monitoring, load surveys, appliance saturation surveys, and other available data. Obtaining details on the energy consumption of the largest customers is essential. This information will detail how much electricity is consumed by each sector, what appliances and equipment are responsible for the energy used, and under which contractual terms energy is consumed. This can in turn allow an assessment of the feasibility of temporarily disconnecting some large users.

- **Identify a wide array of emergency measures** to both reduce/manage demand and increase supply. Emergency responses tend to focus more on supply responses than on demand. International experience shows that success in mitigating electricity crises comes from an integrated use of demand and supply measures.

- **Identify and measure the impacts of the proposed emergency responses to ensure their fiscal feasibility and social acceptability.** Having a fair distribution of costs and having people perceive it as such is critical to effectively implement emergency response measures and to obtain broad public support. Good practice in this regard involves providing funds to shield the poor from price increases through a clear and transparent targeting mechanism.

- **Rank measures according to their costs and benefits to understand orders of magnitude and to set expectations**. A rapid evaluation carried out by the World Bank on six different measures showed that demand side measures focused on appliance replacement (lamps, refrigerators and electric showers) have lower costs for the savings achieved (levelized cost per kWh saved) than supply side measures focused on adding short term capacity. Costs range from $0.02 per kWh saved for a program replacing light bulbs with efficient compact fluorescent lamps (CFLs) to $0.20 or more for leasing high speed diesel engines. In addition, supply side measures add a significant energy price volatility element through the added fuel price risk.

V. Preparing for the "Next" Crisis

23. **International experience shows that emergency response preparation and crisis management has been better handled in countries that anticipated a potential crisis** and that prepared a detailed emergency response plan before the crisis struck. Some of the key enabling factors are:

- The ability to mobilize a coordinated response, which combines demand and supply measures and draws on a variety of existing entities (electricity utilities, regulators, line ministries) and policy mechanisms.
- The quality of information on energy supply and demand.
- The quality of information available to clearly identify entities and citizens at risk of being most impacted by an electricity crisis, and those which could potentially contribute to mitigate the impact of a crisis (such as identifying large consumers whose electricity consumption can be interrupted or rescheduled).

24. Ideally, countries will be able to reduce the likelihood of a crisis through strong planning. However, external shocks and the possibility of weaknesses in planning, or the combination of various factors, make the probability for an electricity crisis sufficiently high to warrant the active preparation of an emergency response plan. In addition, many of the actions set out above (such as energy efficiency, rehabilitation, or repowering) remain relevant under normal planning situations and may in fact be least-cost. Most importantly, experience shows that the better a government is prepared and equipped to address a potential electricity crisis, the higher the chances for sound energy sector growth and for mitigating the social and economic impacts in the event of such a crisis.

CHAPTER ONE
INTRODUCTION

1. Electricity shortages can be divided into three different categories. These three types of problems are not independent from each other. Nevertheless, they have different causes and will require different remedies.

- **Capacity constraints:** the available capacity (generation and/or transmission) is insufficient to meet peak demands;
- **Energy constraints:** the desired consumption of electricity by all users, over a period of time, exceeds the capacity of the system to supply it;
- **Reserve margin constraints:** the difference between installed capacity and peak demand is less than what is required.

2. A system is capacity constrained when the operational generating and/or transmission capacity is not enough to cover peak demand. Solutions can be implemented from the supply side (investment in new capacity) and/or from the demand side (reduce peak demand through load shifting or peak clipping).

3. Energy problems are caused by a gap between consumption levels and the ability to generate electricity over a period of time. Generation is determined by a combination of operational capacity (given by installed capacity and availability) and the ability to run it over sustained periods. This in turn depends in part upon technical requirements for maintenance and in part upon availability of primary energy source. In general, systems with a large share of hydro generation are more prone to energy constraints as it depends on the availability of water. The most likely type of problem will depend on the particular characteristics of each system. Typically hydro systems – and hydro thermal systems with a high hydro component – will be more prone to energy restrictions while pure thermal systems will generally be capacity constrained.

4. Most electricity systems usually require reserve margins of 10-20% of normal capacity as insurance against breakdowns in part of the system or sudden increases in energy demand[1]. Reserve margin problems are generally caused by investment - in generation or transmission - lagging behind demand increases. A reduced reserve margin results in less time to allow routine maintenance, to meet unanticipated surges in demand and to cope with an unanticipated lack of availability. A tight reserve margin will also leave less time for maintenance and induce the use of equipment above the optimal level.

[1] Hydro-thermal systems usually work with a much higher margin due to the relatively low capacity factor of hydro generators.

This in turn will increase the probability of outages leading to energy and or capacity problems in the system. In this sense a reserve margin problem can be seen as a leading indicator of the other two issues.

5. All three problems can be solved through demand and supply measures. For any system, there will be multiple combinations of increased supply capacity and reduced usage which will eliminate the problem. One of the key elements in determining the optimal mix of supply and demand measures will be the timeframe. In the short run (less than six months), there are generally very limited possibilities for increasing generation[2]. This means that during this time frame, the burden of the adjustment will generally be on the demand side.

6. Demand side adjustments act through direct or indirect price signals and through quantity restrictions. Direct price signals – increasing the price of electricity – create incentives for users to save electricity (through the price elasticity mechanism). Indirect signals, for example subsidies for installing appliances, are more energy efficient.

7. Quantity restrictions – rationing – is an alternative way of ensuring demand and supply balance in the short run. Rationing can be specific or general. Specific rationing takes the form of an administrative rule determining which users will cut back, when and by how much. A general rationing rule will be based on geographical area or economic activity (i.e. cement plants) or type of users (i.e. loads over 1 MW of demand) rather than on specific users. In some cases, price and rationing mechanism are used simultaneously as for example in Brazil during the 2002 crisis. The principle is that each customer has a quota of what is available. If they consume above that quota, there is a negative financial implication (penalty), and if they save in relation to the given quota there is a positive financial incentive (bonus).

8. The policy problem is to find the optimal combination of supply and demand measures which will impose the least cost on the economy in terms of reduced output, employment, and social disruption. The optimal policy mix will be a direct function of the nature of the crisis. Both peak demand and total consumption can be affected by price but they are not necessarily affected in the same way. In addition, as many supply-side interventions involve increased thermal generation, demand-side interventions generally have a smaller carbon footprint-an issue which is likely to become increasingly important in power sector management.

[2] Some supply side measures targeting availability of existing plants and or purchases from captive generators can be effective in this time period.

9. For an efficient policy design, it is important to understand the specific problem we wish to address and the appropriate instruments for doing so. Reaching users with the proper signal (price or quantity) is often the binding constraint. In many cases the necessary equipment is already in place. For example, in most countries large users are charged tariffs based on agreed peak demand. They pay penalty prices if they exceed these limits and have installed complex meters which track capacity and energy on a continuous basis. Residential users, on the other hand, will pay energy only tariffs and have meters which just record total energy.

10. Total energy consumption is affected by the cost to the user, although this is not the only determinant. For example, the possibility of fuel switching varies across users. Peak demand depends not only on the level of consumption but also on its pattern. In many cases the level of consumption can be reduced without changes in peak demand. In these cases, a general price rise may accentuate the difference between peak and average demand, with no reduction of the peak. Reducing demand through a price increase requires a time-of-use tariff structure for the user to see the proper economic signal. Similar considerations apply to rationing measures. Even when rationing reduces consumption, it may not reduce peak demand, and vice versa. To affect peak demand, the rationing instrument has to target a specific time of day or seasonal use.

11. The time dimension is also a key element when thinking about supply and demand policy responses to shortages. Impacts can be classified according to the time period in which they take effect:

- ***Very short run (few weeks):*** No supply response is possible. Demand responses are limited to changes in behavior within existing technology (i.e. switching off lights, air conditioning, hot-water geysers, etc.) normally induced voluntarily or through quantity restrictions (general rationing).
- ***Short run (couple of months):*** No supply response is possible. A wider range of demand responses is available, including some minor technical changes which involve capital expenditure to replace existing appliances (i.e. CFLs). A wider range of price (changes in tariffs) and quantity incentives (specific rationing) can be used.
- ***Medium run (up to 24 months):*** Some supply responses are available (i.e. increase availability of existing plants, co-generation from existing capacity, speeding projects under construction, etc.). Demand responses include making ‘easy’ switches in technology. A full set of price and quantity incentives are available.
- ***Long run (years):*** The full range of supply and demand responses is possible.

12. This classification is only tentative and will clearly lie on a continuum that will differ between systems, industries and firms. The expected duration of the shortage will

also influence the choice of instrument and the likely response of different types of users. In principle a shortage that is expected to last only a short period (hours or days) and not be repeated will produce a different response than one that is expected to be sustained for some time.

13. The institutional organization and institutional setting of the sector will also play a key role in the choice of instruments and the likely response of the different agents to the incentives. The main dimensions to consider include:

- Degree of private sector participation.
- Degree of vertical integration and competition in generation.
- Regulatory mechanism.
- Available instruments.
- Availability of information.

14. A sector with large private sector participation based on a competitive generation market will be more conducive to the use of price signals instead of rationing. In theory a competitive market will produce efficient price signals and there will always be a price sufficiently high as to ensure supply demand equilibrium in the short run. Even in the case in which quantity restrictions are needed a well developed market will optimize the outcomes as some users will choose to close production and sell their energy into the market.

15. The problem is that under this institutional setting a severe supply demand gap will result in the energy crisis turning into a price crisis. If the energy or capacity shortage lasts for more than a few days the price increases needed to balance supply and demand can generate affordability problems for many users (particularly low income residential users who have low price elasticity). Consequently, the price crisis evolves into a political crisis. Alternatively, an attempt by the government to mitigate the price crisis through direct or indirect subsidies aimed at insulating the population from the price increases can create a fiscal crisis (and exacerbate the energy crisis because users isolated from price signals will not reduce consumption). So, even if in theory a market based system can rely only on the price mechanism to solve shortages, in practice a combination of price and quantity measures will be needed to ensure long term sustainability.

16. Private sector participation – particularly in distribution - can also condition the response of consumers to appeals for lower consumption or requests for adoption of energy saving measures. In Latin America, there is some dissatisfaction with private sector participation in infrastructure. A recent study by Latinbarómetro[3] shows that in Latin America only 32% of the respondents are more satisfied with private utilities

[3]Latinbarómetro Report 2008.

(“servicios públicos privatizados”) than with the previous state owned companies. For Central American countries the degree of acceptance of private utilities is, with the exception of El Salvador (47%), even lower: 28% in Guatemala, 22% in Nicaragua and 20% in Panamá. The same report shows that only 16% of respondents in Latin America believe that electric utilities should be in private hands. This opposition to private sector participation might condition the response by consumers and is an important factor to take into account when designing a campaign to induce energy savings.

17. Information availability will also be highly conditioned by the institutional setting of the sector. In general, restructuring and privatization of the electricity sector has two impacts on data availability. First, vertical and horizontal unbundling will generally produce a fragmentation of information as no single player or entity has a comprehensive set of data. Secondly, introduction of competition turns information into a private good with a high market value. Reliable and timely information is a key ingredient in designing and implementing short term measures to reduce supply demand gaps in the electricity sector. A liberalized sector will require strong actions by the government to ensure the needed information is available during a crisis.

18. Regulatory mechanisms will also influence the set of instruments available and the impact that each one of them will have on the different stakeholders. A first element to consider is the potential legal and administrative restrictions which might prevent the use of certain instruments. For example, tariff changes may have to be approved through a pre defined administrative process including public hearings which means that it would not be possible to substantially increase tariffs in the short run.

19. The regulatory regime – price cap or cost of service – is mainly designed to provide different incentives for productive efficiency (cost minimization), sustainability (cost recovery), allocative efficiency (cost reflecting tariffs) and equity (access and affordability). But these mechanisms will also condition the impact that alternative measures used to cope with demand supply imbalances will have on the different stakeholders particularly in a vertically unbundled sector. For example, a demand reduction can negatively affect the financial situation of distribution companies working under a price cap even when the crisis has originated in the generation sector. Taking into account possible negative effects that disproportionally affect some stakeholders might be necessary, particularly when the crisis is relatively long.

20. In summary, the optimal response to a supply demand gap in the electricity sector will depend on the origin of the problem (energy, capacity or reserve margin constraints), the expected duration of the shortfall (and the lead time available), the available instruments (from both the supply and demand side) and the institutional organization of the sector. Examples abound of countries that have experienced an imbalance of

electricity supply and demand. Their responses have varied as the following nine examples show.

Table 1 – Responses to Electricity Supply-Demand Crisis - International Cases

Case	Source of Problem	Advance Warning	Duration	Main Measures	Estimated Savings
Brazil	Drought	5 months	10 months	Electricity rationing Penalties for failure to cut consumption Extensive press coverage Distribution of conservations devices to the poor Higher savings goal for public sector Fuel switching	20%
California	"Perfect Storm"	12 months	9 months	Over 200 programs involving all sectors Rebates to customers who used less than previous year Public awareness campaign Extensive media coverage Rebates for purchasing efficient appliances Higher prices to some customers Updated efficiency standards	14%
New Zealand	Droughts	2001 1 month 2003 1 month	2001 3 months 2003 6 weeks	Media campaign with suggested measures Establishing individual goals for all consumers Consumer hotline Rebates to some customers for successful conservation	10% 10% -2003
Norway	Drought	2 months	4 months	Extensive media campaign urging conservation Subsidy scheme for household conservation measures Fuel switching Close down of electricity intensive factories (to sell in the spot market)	8%
Ontario	Recovery from blackout	None	2 weeks	Appeals for conservation in mass media Shutdown of government offices Closure of electricity intensive industries Curtailments	17%
Tokyo	Nuclear plant closure	8 months	3 months	Frequent paid appeals and voluntary discussions in TV Utility staff visited thousands of customers to request conservation Leadership by example in government buildings Re-negotiation of interruptible contracts Shifting and rescheduling of factory production	4-5%
South Africa 2006 Cape Region	Rapid growth		1 year	Mass media campaign Voluntary conservations campaing (Power Alert) Efficient lighting (CFLs) Industrial, municipal, and commercial efficiency measures Subsidies on efficient appliances Extensive conservation drive Fuel switching (Gas cooking and heating) Water heating load management	400 MW (2006)
Cuba 2004 2005	Lack of Investment		over 2 years	Energy Revolution (EE, Increase availability and loss reduction, NCRE) Mass media campaign (grass roots organizations) Appliance replacement for residential sector (CFLs, Fridges, Fans, TVs,etc) EE measures in government sector Price Increases	20% saving in primary energy
Chile 2007-2008	Gas imports interruption + drought		over 1 year	Fuel Price Stabilization Fund Electricity subsidy for 40% most vulnerable population (direct subsidy) Reduction in voltage Media Campaign (Energy Savings) Day light saving time (extension) Financial offers from generators for consumption reductions by regulated 2009 CFL campaign	10% average 12% some months

Source: IEA, 2005 and authors.

21. The first six cases considered - Brazil, California, New Zealand, Norway, Ontario and Tokyo - are drawing largely from IEA, 2005. The other three cases – South Africa, Cuba and Chile – are own elaborations on which details can be found in annexes. The shortfalls occurred in many different forms of electricity markets and for diverse reasons.

The table summarizes the main elements of each crisis: source, duration, advance warning, main measures and savings obtained.

22. Four of the cases are pure energy shortfalls: Brazil, New Zealand, Norway and Chile. The first three were generated by droughts while the Chilean case was originated by a drought combined with the interruption of gas exports from Argentina. The common element in these cases is the need to cut total energy consumption during a period of time. The other five cases involve capacity restrictions meaning that the main objective was to reduce peak demand in the system rather than total energy. The cases included in IEA and the Chilean case relate to external events affecting the electric system during a relatively short period of time. The South African and Cuban cases, on the other hand, are crisis situations arising mainly from structural problems in the systems.

23. The rest of the report is organized as follows. Chapter 2 discusses demand side measures. Chapter 3 presents supply side alternatives for solving short term electricity crisis while Chapter 4 presents some practical recommendations for dealing with short term electricity crisis and data requirements for designing and implementing an efficient response to a crisis.

CHAPTER TWO
MEASURES TO RAPIDLY REDUCE THE DEMAND OF ELECTRICITY

2.1 Available measures

1. Reducing demand for electricity can be achieved through changes in the quantity demanded or through changes in demand patterns. Changes in quantity demanded are responses to changes in prices (tariffs). Demand for electricity is a derived demand for lightning, cooling, heating, power, etc. Changes in demand, therefore, will reflect changes in the demand for each one of these or to changes in the efficiency of the equipment using electricity.

2. There are three major instruments to reduce demand in the short run:
   - Increases in electricity prices.
   - Changes in behavior.
   - Introduction of more energy efficient technologies.

3. The international experiences reviewed shows that most countries use more than one instrument[4]. The optimal mix of instruments will depend on the time available to prepare before the shortfall arrives, the anticipated duration of the shortfall and the structure of the electricity markets (IEA, 2005).

4. Time to prepare clearly depends on two variables: advanced warning and preparedness of the system. Even if the nature of the crisis means that there will never be a very advanced warning, preparing for the eventuality of the next crisis is the key measure that needs to be taken.

5. Table 2 presents the measures taken by several countries that faced an emergency situation. Measures have been grouped into four main categories: communicating with customers, rationing, economic incentives and appliance replacements. We examined each measure separately in the following paragraphs.

[4] Some cases reviewed in IEA, 2005 and not included here show the use of a single instrument. This is the case for example of Arizona where given the short period to prepare – crisis originated in an fire in a substation - only requests to the population to reduce consumption were used.

Table 2– Demand Measures – International Experience

	Brazil	California	New Zealand	Norway	Ontario	Tokyo	South Africa	Cuba	Chile
Communicating with customers									
Channel									
- Media campaigns	x	x	x	x	x	x	x	x	x
- Press releases									
- Consumer Hotline			x						
- Internet		x	x						
- Individual visits						x		x	
Contents									
- General information on crisis	x	x					x		
- Evolution of situation	x			x					
- Requests for reducing consumption	x	x		x	x	x	x	x	x
- Specifc Measures			x				XXX		
Rationing									
Voluntary									
- Government	x				x	x			
- Industry				x		x			
- General	x		x				x		
Compulsory									
- Industry					x	x			
- General					x			x	
Fuel Switching	x			x			x		
Day light Saving Time									x
Economic Incentives									
Own Price									
- Tariff increases		x						x	x
- Tariff Rebates		x	x						
- Penalties for not acheving goals	XXX								
- Subsidies to protect poor									x
Price of Complements									
- Subsidies for EE meassures	x	x		x			x		x
Appliance Replacement									
- CFLs	x						x	XXX	x
- Others								x	

Source: authors.

2.1.1 Communicating with Customers

6. Communication actions aim at changing user's behavior. Two dimensions are considered: 1) the channel used to communicate with customers and 2) the content of the message. As we can see from the table, all countries considered resort to some form or other of broad communication campaign. Although this may appear as a soft measure as compared to physical investments, good communication proves to be absolutely indispensable to influence electricity demand behaviors rapidly. Mass media is the main tool for reaching consumers during an electricity crisis. No other tool can be as quickly mobilized and reach as many consumers as television, radio, newspapers and (increasingly) the internet (IEA, 2005).

7. The objective of mass media campaigns is informing and motivating consumers to take actions that will quickly reduce electricity consumption. The chain of events needed to achieve actions is enumerated in the Box below.

Box 1 – Chain of Events Necessary to Stimulate Consumer Action

The challenge of mobilization can best be appreciated by examining the chain of actions leading to implementing an electricity conservation measure. The steps are shown below:

- Consumer learns that a shortfall exists.
- Regardless of the cause, the consumer recognizes that measures to reduce electricity use must be taken.
- Consumer recognizes that his/her contribution will help mitigate the shortfall.
- Consumer decides to reduce electricity use.
- Consumer selects feasible measure from universe of alternatives.
- Consumer selects measure(s) to implement.
- Consumer arranges for implementation of measure (buys, hire contractor, studies operating manuals for thermostat, etc.
- Consumer implements measure.
- Electricity use declines (assuming measure actually works as intended).

The corporate consumer's decision path can become even more complicated as it balances costs, impacts on revenues and its public image.

The scale of this task can best be appreciated by quantitatively examining the chain of events. If an 80% success rate is achieved at each step, then less than 10% of all consumers will actually achieve electricity savings. An electricity conservation program will not deliver savings if any of the steps above have a low success rate.

8. To be effective, a mass media campaign has to link the solution to the shortfall to direct customer behavior. The choice of the channel to be used and the content of the message will be crucial to stimulate consumer actions. The Content of the messages will be different when dealing with a capacity or an energy shortfall. Capacity crisis requires users to take measures in specific time of the day (peaks).

9. Most utilities resort to qualitative appeals for conservation through television, radio and newspapers when a problem arises. But even where a real-time price is not available, utilities have found that other quantitative, non-price signals are also valuable. This information can more effectively describe the severity of a crisis and possibly help avert a blackout. Such signals alert customers to unstable situations and encourage more effective conservation. For example, during their droughts, Brazil, New Zealand and Norway broadcasted or published the key reservoir levels every day. The status was typically translated into remaining days of electricity supplies. These reports often became the starting point for many informal discussions among consumers and unquestionably raised awareness.

10. An innovative solution in providing real time information on the situation of the system and at the same time giving users information on specific measures to be taken at that moment is the Power Alert mechanism implemented in South Africa (see Box 2

below). The system, which can also be viewed online, has a very high impact at a very low cost. According to Eskom's information, the average impact per message of the National Power Alert goes from over 500 MW for brown alerts to slightly less than 100 MW for green alerts.

Box 2 – South Africa Power Alert

Power Alert is a residential load reduction Demand Side Management (DSM) project. Visual inserts in the form of Power Alert meters are broadcast on the main television channels at 30-minute intervals on weekdays between 17h30 and 20h30. These Power Alert meters give an indication of the strain on the electricity supply and will urge people to switch off their appliances if the need arises. This is not a permanent intervention. The Power Alert meter creates real-time awareness and voluntary reaction by the public when broadcast.

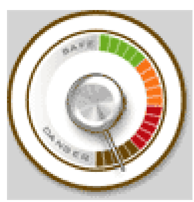
Four status levels occur, each calling for specific measures to be taken by consumers in all geographical areas. These are:

Green: indicates that there is only limited strain on the system. Consumers are requested to save power as part of their everyday activities to achieve energy efficiency.

Orange: the demand on the system is increasing. Consumers are prompted to switch off some non-essential power-consuming appliances. These include tumble dryers, dishwashers, pool pumps and unnecessary lights during peak periods.

Red: strain on the system is increasing and load shedding is imminent. Consumers are asked to take action by switching off geysers, stoves, microwave ovens, kettles, heaters, air conditioning units and unnecessary lights.

Brown: the most serious state indicates that there is significant strain on the national grid and that load shedding is being undertaken. Consumers are requested to switch off all appliances that are not absolutely necessary and rely only on essential lighting and their TV's (which, at this stage, indicate changed status as it occurs).



11. In terms of the content of the message, one of the main objectives is to inform the population on the available measures which can be taken to help reduce the supply demand gap. A list of the most commonly suggested measures is presented in Table 3.

Table 3 – Immediate Energy Saving Measures

Measure	Implementation		Effects	Relevant Sectors	Comments
	Time	Cost			
Changing hours of operation	Short	Low	Seasonal	Public Commercial Industry	Can help saving light (public and commercial sector) or save peak demand (industrial production shifts)
Fuel switching	Medium	Medium	Permanent	ALL	Only relevant for countries with other efficient energy source (gas)
Unplug freezer / second refrigerator	Short	Low	Permanent	Residential Commercial	A refrigerator or freezer draws 400 to 1000 kWh/year.
Reduce elevator / escalator service and speed	Short	Low	Permanent	Public Commercial	Some new escalators switch themselves off when not in use and speeds of elevators can be automatically varied depending on the demand.
Eliminate leaks in pressurized air systems	Short	Medium	Permanent	Industrial	Most systems are very leaky and waste much of the energy used to pressurize the system
Replace belt drives on motor systems	Short	Medium	Permanent	Industrial	Friction losses in motor belts represent up to a 10% loss in motor output
Enable power management features on computers	Short	Low	Permanent	ALL	Automatic in some peripherals. Might need assistance from IT department for computers
Shift pumping for water and sewage to off-peak	Short	Low	Temporal	Public Utilities	Many operators are not even aware of peak electricity consumption and opportunities to shift to offpeak.
Shorter showers / fewer baths	Short	Low	Temporal	Residential	Applies only where water is heated electrically.
Reducing light levels	Short	Low	Temporal	ALL	PROs: can be implemented almost immediately at negligible cost. CONS: changes in behavior or operating practices may be difficult to sustain.
Adjusting thermostats	Short	Low	Temporal	ALL	
Unplug appliances	Short	Low	Temporal	ALL	

Source: adapted from IEA, 2005.

12. The measures most quickly implemented typically require energy consumers to change operations or procedures. These actions sometimes result in inconvenience, discomfort or reduced productivity. Changes in procedures include switching off lights (or lowering lighting levels), adjusting thermostats, taking shorter showers, and reducing

(or shifting) hours of operation. Such measures are attractive because they can be implemented almost immediately and cost almost nothing. On the other hand, changes in behavior or operating practices may be difficult to sustain (IEA, 2005).

13. Unplugging appliances which are not used can have a major impact. Standby power represents up to about 10% of the electricity in homes and much of it is used by appliances that are "switched off" or inactive. It is an attractive operational measure because consumers easily understand the waste and they are not intimidated by unplugging most appliances.

2.1.2 Rationing

14. The second group of measures commonly adopted by countries facing an emergency situation includes voluntary and involuntary rationing for different categories of users: government, industrial and general. Rationing electricity or mandating reductions in consumption are the most drastic forms of electricity conservation.

15. The main objective of an electricity system, even in a crisis situation, is to avoid power cuts. This is not always possible and in some cases some level of rationing is needed to preserve the stability of the system. During the 2001 crisis, Brazil decided to implement mandatory energy savings for all electricity consumers in the country, aiming at reducing power consumption by 20%. Sectoral targets are listed in the Table below.

Table 4 – Energy Saving Targets in Brazil

Sector	Savings (%)
Street lighting	35
Public service agencies and some industry (steel, cement, chemical, mining, paper, wood, furniture)	25
Households (more than 100 kWh/month)	20
Industry (electric equipment, food, beverages, textiles, leather, oil and gas	15
Households (less than 100 kWh/month)	0

Source: IEA, 2005.

16. In New Zealand during the 2001 crisis, the government called for a voluntary 10% reduction in electricity use for ten weeks. Ten weeks was chosen as the duration because heating demands would have diminished and further rains were expected. This became its "10 for 10" campaign. It also called for 15% savings in the public sector. Similar measures, sponsored by industry rather than by the government, were implemented during the 2003 crisis.

17. Norway is an example of self administered rationing based on market signals. Electricity intensive industries (such as aluminum) with long-term, fixed-price contracts

with the local utilities found that it was more profitable to temporarily shut down operations and sell the electricity on the spot market (and did so). This was in line with the declared objective of the government of finding market based solutions to the crisis.

18. In the Ontario province of Canada, the provincial government requested a 50% reduction in consumption from all commercial and industrial customers. To achieve this goal, energy-intensive industries — such as automobile manufacturing and refining — shut down operations rather than face unpredictable curtailments. Provincial and federal governments shut down all non-essential operations.

19. In Tokyo (Japan), during the crisis, several factories created plans to increase production at night or on weekends when electricity demand is lower. Other factories sought to cease production entirely during the critical period — late July — by scheduling all holidays for that time (IEA, 2005).

20. The continuing crisis in South Africa has forced the continuation of load shedding measures. In 2008, the Government announced plans to cut the country's general electricity use by 10 percent to cover the 4000 MW needed reduction. In order to achieve this target, a three-point plan would be used to counter the electricity crisis:

- The first phase was electricity cuts (load shedding).
- The second phase – lasting a period of four months – involved a power rationing phase of the plan. This is aimed at cutting usage by 3,000 MW.
- The third phase of the plan will include a quota-based incentive scheme, for residents and businesses, as well as penalties for those exceeding their electricity rations.

21. The electricity crisis in Cuba of 2002-06 involved severe blackouts throughout the country. In July 2005 for example, lost load represented 18% of total system demand (OLADE, 2008). In this case rationing was not an instrument used to solve the crisis but rather the result of the inability of the system to solve it.

2.1.3 Economic Incentives

22. Economic incentives for reducing energy consumption can be separated into two groups. One affecting the price of electricity (tariffs) to induce a market based reduction (through the price elasticity mechanism). The other alternative is to change the relative price of efficient appliances via rebates, subsidies or tax breaks.

Tariffs

23. Cost reflecting tariffs are a key element of long term energy efficiency programs and also play an important role during a short term crisis. To be effective, programs aimed at changes in consumer behavior have to be implemented hand in hand with efficient pricing signals. Increasing prices to final consumers during a shortfall is the single most effective action to reduce the supply demand gap. In market based electricity systems an energy or capacity shortfall will translate automatically into higher prices signaling consumers the scarcity[5].

24. For the price mechanism to be effective in a short term crisis, some conditions have to be met. First, the wholesale market has to be competitive to ensure that prices reflect the true scarcity of the product. Second, there has to be a clear and efficient pass-through mechanism going from the wholesale market to final consumers. In most liberalized markets, this link is direct for large users (which have direct access to the wholesale market) but not for small residential and commercial users.

25. Two other elements are important to consider. First, for most small users there is a lag between the moment they consume and the moment they pay for their electricity. This means that for a crisis of relatively short duration, there will be no time for consumers to see the true cost of electricity. To this we have to add the delays and transaction costs associated with changing billing procedures in most utilities. Secondly, the nature of the crisis will also condition the use of the price instrument for certain users. Capacity constraints require the reduction of peak demand. Most small users do not have time of use tariffs and their meters record just total energy, making it impossible for the needed signal to reach them.

26. In Norway, New Zealand and Chile electricity markets have been liberalized and the shortfalls in these cases translated into price crisis. But even if spot prices rose substantially during the crisis, retail prices did not always reflect the increases. As a result, the price mechanism only affected large industrial users. Even when these users had long term contracts which isolated them from price increases, in some cases they found it profitable to shutdown production and sell the energy to the wholesale market (as in the case for Norway discussed above).

27. In Chile, the government allowed price signals to work and at the same time, introduced a direct subsidy for poor residential consumers to protect them from the sharp increases which would have had a substantial impact on the affordability of the service.

28. Even if in theory the price mechanism is an important tool to solve energy shortfalls, technical (out-dated metering technologies, lack of real-time price information

[5]Competitive electricity markets have often been less successful in accommodating reserve margin constraints. In practice, it is difficult to distinguish between true scarcity and market power so regulators and market administrators are reluctant to allow high prices.

reaching consumers), institutional (regulated retail prices), and political (opposition to high prices) constraints will prevent most systems from relying efficiently on this mechanism in the short run.

29. In summary, the price mechanism is most useful for large users and for prolonged energy crisis and of more limited utility with small users and during short crisis originating from capacity shortfalls. This by no means implies that there is no use for the price mechanism to induce energy consumption reductions for small users. For residential and commercial users, the price mechanism has to be seen as a necessary complement to other measures rather than a tool to be used in isolation.

30. This is the experience in Cuba, Brazil and South Africa. In Cuba, in support of all the other program's measures, residential electricity tariffs were increased by over 300% (see Table below). To preserve the progressive nature of the increasing block tariffs, consumers below 100 kWh/month were not included in the tariff adjustment. For the other blocks the rise was progressive, making the tariff blocks steeper. Brazil, facing an energy crisis expected to last several months, implemented a tariff mechanism aimed at achieving reductions in consumption by all users' categories.

Table 5 – Tariff Increases in Cuba

Consumption Range	Tariff $/kWh	
kWh	Previous	New
Over 300	0.30	1.30
251 – 300	0.20	0.80
201 – 250	0.20	0.60
151 – 200	0.20	0.40
101 – 150	0.20	0.30
0 – 100	0.09	0.09

Source: case studies in annex.

31. Tariffs for electricity consumed in excess of the quota (80% of previous year's consumption) by the low-load demand sectors (residential and commercial) were augmented. This increase was 50% for consumers with a demand between 201 kWh and 500 kWh and 200% for consumers using more than 500 kWh. Additionally, a bonus of one Brazilian real was offered for each kWh saved in excess of the quota for consumers with a demand of less than 200 kWh a month. The high-load consumers paid the spot price for any demand above their quotas (though this price was capped at about $250 per MWh).

32. In South Africa, following the 2006 Cape region crisis and given the structural nature of the shortfalls faced by the entire country, a new tariff system designed to achieve an overall savings target of between 10-15% over time is being considered. The

proposed tariff scheme is similar to the one adopted by Brazil with penalties for consumers exceeding their allotted quota (based on past consumption), and cut–offs for a specific period for repeat offenders. They are also considering schemes for large consumers to trade in their unused portion of the quota allocation and a "take or pay" of their allocated portion. These adjustments in tariff structure are coupled with substantial increases in the tariff level to ensure Eskom's financial viability[6].

33. California adopted a tariff rebate scheme. Through an executive order, Governor Davis established the "20/20" utility rebate scheme. The 20/20 program offered a 20% rebate to customers who consumed 20% less electricity than in the previous year. The rebate applied only to the summer months of June through September. The program was quite successful achieving substantial savings (see Table below). All customers were eligible to participate, but the rebate for large commercial and industrial customers with time-of-use meters was based on savings in on-peak demand. A 30% rebate was available for customers who saved more than 30% of their bill.

Table 6 – Participation, Savings and Costs of the California "20-20" Program

Customer type	Customer receiving credit (%)	Electricity savings (GWh)	Total rebate ($ million)
Residential	33	3,021	134
Non-residential	26	2,237	153
Total	32	5,258	286

Source: IEA, 2005.

Subsidies for energy efficiency

34. An alternative form of economic incentives is to subsidize the adoption of energy efficient appliances and investments. California, Brazil, Norway, South Africa, Cuba and Chile adopted this type of measure. In California appliance rebates and low income weatherization programs totaled 95 U$ MM and saved over 100 MW by 2002 while in Brazil the government subsidized CFLs and efficient appliances for low income customers. In Norway the government launched an electricity savings program called the Household Support Scheme. The program offered investment aid to households for air-to-air heat pumps, wood pellet stoves and energy management systems. The government subsidized 20% of the total cost, which was capped at about $700. Cuba, in addition to the massive program of residential appliances exchange (see below), it also implemented a mechanism of subsidized credit for new appliances for residential users (OLADE 2008).

[6] Government of South Africa - National Response to South Africa's Electricity Shortage – 2008. - http://www.info.gov.za/otherdocs/2008/nationalresponse_sa_electricity1.pdf

35. In South Africa, a DSM Fund was created in 2002. Following the major electricity blackouts experienced during the first quarter of 2006 in the Western Cape, a regional Eskom Energy Crisis Committee was established. The Eskom Energy Crisis Committee was responsible for the complete strategy and activities to alleviate the energy constraints experienced in the Western Cape. Eskom's DSM initiative was incorporated as a key part of the action plan, with the allocated target to reduce demand in the Western Cape by 400 MW by June 2006. It required an acceleration and amplification (approximately 2.5 times the annual national target) of the existing DSM initiative, with an intensified regional focus (Eskom)[7].

36. Specific financial instruments to promote longer term energy efficiency measures are also valuable tools to consider when the need arises for an extra conservation effort to be implemented. For example, the existence of Chile's CORFO funding for pre-investment research and detailed engineering; preferential financing lines; guarantee fund; and risk capital; contributed to help the country face the challenge of the 2007-2008 electricity crisis. These instruments are aimed at the industrial sector – particularly small enterprises – and provide long term finance (up to 12 years) for energy efficiency investments[8].

37. Although financing energy efficiency appliances can have a relatively rapid impact, the implementation of this mechanism during a short term crisis will normally not be possible. The pre-existence of a long term energy efficiency strategy then becomes a prerequisite for the implementation. California, Brazil and South Africa all had energy efficiency programs in place before the crisis which were used as a platform during the crisis period.

38. Norway, which lacked an established tradition of energy efficiency policies, faced difficulties when implementing financial mechanisms for efficient appliances during the crisis. According to IEA, 2005, the program was created to meet mostly political objectives rather than to save electricity quickly as none of these technologies could be installed soon enough to make an immediate, widespread impact on electricity consumption. Furthermore, the technologies were selected without regard to standard requirements for cost-effectiveness used by the Norwegian government.

2.1.4 Appliance Replacement

39. Replacing inefficient appliances for more efficient equipment is a medium term alternative for saving energy and capacity. Time to install the new appliances and their

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[7] http://www.eskom.co.za/live/content.php?Item_ID=2787
[8] http://www.corfo.cl/lineas_de_apoyo/programas/credito_corfo_eficiencia_energetica

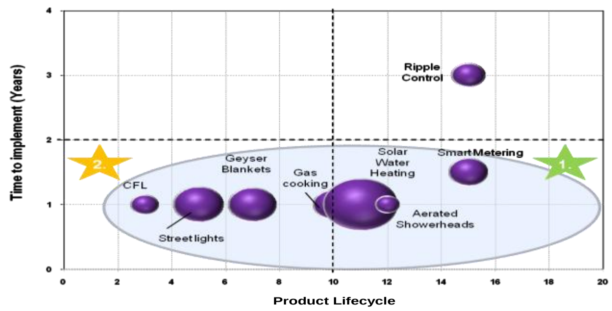
cost will be an important element in the decision to use this alternative (see Box below for an example).

Box 3 - Costs per MW, time to roll-out and sustainability of DSM technologies – South Africa.

Residential Sector

Short-term implementation programmes include CFLs Street Lights and Geyser Blankets & Gas Cooking.

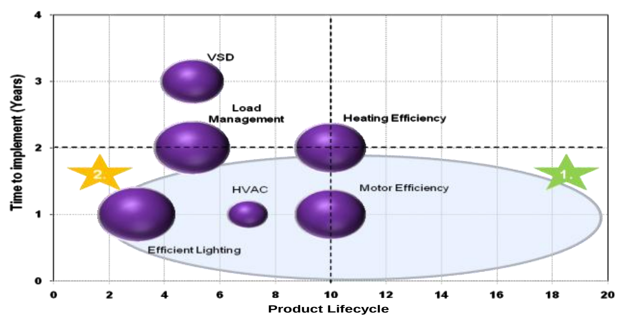
Medium to Long-term implementation projects include Solar Water Heating, Smart Metering (limited to 20 Amps), Aerated Showerheads.



Commercial Sector

Motor efficiency savings have high sustainability and can be quickly implemented.

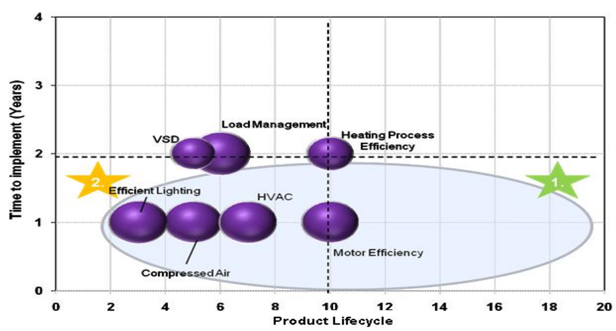
Efficient lighting and air conditioning (HVAC) can be quickly implemented but offer less in the way of sustainable savings.



Industrial Sector

Motor efficiency initiatives can be rapidly implemented and offer the most sustainable MW savings.

All other technologies can be implemented within a shorter year horizon but offer less sustainability in terms of MW savings



Note: Bubble size indicates Rand per MW – the larger the bubble the more expensive the cost per project
Source: ESKOM - Maximizing DSM's Potential as a Response Option – June 2008

40. Brazil, South Africa, Chile and Cuba all implemented campaigns to replace appliances for more energy efficient ones. All of them developed CFLs programs. Of all these programs, the Cuban case is the most comprehensive involving a massive

campaign, which replaced almost the entire stock of existing home appliances in less than two years. This was a nationwide program, conducted and financed by the government. Through the Social Workers Program, inefficient home appliances are replaced by energy efficient equipment. The table below presents the replacement ratio reached for each appliance type by June 2008.

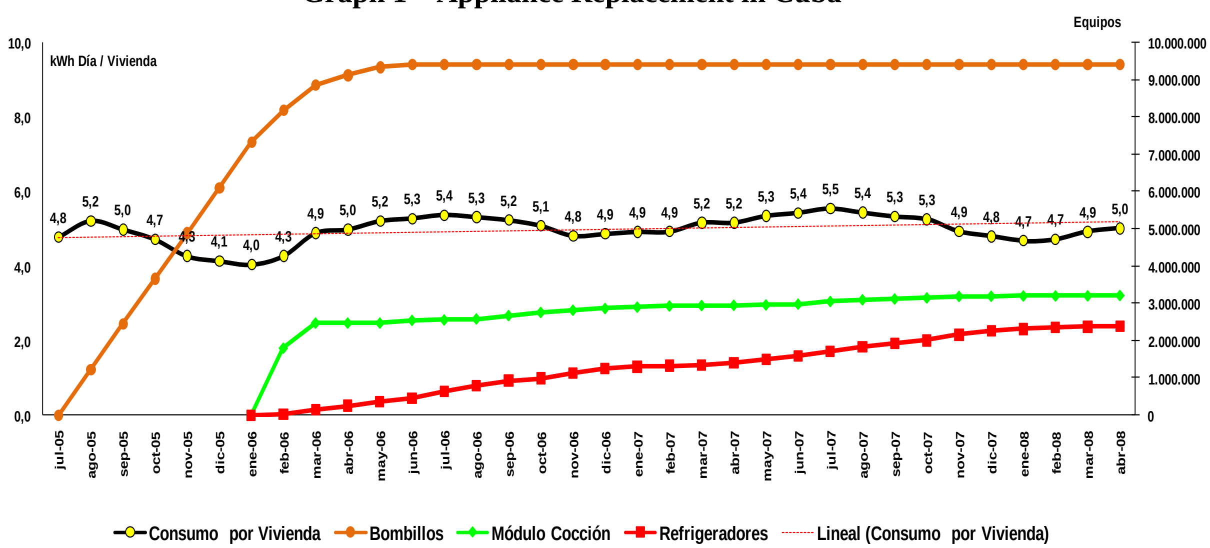
Table 7 – Appliance Replacement Ratio – Cuba June 2008

Appliance	Ratio
Refrigerators	91%
CFL	100%
Air Conditioning	9%
Electric Fans	100%
TV	21%
Water pumps	97%

Source: case studies in annex.

41. The Cuban program was not only very wide – covering all commonly used appliances – but also extremely fast. The Graph below shows monthly replacements for CFLs, cooking modules and refrigerators since 2005.

Graph 1 – Appliance Replacement in Cuba



Source: OLADE, 2008.

42. As we can see from the graph, the CFL program (brown line) started in July 2005 and by January 2006 it had replaced almost 9 million bulbs. The cooking module program (green line) also ramped up very fast (nearly 2 million in three months) while the refrigerator program (red line) shows a more steady path of around 100 thousand refrigerators a month.

43. In Brazil, during the 2001 crisis the government distributed over 5 million CFLs among the poor. At the same time sales of CFLs by one company jumped from 14 million in 2000, to 50 million in 2001. During this time, sales of incandescent lamps in 2001 were about half that of the previous year (IEA, 2005). In South Africa, Eskom embarked on a national program to exchange incandescent globes with CFLs in selected areas. Since the program began in 2004, more than 18 million CFLs have been exchanged for incandescent globes. Following the 2006 crisis in the Western Cape, the program was intensified in this area and in the Northern Province, Gauteng and Free State where four million CFLs were exchanged for incandescent globes.

44. Depending on the duration and advance notice of the crisis and the preparedness of the system, the set of possible technical fixes will vary. The table below presents a summary of the most commonly available measures.

Table 8 – Most Common Energy Consuming Equipment Replacements

Measure	Implementation		Relevant Sectors	Comments
	Time	Cost		
CFLs	Medium	Medium	ALL	The most common measure. Cuts power consumption by about two-thirds
Direct load controls on key devices	Medium	High	Residential Commercial	Can have large effect on peak demand with little cost to users
Aerated Showerheads	Medium	Medium	Residential	Only relevant if water is heated with electricity
Smart Meters	Medium	Medium	ALL	Improves signals to consumers
Replace traffic lights	Medium	Medium	Public	LEDs draw less than a quarter of the power of a traditional bulb
Replace street lights	Medium	Medium	Public	
Replace motors with more efficient units	Medium	High	Industrial Commercial Public	Retrofits to motor systems can cut use 75%
Replace major appliances with efficient ones	Medium	High	Residential	Technical and financial constraints

Source: Adapted from IEA, 2005.

2.1.5 Importance of the Public Sector

45. Although electricity consumption by the public sector is not very high in relation to total consumption, energy saving activities in this sector is important due to the high

visibility and the exemplary role it has on the other sectors. This is explicitly acknowledged by Chile in its overall energy efficiency strategy. All countries that used rationing or economic signals did impose more demanding targets on the public sector than for the other sectors. In this way the government increased its credibility when requesting sacrifices from the general population.

46. Not only is the public sector important due to this demonstration effect, but it also has the advantage that measures can be implemented through a centralized decision mechanism rather than through incentives. This allows fast implementation of highly visible measures. In Cuba, a special project was implemented in the public sector in order to regulate demand and distribute the load among 1,720 selected services (large users). The actions performed in relation to these services included appointing 200 energy supervisions; introduction of the Energy Efficient Management Program; design and control of electricity consumption programs; and training of the personnel in charge of energy control and subsequent inspections to test results.

47. As a result of these actions, while the electric power consumption in the overall economy grew 7.5% from 2006 to 2007, in the state sector such growth was down to 4%. In the selected public services impacted by specific energy conservation measures, electricity demand growth was a mere 1.2%. These services account for 45.6% of the state consumption. The electricity intensity in the state sector fell from 0.16 GWh/MMP in 2005 to 0.13 GWh/MMP in 2008.

2.2. Tariffs

2.2.1 Residential Tariffs

Situation in Central America

48. Tariffs are one of the key elements in the determination of incentives for rational use of energy. Tariffs which do not reflect the economic cost of the service create allocative distortions in the economy. In the particular case of electricity, in many cases this means adopting inefficient appliances – which cost less but consume more energy – and using them more than what is economically efficient.

49. Two elements relating to tariffs have to be considered when analyzing incentives to save energy. In the first place is the overall tariff level. Electricity tariffs in the Central America region have generally experienced a sharp increase during the last years as a result of high international oil prices and an increasing share of thermal generation. A

second element to consider is the tariff structure for each of the user's categories. Considering in first place residential consumers, we find that 4 countries in the region (Costa Rica, Guatemala, Honduras and Nicaragua) have increasing block tariffs, one (Panama) has a linear tariff and the remaining one (El Salvador) has a decreasing block tariff (see Table below).

Table 9 – Tariff Structure – Residential Sector Central America

	Structure	Number of Blocks	Fixed charge
Costa Rica	Increasing block	3	No
Guatemala	Increasing block	2	Yes
Honduras	Increasing block	4	No
Nicaragua	Increasing block	7	Yes
Panama	Linear	1	Yes
El Salvador	Decreasing block	3	No

Source: authors.

50. Given a general tariff level which ensures sustainability, the tariff structure will determine the degree of allocative efficiency and equity (affordability) in the sector. These two objectives generally present a clear trade-off.

51. Increasing block tariffs are generally aimed at distributional objectives. Under the assumption that richer households consume more than poor households, increasing block tariffs seek to incorporate a redistributive effect in the tariff structure[9]. Decreasing block tariffs – on the other hand – will in general reflect the cost structure (particularly of distribution) and therefore will create a good allocative signal for the economy. This is generally true under the assumption that there are no supply restrictions in the sector. In the face of supply restrictions, the allocative efficiency requires increasing tariffs to signal the high cost of incremental investments needed to overcome supply shortages.

52. In terms of energy efficiency, it is clear that increasing block tariffs will create stronger incentives for energy savings. The prevalent increasing block structure in the region therefore serves not only a redistributive objective – which was probably the original intention – but also creates the proper signals for the efficient use of electricity. The number, size and price of the different blocks are key elements that need to be considered. A summary of the main characteristics of the residential tariffs in the six countries of the region is presented in the table below.

[9]This assumption usually holds at the individual level. But with poor households having in general more individuals than rich households, this is not always true. Furthermore, in many cases, several households share a connection. With tariffs fixed for each connection and no information about the number of households per connection. Thus, the increasing block could even be regressive in some cases.

Table 10 – Residential Tariff Structure – Central America ($)

<table>
<tr><th>Categories</th><th>Costa Rica</th><th>Guatemala</th><th>Honduras</th><th>Nicaragua</th><th>Panama</th><th>El Salvador</th></tr>
<tr><td>Fix Charge U$D/month</td><td>0.0000</td><td>1.4592</td><td>0.0000</td><td>0.9173</td><td>2.0400</td><td>0.0000</td></tr>
<tr><td>Variable Charges</td><td colspan="6">$/kWh</td></tr>
<tr><td>000 - 025 KWh</td><td rowspan="5">0.1087</td><td rowspan="6">0.1726</td><td rowspan="3">0.0743</td><td>0.0660</td><td rowspan="9">0.1811</td><td rowspan="3">0.1018</td></tr>
<tr><td>026 - 050 KWh</td><td>0.1421</td></tr>
<tr><td>051 - 100 KWh</td><td>0.1488</td></tr>
<tr><td>101 - 150 KWh</td><td rowspan="3">0.1321</td><td>0.1967</td><td rowspan="2">0.1008</td></tr>
<tr><td>151 - 200 KWh</td><td rowspan="3">0.1834</td></tr>
<tr><td>201 - 300 KWh</td><td>0.1960</td><td rowspan="4">0.1001</td></tr>
<tr><td>301 - 500 KWh</td><td rowspan="3">0.2691</td><td rowspan="3">0.2141</td><td>0.1651</td></tr>
<tr><td>501 - 1000 KWh</td><td rowspan="2">0.1816</td><td>0.2914</td></tr>
<tr><td>Over 1000 KWh</td><td>0.3266</td></tr>
</table>

Source: authors, based on official tariff information.

53. The tariff structure of Costa Rica and Honduras is very similar despite the differences in the number of blocks (3 and 4 respectively). In fact, the ratio of the last to first block is almost the same in the two countries (2.47 and 2.44 respectively). The structure in Guatemala, with only two blocks shows much less differentiation (with a ratio of only 1.2). On the other extreme, Nicaragua is the one with the most blocks (seven) and the highest difference between the first and last blocks (4.95).

54. Panama shows a single block – or linear tariff – but has a direct subsidy for users with consumption of less than 100kWh/month (see below). El Salvador has a decreasing block tariff, with the difference among blocks being very low.

55. Two elements are central in terms of the trade-off between social affordability concerns and incentives for energy efficiency: the size of the blocks (in kWh/month) and the values of the subsidized blocks (in $/kWh). Ideally, the size of the first – subsidized – block should be determined based on the consumption of a poor household. This seems to be the case in Costa Rica where the average consumption of the low income group is slightly less than the first block of consumption in the tariff structure (193 kWh vs. 200 kWh).

56. No information is readily available on consumption by income group for the other countries of Central America. As a first approximation we can look at average residential consumption and compare it to the block size for the different countries. Available information shows that the level of the first block seems to have a relation with consumption levels of the poor groups in Honduras and Nicaragua. In Guatemala on the

other hand, the first block is several times higher than average consumption meaning that a disproportionately high percentage of the population is receiving the reduced tariff. The second element to analyze is the value of the different blocks and their relation to the economic cost of providing the service. Given that data on economic costs of service by user category and consumption level is not readily available, a first estimate can be done by comparing the tariff of the first block with the wholesale price of electricity.

57. In order to preserve incentives for allocative efficiency and the efficient use of electricity, the price of the first block should at least cover the direct avoidable costs of providing the service. Data on wholesale prices, losses and value of the first block for the four countries with increasing block tariffs in Central America is presented in the table below.

Table 11 – Avoidable Costs and First Block Tariff

	Costa Rica	Guatemala	Honduras	Nicaragua
Wholesale Price (1)	0.0569	0.0896	0.0719	0.1234
Losses (2)	11%	16%	21%	28%
(1) + (2)	0.0632	0.1039	0.0870	0.1580
First Block	0.1087	0.1726	0.0743	0.0660

Source: authors.

58. A first measure of avoidable costs is the production cost of electricity. In sectors with vertical unbundling, this price is directly observed as the wholesale price of electricity. For vertically integrated sectors the price has been approximated by high voltage tariffs. To make this number comparable for residential users we have to take into account losses in the system and calculate a price including losses.

59. As we can see from the table, while Costa Rica and Guatemala meet this basic allocative efficiency criterion, Honduras and Nicaragua fail the test. In fact the first three blocks in Nicaragua (including consumptions up to 100kWh/month) show values below the avoidable production costs[10].

60. A subsidized price for the first consumption blocks which is below the avoidable costs creates a clear disincentive for energy efficiency and serious allocation inefficiencies in the sector. Two approaches can be used to solve this problem while preserving the redistributive effect of the subsidy. One first approach would be replacing the actual system of tariffs with one of fixed amount subsidies. This means defining a fixed amount of subsidy and setting the tariff equal to the economic cost of the service. If the fixed subsidy is set properly, and with no changes in consumption, the median

[10] This means that the subsidized tariffs cover users with consumption above the average for the residential sector which is 92 kWh/month.

household will be indifferent between the new and the old tariff. By valuing the variable charge at the economic cost of service, the incentives for allocation efficiency and rational use of energy are preserved and at the same time, poor households receive the same amount of subsidy. For example, in Nicaragua, under the current tariff structure, a residential user with consumption equal to 92 kWh/month (average residential consumption) pays a bill of 12.4 $/month while the cost of service is 15.5 $/month. Changing the tariff structure to a fixed subsidy of $ 3.1 /month plus a variable charge equal to avoidable costs – 0.1580 $/kWh – leaves users with consumption of 92 kWh/month indifferent and improves the situation of anyone with consumption below that.

61. An alternative approach would be to channel the subsidies through energy efficient appliances rather than through the price of electricity. By subsidizing the purchase of energy efficient appliances and at the same time increasing tariffs to their economic costs households could end with the same energy bill but with a more efficient use of energy. At the same time, the fiscal cost for the government could be less than under the actual arrangement depending on the level of the subsidy and the relative price of appliances.

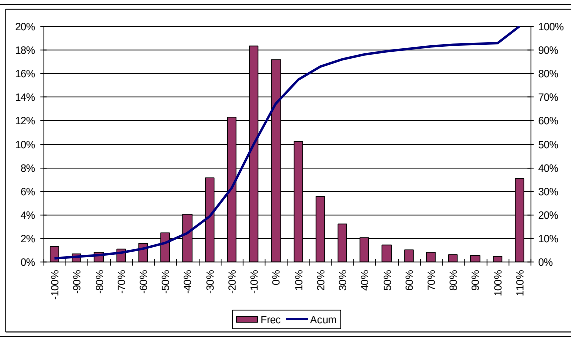
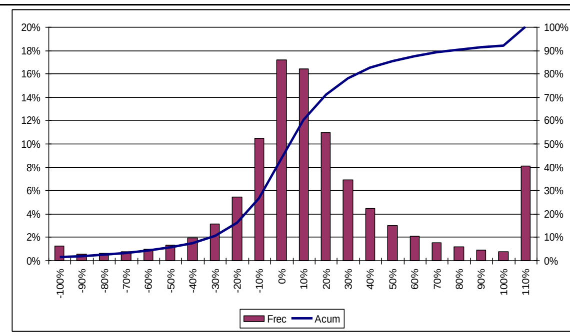
Using Residential tariffs as an instrument during crisis

62. International experience with short term electricity crisis shows that a majority of countries use tariff mechanisms to induce energy savings during the shortfalls. Of these, the case of Brazil (also being discussed for adoption in South Africa) is worth analyzing in detail. As described in the previous section, Brazilian tariffs for electricity consumed in excess of the quota (80% of previous year consumption) by residential and commercial users were increased by 50% for consumers with a demand between 201 kWh and 500 kWh and 200% for consumers using more than 500 kWh.

63. Formally, this can be seen as a form of increasing block tariff in which the size of the block is determined by past consumption of each user. In other words a stock of "cheap" energy is allocated between users based on their individual past consumption. This mechanism has a number of problems. In the first place, there is a targeting problem. In a typical electricity system, a number of users will vary their consumption from one year to the other for completely exogenous causes. According to IEA, 2005, natural variation in energy use ensures that about 20% of the customers will use 20% less energy than the previous year. For a sample comparing consumption of individual residential customers between 2003 and 2005 in a distribution company in Latin America with fixed tariff, we find significant variations as shown in the figure below. In the second place, the administrative costs of the implementation of this kind of program can

be very high. Normally utilities billing systems are not prepared for this tariff structure and the time and costs to adapt can be substantial. In the third place, this rule has negative distributive effects. By allocating "cheap" energy on the basis of past consumption, this rule privileges "old wealth". This can be very regressive in the context of a fast growing middle or low income economy (e.g.: South Africa).

Graph 2 – Percentage of electricity consumption variation from one year to the other

2003-2004	2004-2005
	

Source: authors.

64. The bars in the graph show on the left axis, the frequency distribution of users varying their demand in relation to the previous year. The lines show on the right hand axis the cumulative value. In the period 2002-2004, 30% of customers reduced their consumption by 20% or more. As we can see from the figure, the number goes up to 50% if we consider a variation of 10% in relation to the previous year. In 2004-2005, 15% of customers reduced their consumption by 20% or more and 25% show variation of over 10%. This indicates that to make tariff reductions or penalties rely on past consumption is prone to a large targeting error. This problem will be compounded by exogenous variables affecting average consumption of the whole system (e.g.: air temperatures) as shown by the differences in the two periods considered in the graph above.

65. At the core of all these problems is the allocation of a quota for each individual user. With an increasing block tariff, changing the price or the size of the blocks can generate the same type of incentives while avoiding the discussed draw backs. This is illustrated using the tariff structure of Costa Rica. The different options are illustrated in the table below.

Table 12 – Individual electricity consumption quotas and equivalent block prices

	Actual Tariff	**Actual Tariff**	**50% Penalty**	**Equivalent block 3**	**Equivalent block 2 & 3**
Period	T	T+1	T+1	T+1	T+1
Consumption (kWh)	381	342.9	381	381	381

Tariff Block					
< 200	0.109	0.109	0.109	0.109	0.109
< 300	0.196	0.196	0.196	0.196	0.220
>300	0.269	0.269	0.269	0.332	0.302
> T-1			0.404		
Monthly Bill ($)	63.13	52.88	68.26	68.26	68.26
Variation Bill		-16%	+8%		

Source: authors.

66. Column 2 in the table shows the initial situation. Average consumption is 381kWh/month and there is an increasing block tariff with three blocks: less than 200 kWh, between 200 kWh and 300 kWh and more than 300 kWh. This results in a monthly bill of $ 63.13. Column 3 shows the effect on the monthly bill of a 10% reduction in consumption under the current tariff (with no incentives). Given the increasing block structure, a 10% drop in consumption generates savings of $ 10 (-16%) in the monthly bill.

67. The fourth column shows a tariff including a 50% surcharge on the third block for all consumption exceeding 90% of the consumption in the previous period. For a consumer failing to adjust its consumption at all, the monthly bill goes up by $5 (+8%). The following column shows the increase in the price of the third block which results in the same monthly bill for a constant consumption. This is achieved by increasing the tariff of the third block from 0.269 to 0.332 $/kWh (+23%). If we adjust the second and third blocks (column 6) the resulting tariff structure shows an increase of 12% in both tariffs to keep the monthly bill constant[11.]

68. As this exercise shows, a change in block prices can produce the same economic effect as the allocation of quotas based on past consumption. This avoids the implementation and equity problems discussed while at the same time produces the economic signal to induce the desired savings.

69. By working with a homogeneous consumption block, rather than the individual one implicit in the quota system, this alternative is more progressive as higher consumption is penalized with higher increases in the monthly bill. It has to be stressed that this alternative replicates the economic incentives implicit in the individual quota approach but is no replacement to the complementary measures (media campaign, consumer information, etc.) needed to ensure the necessary demand reduction during a crisis. The way in which the tariff increase is presented to the public is also important as it should be viewed as part of a crisis energy saving package rather than an attempt by the electric companies to increase their revenue.

[11] A similar exercise varying the size of the blocks instead of the price results in a constant bill by reducing from 300 to 230 kWh/month the third block, or alternatively reducing the second block from 200 to 174 and the third from 300 to 261 kWh/month

2.2.2 Large Users

Situation in Central America

70. In this section we present a brief summary of tariffs for large users in Central America. The main elements of medium voltage tariffs in each of the six countries are summarized in the table below.

Table 13 – Medium Voltage Tariff – Central America 2009 ($)

<table>
<tr><th></th><th>Costa Rica</th><th>Guatemala</th><th>Honduras</th><th>Nicaragua</th><th>Panamá</th><th>El Salvador</th></tr>
<tr><td colspan="7">Energy charge $/kWh</td></tr>
<tr><td>Peak</td><td>0.0980</td><td rowspan="3">0.1164</td><td rowspan="3">0.1246</td><td>0.1733</td><td>0.2082</td><td>0.1227</td></tr>
<tr><td>Valley</td><td>0.0374</td><td rowspan="2">0.1677</td><td rowspan="2">0.1184</td><td>0.1191</td></tr>
<tr><td>Night</td><td>0.0214</td><td>0.0984</td></tr>
<tr><td colspan="7">Capacity charge $/kW/month</td></tr>
<tr><td>Peak</td><td>15.4460</td><td rowspan="3">5.6965</td><td rowspan="3">5.8986</td><td rowspan="3">17.5455</td><td>10.9300</td><td rowspan="3">3.3646</td></tr>
<tr><td>Valley</td><td>11.0339</td><td rowspan="2">1.2400</td></tr>
<tr><td>Night</td><td>7.0655</td></tr>
</table>

Source: authors, based on official tariff data from each country.

71. All countries have energy and capacity charges and hourly metering for medium voltage customers. Guatemala and Honduras have a single charge for both energy and capacity while the other four separate between peak and non peak periods. Costa Rica shows three periods with a high differentiation of the price among periods. Panamá has two periods, while El Salvador has three energy charges but a single capacity value and Nicaragua two energy charges and a single capacity charge. Hourly metering allows sending more precise signals which are important particularly during periods of capacity shortfalls. Unlike the case of residential consumers, for which only total energy consumption can be limited due to the lack of time of use metering, signals for medium voltage users can target total energy and peak demand separately.

Using Large User tariffs as an instrument during Crisis

72. Demand response to price changes is a useful alternative to traditional supply-side remedies in constrained electricity markets. Demand response offers a highly-flexible and naturally-distributed resource to network operators, and reduces the need for investment in peak supply capacity. Critically, demand response enhances security,

particularly on constrained networks, as higher concentrations of demand are typically located at network nodes where congestion is high and network security most vulnerable.

73. The key element for inducing efficient consumption by large users is a pricing mechanism that reflects real time costs of production known as dynamic pricing. Dynamic pricing includes time-of-use (TOU) pricing, critical-peak pricing (CPP) and real-time pricing (RTP) as described in the table below. Implementation of these pricing mechanisms requires substantial investment in metering, communications and data processing systems.

Table 14 – Dynamic Pricing Alternatives

Pricing Mechanism	Description
Time-of-use (TOU)	Traditional time-of-use programs, which vary the price according to the hour, day or season of consumption, have long been used by utilities as a tool for balancing demand.
Real-time (RTP)	More advanced form of pricing designed to increase the transparency between wholesale and retail markets. The basic principle is that the end-user price is linked to the wholesale market clearing price. Also known as dynamic pricing, these products refer to any electricity tariff where the timing and prices are not known or set in advance.
Critical –peak (CPP)	hybrid of real-time-pricing and time-of-use; a typical design will feature a traditional time-of-use rate in effect all year except for a contracted number of peak days, the timing of which is unknown, where a much higher price is in effect. The number of these critical peak days is known in advance, but the price and timing of them is not.

Source: based on IEA, 2005.

74. During a crisis, these alternatives can be used only if the required equipment is already in place. At present, most electricity systems – particularly those based on a competitive wholesale market - have this kind of system implemented in at least some of the largest users. For these users, international experience shows several emergency demand response programs as described in the table below.

Table 15 – Emergency Demand Response Programs

Company	Program	Minimum Size	Price Incentive	Financial Penalty
Independent Market Operator (Ontario)	Emergency Demand Response Program	N/A	Cost reflective real-time rate	None
US State Utilities	Optional Binding Mandatory Curtailment Program	15% reduction on entire circuit, in 5% increments	Exemption from rotating outages	$6,000 MWh of excess energy
PJM	Emergency Load Response Program	100 kW	Higher of $500 MWh or Zonal LMP	None
California Independent System Operator	Demand Relief Program	1 MW Load reduction	USD20,000/MW – month and $500/MWh	Performance Based Capacity Payment
San Diego Gas & Electric	Rolling Blackout Reduction Program	15% reduction from maximum demand, at least 100 kW	$200/MWh	None
New York Independent System Operator	Emergency Demand Response Programs	100 kW reduction per zone (aggregated)	Greater of real-time price or $500/MWh	None

Source: IEA, 2003.

75. These Emergency Demand Response Programs are measures designed to deal with declared emergencies in the system. The trigger for the emergency "event" will be defined by network reliability and security standards.

76. In terms of tariffs for large users, there are several steps that can be taken as a way of ensuring a flexible set of instrument during a crisis. The main ones are:

- A set of clear tariffs and rules for use of the distribution network by captive generation (cogeneration and auto generation by large users). This would allow captive generators to sell excess power during an energy or capacity shortfall.
- An existing secondary market or clearing rules for large users with long term contracts so they can resell contracted power. With proper incentives in some cases large firms might choose to shut down production – or shift it outside the peak – and sell contracted capacity back to the market.
- A wholesale price allowed to reflect the true cost of energy during the crisis. Large users should face rationing prices in order to get proper incentives during a crisis.
- Rules which will allow interruptible contracts for large consumers. Typical interruptible contracts will include number of interruptions allowed per year; size of load reduction; period of reduction; season or period during which interruptions are possible. Payments for participation are based upon all of these factors.

2.2.3 Tariff Regime

77. The tariff regime is the set of rules by which tariffs are updated and modified over time. This is the key to the incentives firms face for productive efficiency. There are three main types of regulatory regimes: Cost of service or Rate of Return; Price or revenue caps and Hybrids. Tariff regimes are not only central to the creation of productive efficiency incentives but they also have a large impact on the incentives electricity distribution firms face for promoting or supporting energy efficiency measures among their customers.

78. In general, price caps create not only an incentive for cost minimization but also a perverse incentive for firms to maximize sales as a way of maximizing profits, especially when the share of fixed costs is large as in electricity supply. In theory, this problem is not present under traditional cost of service (or rate of return) regulation although in the practical application some disincentives exist. Under this regulatory regime utilities' earnings are based on capital invested and electricity (kilowatt-hours) sales which results in financial incentives biased towards increased electricity sales and system expansion.

79. In Central America, following the reform wave of the 90s, most countries have vertically unbundled sectors with some degree of competition in generation and high incentive regulatory regimes based in some form of price cap for transmission and distribution companies. The only exception is Costa Rica where the integrated utility is subject to rate of return regulation (see Table below).

Table 16 – Tariff Regime Central America

Country	Tariff Regime	Review Period (years)
Costa Rica	Cost of Service	
Guatemala	Price Cap	?
Honduras	Price Cap	5
Nicaragua	Price Cap	5
Panama	Price Cap	4
El Salvador	Price Cap	?

Source: authors.

80. In Costa Rica, ICE, the vertically integrated state owned company, is regulated by a rate of return mechanism. There seems to have been no problems for the company to

implement energy efficiency programs which have been accepted by the regulator as part of the regulatory asset base[12].

81. Following the reform of the electricity sector in the UK, the adoption of price caps with pass-through of generation costs was part of the standard sector reform. While price caps have proved effective in providing incentives for cost reductions, they have some disadvantages that have led regulators to consider alternative mechanisms. In particular, they provide an inventive for companies to sell as much as possible at the maximum allowed price—perhaps more than would be efficient in the absence of such a cap. This is of particular concern when supply-demand balances are relatively small and when environmental considerations are important.

82. One way to correct the incentive to sell large quantities is to cap revenue rather than price—allowing companies to earn a particular allowed revenue and compensating them should they sell too few and removing revenue arising from excess sales[13]. There are two main disadvantages[14]. First, the company will have to set its prices in advance, but can only check the revenue that they yield afterwards. This means that the company may, quite innocently, earn more than the price control allows.

83. For example, if the company has a fixed charge for each consumer and a unit rate, the average revenue per unit falls as demand increases. If demand is lower than expected, then the company's average revenue per unit will be higher, leading it to breach the price control. The control therefore has to include a correction factor, so that the company's allowable revenues in one year are reduced if it over-recovers in the previous year. (The correction factor also allows the company to recover the revenue forgone if its prices turn out to be lower than the control would have allowed). Second, the cap is likely to be more complicated to specify. If the cap simply specifies the revenue per unit of sales, the company can effectively `ease' the cap by expanding sales to low-price customers, since this will increase its volume by a greater proportion than its revenue. More generally a combination of price and revenue cap mirroring the cost structure of the company (revenue cap to cover fixed costs and price cap for variable costs) could result in the same incentives for productive efficiency while eliminating the incentives to sell as much as possible.

2.3 Quantifying Appliance Replacements

84. Promoting appliances' replacement is often used as a measure to reduce electricity demand. In this section, we present some quantifications of the likely impact and costs of three appliance replacement programs using available data. Evaluating costs

[12] According to ICE officials interviewed by authors in January 2009.
[13] In the US, this is known as revenue decoupling – See Kushler & al., 2006 for a discussion on the US experience.
[14] See Green & al., 1997 for a general discussion of price and revenue cap formulae.

and benefits of such programs is the first step in assessing the feasibility of a replacement effort. The success of implementing such measures will rely on a sustained effort and strong local knowledge to reduce leakage or rebound effects to a minimum. Implementation of appliance replacement can be done rapidly with energy savings achievable in a year and more. However, those programs typically take a little more time to be designed and implemented and should be included as a complementary set of measures to an emergency response.

85. The replacement programs examined below focus on refrigerators and lamps, which are two major sources of residential electricity consumption. There are other items that could be worth investigating. For example, Brazil launched a program to replace electrical showerheads, an appliance used extensively in Brazil. An assessment of a similar program in Costa Rica is presented in Annex.

2.3.1 Refrigerator Replacement

86. There is no information on the average efficiency of the existing stock of refrigerators in the Central America countries. For illustrative purposes the analysis uses historic data from North America on the likely impact of a replacement policy. The table below shows the evolution of average annual energy consumption of refrigerators of different sizes in the US since 1980.

Table 17 – Refrigerators Average of Annual Energy Consumption kWh

	Year						
Size (cu ft)	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2008**
6	503	517	489	429		306	
8	554	585	483	407			
10	626	611	668	474	427	304	
12	909	889	733	533	558		
14	1,093	954	801	571	601		
16	1,160	1,019	841	620	626		456

Source: Energy International Agency.

87. As we can see there has been a significant increase in energy efficiency in refrigerators during this period. For example, for refrigerators of 10 cubic feet the average annual consumption fell from 626 kWh in 1980 to 304 kWh – less than half – In 2005. If we compare the maximum and minimum annual consumption for each size we can have a measure of energy efficiency gains during the period (Table below).

Table 18 – Refrigerator's Energy Efficiency Increase

	Annual Consumption	**Efficiency**

Size (cubic feet)	Max	Min	**Gain**
6	517	306	-41%
8	585	407	-30%
10	668	304	-54%
12	909	533	-41%
14	1,093	571	-48%
16	1,160	456	-61%

Source: authors.

88. The energy efficiency gains range from a minimum of 30% for 8 cubic feet refrigerators to a maximum of 61% for 16 cubic feet refrigerators. It is also worth noting that the minimum efficiency levels for the smaller refrigerators are not associated to 1980s values but to 1985 and 1990 values. This seems to suggest that increases in energy efficiency occurred mainly in the last two decades. Based on the available information for Costa Rica, we can estimate the average efficiency of the refrigerator stocks in that country. There are two approaches. The first one is based on macro data (total residential consumption, % of energy used in refrigerators and total number of refrigerators). The second one is based on average energy consumption and energy used data from the household surveys. Both estimates are presented in the table below.

Table 19 – Average Refrigerator Efficiency in Costa Rica

		Rich	Poor
Number of Refrigerators	1,111		
Penetration	92.7		
Number of households	1,198		
Annual consumption	3,284,000	4,571.8	2,319.6
% Consumption Refrigerator	36.9%	30.1%	40.3%
Total refrigerators consumption (GWh)	1,211.8		
Average Refrigerator C (kWh/year)	1,091.1	1,376.1	934.8

Source: authors.

89. First, we use the share of refrigerators in total electricity consumption and the estimated number of refrigerators to calculate average refrigerator consumption for the population as a whole. For the second approach we use only the household survey data to estimate the average consumption of the refrigerator in a poor and middle rich household. The results of both methods are consistent and show annual consumptions ranging from 935 kWh/year for poor households to 1,376 kWh/year for rich households with an average of 1091 kWh/year for the population as a whole.

90. Given the lack of data for Central America and based on the evidence from Costa Rica, we can assume that the existing stock is on average a 1980 16 cubic feet refrigerator. Under this assumption, a replacement plan would replace a refrigerator with

an annual consumption of 1,160 kWh for an efficient one of 601 kWh. This implies a saving of 569 kWh a year for each replacement. To estimate the aggregated effect of a refrigerator replacement plan we need to consider the existing stock of refrigerators in each country. The table below shows the penetration ratio of refrigerators in five of the six Central American countries.

Table 20 – Refrigerators Stocks in Central America

	Costa Rica	Guatemala	Honduras	Nicaragua	Panama	El Salvador
Refrigerator Penetration	92.7	NA	50.9	26.4	61.7	58.91
Population	4,400	13,030	6,970	5,530	3,290	6,760
Number of households	1,198	3,548	1,898	1,506	896	1,841
Number of refrigerators (thousand)	1,111	NA	966	398	553	1,084

Source: authors.

91. The penetration ratio shows that the situation is very heterogeneous with almost universal access in Costa Rica to only a fourth of the households having a refrigerator in Nicaragua. Based on the penetration ratio and the number of households we can calculate the stock of refrigerators in each of the countries in the region. We find three countries with around one million refrigerators (Costa Rica, Honduras and El Salvador) and two countries with 400 and 550 thousand each (Nicaragua and Panama). In the first group the results are more homogeneous as a result of the lower penetration ratio being compensated by relatively large populations in Salvador and Honduras. Based on the estimated stock, the energy savings associated with different replacement ratios in each country is calculated and presented in the table below.

Table 21 – Potential Energy Savings (% Residential Consumption)

Replacement	Costa Rica	Guatemala	Honduras	Nicaragua	Panama	El Salvador

10%	1.9%	ND	2.7%	3.4%	1.9%	3.8%
20%	3.8%	ND	5.3%	6.9%	3.9%	7.6%
30%	5.8%	ND	8.0%	10.3%	5.8%	11.4%
40%	7.7%	ND	10.7%	13.7%	7.7%	15.2%
50%	9.6%	ND	13.3%	17.2%	9.7%	19.0%

Source: authors.

92. The electricity savings impact ranges from 2% to nearly 20% of the total residential consumption depending on the percentage of refrigerators replaced. A key underlying assumption in this exercise is that old refrigerators are effectively replaced by the new ones. This could be problematic particularly in countries with low levels of penetration (like Nicaragua) in which the incentive to keep the old refrigerator (or give it to a friend or relative) is extremely high. Similarly, there may be income threshold effects to be considered while preparing the implementation of a refrigerators' replacement program, to ensure that low income groups can benefit from the program.

2.3.2 Refrigerator Efficiency Choice – Private Valuation

93. In this section, we analyze the incentives to buy an efficient refrigerator under current tariffs in the six Central American countries. Based on available information from the web, two refrigerators are compared with different efficiencies using published prices in Costa Rica. The information on the refrigerators – prices and efficiency – is presented in the table below.

Table 22 – Refrigerator Parameters

Model	Frigidaire FRT8S6ESB	Frigidaire FRT18HB5JW
Size (cubic feet)	18	18
Price in Costa Rica ($)	2,574.0	3,015.1
Consumption (kWh)	479.0	383.0

Source: compiled by authors from the sources below.

Model	Price	Efficiency
Frigidaire FRT8S6ESB	http://articulo.mercadolibre.co.cr/MCR-182862liquidacion-refrigerdor-100-nuevo-en-oferta-_JM	http://www.fixya.com/support/p521020-frigidaire_frt8s6esb_stainless_steel_top
Frigidaire FRT18HB5JW	http://www.gollotienda.com/productosInfo.asp?dep=60&prod=6001130036&ncat=	Energy Star

94. Based on these published prices and efficiencies, the subsidy needed to induce consumers to choose the more efficient refrigerator is estimated given the residential tariffs in each country and assuming two different discount rates: 10% and 15% per

annum. The estimation was done using a simple financial model comparing the net present value of the two alternatives over a 15 year life period. Results for each country and tariff block are presented in the tables below for the 10% and 15% discount rates respectively.

Table 23 – Required Subsidy to purchase energy efficient refrigerators ($)

At a 10% Discount Rate

<table>
<tr><th>Residential electricity tariff categories</th><th>Costa Rica</th><th>Guatemala</th><th>Honduras</th><th>Nicaragua</th><th>Panama</th><th>El Salvador</th></tr>
<tr><td>000 - 025 KWh</td><td rowspan="5">356.38</td><td rowspan="6">306.60</td><td rowspan="3">383.61</td><td>389.94</td><td rowspan="9">300.30</td><td rowspan="3">361.99</td></tr>
<tr><td>026 - 050 KWh</td><td>330.71</td></tr>
<tr><td>051 - 100 KWh</td><td>325.27</td></tr>
<tr><td>101 - 150 KWh</td><td rowspan="3">338.49</td><td>288.16</td><td rowspan="2">362.76</td></tr>
<tr><td>151 - 200 KWh</td><td rowspan="3">298.51</td></tr>
<tr><td>201 - 300 KWh</td><td>288.71</td><td rowspan="4">363.31</td></tr>
<tr><td>301 - 500 KWh</td><td rowspan="3">231.92</td><td rowspan="3">274.70</td><td>312.82</td></tr>
<tr><td>501 – 1,000 KWh</td><td rowspan="2">299.60</td><td>214.49</td></tr>
<tr><td>Over 1,000 KWh</td><td>187.11</td></tr>
</table>

At a 15% Discount Rate

<table>
<tr><th>Residential electricity tariff categories</th><th>Costa Rica</th><th>Guatemala</th><th>Honduras</th><th>Nicaragua</th><th>Panama</th><th>El Salvador</th></tr>
<tr><td>000-025 kWh</td><td rowspan="5">372.29</td><td rowspan="6">331.85</td><td rowspan="3">394.41</td><td>399.47</td><td rowspan="9">326.73</td><td rowspan="3">376.84</td></tr>
<tr><td>026-050 kWh</td><td>351.44</td></tr>
<tr><td>051-100 kWh</td><td>347.01</td></tr>
<tr><td>101-150 kWh</td><td rowspan="3">357.76</td><td>316.87</td><td rowspan="2">377.47</td></tr>
<tr><td>151-200 kWh</td><td rowspan="3">325.27</td></tr>
<tr><td>201-300 kWh</td><td>317.31</td><td rowspan="4">377.92</td></tr>
<tr><td>301-500 kWh</td><td rowspan="3">271.18</td><td rowspan="3">305.93</td><td>336.90</td></tr>
<tr><td>501-1,000 kWh</td><td rowspan="2">326.16</td><td>257.02</td></tr>
<tr><td>Over 1,000 kWh</td><td>234.77</td></tr>
</table>

Source: authors.

95. The tables indicate that Nicaragua is the country with the widest variation. At a 10% discount rate, the subsidy ranges from just below $390 for the first block to $187 for the last tariff block. With a higher interest rate subsidies are higher: between $ 400 and $ 235. With the prices used in this example, current tariffs in Central America are not enough to induce a private consumer to adopt the most efficient technology.

2.3.3 CFL Replacement

96. In this section, costs and possible impacts of a CFL program are estimated for Central American countries.

Table 24 – Estimates of Total Lamps Stock per Country

	Costa Rica	Guatemala	Honduras	Nicaragua	Panama	El Salvador
Electricity Coverage	96%	63%	50%	40%	74%	69%
Consumption kWh/month	237	102	180	92	206	107
GDP per capita	9,889	4,311	3,553	2,441	10,135	5,477
Number of households	1,198	3,548	1,898	1,506	896	1,841
Residential Clients	1,153	2,252	954	597	660	1,268
% Lighting*	12.2%	25.0%	15.0%	25.0%	12.2%	25.0%
Lighting consumption	29	26	27	23	25	27
Number of incandescence lamps per household	8	7	8	6	7	7
Total number of incandescent lamps (thousand)	9,261	15,952	7,155	3,814	4,608	9,422

*: estimates.
Source: authors.

97. Starting from coverage ratios, average consumption, and number of households, we calculate the total number of lamps for each country. The average the number of lamps per household is estimated from consumption on lighting, assuming that 40W lamps are used 3 hours a day.. Total lamps are calculated by multiplying by total residential users. Assuming that 40W incandescent lamps are replaced by 10W CFLs producing a 30W saving per lamp, savings are estimated in the table below.

Table 25 – Estimated Savings (MWh/year)

Replacement Ratio	Costa Rica	Guatemala	Honduras	Nicaragua	Panama	El Salvador
10%	28	48	21	11	14	28
20%	56	96	43	23	28	57
30%	83	144	64	34	41	85
40%	111	191	86	46	55	113
50%	139	239	107	57	69	141

Source: authors.

98. Given the unit cost per CFL lamp replaced, the total cost of each replacement ratio can be estimated. In reality, replacement costs will vary across countries and even within regions in each country. In the Dominican Republic for example, a program to

replace 10 million incandescent light bulbs with energy-saving compact fluorescents (CFLs) in 840,000 homes is valued at $18.5 million – or about US1.85 per bulb[15]. The total lamp replacement program costs – assuming a cost of U$ 2.5 per lamp are presented in the table below.

Table 26 – CFL Replacement Program Costs ($ Millions)

Replacement Ratio	Costa Rica	Guatemala	Honduras	Nicaragua	Panama	El Salvador
10%	2,315	3,988	1,789	954	1,152	2,355
20%	4,630	7,976	3,578	1,907	2,304	4,711
30%	6,945	11,964	5,366	2,861	3,456	7,066
40%	9,261	15,952	7,155	3,814	4,608	9,422
50%	11,576	19,940	8,944	4,768	5,759	11,777

Source: author's calculations

[15] Source: http://dr1.com/blogs/entry.php?u=environment&e_id=3990

CHAPTER THREE
MEASURES TO RAPIDLY INCREASE THE SUPPLY OF ELECTRICITY

3.1 Introduction

1. Central America is faced with capacity shortages to meet growing demand in the short term. In addition to the available data on demand, generating capacity, and load forecasts, there is most likely suppressed demand that will contribute to the increase in the load as the regional grid becomes more reliable. This chapter presents possible solutions to bridge the gap between the potential power shortages in the near term and the installed capacity in accordance with the expansion plans in the long term.

2. Most of the countries have implemented emergency generation plans that include reciprocating engines using diesel fuel for high speed engines or heavy fuel oil (HFO) for medium speed engines. Diesel fuels are high in cost and suffer from volatile pricing, but diesel power plants are quick to set up, which explains the general preference for this solution when it comes to rapidly filling a supply-demand gap. For example, the Barranca Plant in Costa Rica, rated 90 MW was operating within 90 days of signing the contract. Nicaragua used high speed diesel engines for the Hugo Chavez Plant and replaced them with medium speed engines burning HFO for the long term. Medium speed engines may take as long as 24 to 30 months to engineer, procure and construct.

3. Each Central American country also has an ongoing expansion plan that is expected to meet the capacity requirements for long term growth, but delayed progress in building the expansion plan may result in continued use of emergency generation units. The private sector will be relied upon to build a portion of the expansion plan. Private sector participation currently ranges from 17% to 85% in installed generating capacity among the countries in the region.

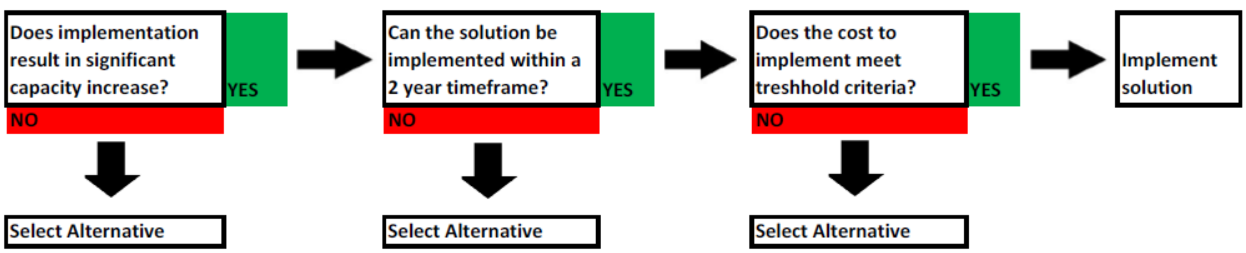
3.2 Ten Measures to Increase Electricity Supply

4. Ranking specific measures gives preference to modification of equipment, systems or structures that are already installed or are in the process of being installed, rather than adding temporary capacity through the use of rental equipment. Measures considered range from increasing capacity by improving the availability and effective capacity by improving maintenance practices, corrective maintenance and supply of spare parts to expediting schedules of plants being built under expansion plans. Plants that become candidates for modification have to be identified by analyzing the availability and effective capacity of the operating units.

5. Total system losses in the Central American region average 16% ranging from 10% for Costa Rica up to as high as 27% for Honduras. High losses in the region also provide a significant opportunity for reduction, which could free up the capacity needed to fulfill demand. Advanced technology metering can significantly reduce non- technical losses. Upgrades to the regional transmission system, such as adding capacitor banks at the 230 kV level provides a minimal reduction of transmission system technical losses but the improved system conditions can allow nearby generators to increase the power factor and produce additional megawatts.

6. Increasing capacity by utilizing existing back up or "inside the fence" generation by offering temporary incentives is another option. It may require only limited hardware additions to include the capacity in the dispatch pool but would need to develop a standard PPA and may require regulatory or legal changes. The ranking of measures will depend on the impact of increasing capacity, the schedule to implement the alternate and the cost to implement the alternate. Each step in the decision matrix will have to be measured against criteria for cost, schedule and impact in order to make the decision to implement the solution.

Figure 1 Decision matrix



Source: authors.

7. The measures examined have been subdivided into actions that can be considered and are ranked on a preliminary basis. The effectiveness of each of the actions can only be determined after additional data has been collected and analyzed for a specific application. In general, the measures proposed are as follows, in priority order:

1) Increase availability of existing operating plants that have been identified as having low availability by increasing reliability and improved schedules for maintenance outages

2) Increase capacity of existing operating plants that have been identified as having low effective capacity by obtaining necessary parts and conducting corrective maintenance. Rehabilitation of units that have been retired or de-rated can also be considered.

3) Expedite completion of Plants in the Expansion Plans and transmission lines being built under SIEPAC, that are currently being planned or under construction to advance the completion date or prevent schedule slippages.
4) Integrate backup generation into the dispatch pool for peaking by offering Power Purchase Agreements on a short term basis to make use of existing operating equipment and prevent blackouts rather than have the on-site generation operate as back up after the blackout occurs.
5) Increase the availability of bagasse fueled plants that are used by the sugar mills only during the sugar cane harvest by using alternate fuels after the harvest.
6) Upgrade transmission systems by the addition of capacitor banks at selected sites which reduce transmission system losses and can increase the operating megawatt capacity of existing generators.
7) Install advanced metering systems to reduce non-technical losses.
8) Install high speed reciprocating engines to operate on diesel fuel on a temporary basis.
9) Install leased power generation barges equipped with reciprocating engines or combustion turbines.
10) Install fixed, combustion turbine (GT) plant, simple cycle (SC) at a prepared land site to operate on light distillate oil.

8. Measures 1 through 7 can be initiated simultaneously to determine their impact on increased capacity and then the balance of the required increase in capacity can be installed using measures 8 through 10.

3.3 Analysis of the Ten Measures to Increase Electricity Supply

3.3.1 Increasing Availability and Capacity of Existing Generating Plants

9. Increasing the availability of existing generating plants can be accomplished by increasing the reliability of the plants or by reducing the time required for scheduled and unscheduled maintenance. The former will require either improved O&M or partial or full rehabilitation of plants. The latter can be accomplished by improved outage management and planning. Working with existing generating plants to increase effective capacity through repairs or refurbishments can increase capacity available during peak operating times. A review of the existing power plants with effective capacity significantly lower than nameplate capacity would be required to determine the necessary corrections, cost, schedule and effectiveness. Costs are likely to be less than other fixes because the modifications are being made to existing operating equipment unless it is

determined to be advantageous to refurbish a unit, in which case the unit has to be retired from service.

10. Information required for this analysis includes:

- Availability of operating power plants.
- Outage history of operating power plants.
- Nameplate and de-rated capacity of operating power plants.
- Reasons for de-rating.

Effective Capacity

11. Many of the countries reported installed capacity and effective capacity. The effective capacity of the hydro plants is dependent on water level. The thermal plants with effective capacity less than installed capacity indicates that capacity could be improved with correction of problems, overhaul of the equipment or a change in a regulation, contract or operating time.

12. The effective capacity of the Central American countries who report such a statistic is 83% of the installed capacity, representing a potential capacity of 653 MW. If improved maintenance, correction of equipment deficiencies, and modification of agreements could recapture 90% of that capacity, this would amount to a 588 MW power plant. Additional information about the effective capacity of thermal plants in the region is required to determine the opportunities for improvement.

Availability

13. Availability is the long term performance of a component or system in service and available to satisfactorily perform its intended function. For a power plant unit the definition of availability is the measure of time a generating unit is capable of providing service, whether or not it actually is in service.

14. Generating units with low availability can be targets for repairs or corrective maintenance outages to improve availability and increased capacity and the reliability of the system. Reciprocating engines and diesels have industry reported availability between 91.5% and 97%. Gas turbines have industry reported availability between 93.5% and 97%. Lower figures would point to deficiencies worth investigating in case of a lack of available capacity to determine the opportunities for improvement.

15. For example, in a country of the Middle East, a utility owned and operated a plant consisting of two 165 MW gas turbines working in combined cycle. The first year of operation, the plant experienced 91% availability, which is reasonably good, especially

for the first year. For the second year, the O&M contract was given to a local contractor whose experience was questionable. The availability deteriorated to 69%. Following that year, and for the succeeding three years, O&M has been in the hands of an internationally known operator and availability has increased to 98%, though the current operator continues to correct inherited problems.

Capacity Factor

16. Rehabilitation of existing units including: retired units, units which have been de-rated, and units with low capacity factors, may be capable of rehabilitation. Rehabilitated units can be available to increase capacity for use in the short term and provide generation capacity that can be called on to meet peak demand. Additional information about the condition of retired, de-rated, and low capacity factor thermal plants in the region is required to determine the opportunities for improvement.

17. Examples from international experience abound. For example, in Tanzania, a plant in Dar es Salaam consisted of two Asean Brown Boveri (ABB) GT10s and two General Electric LM6000 aero derivative turbines. Only one of the GT10s was operable and both of the LM6000s were out of service for blade problems for an operating capacity of approximately 15 MW. All units had been operating on Jet A fuel. When the plant was taken over by an independent power producer, all units were removed and overhauled with the ABB GT10s upgraded to GT10B. The reinstalled units were then put into service on natural gas from off shore of southern Tanzania. The operating capacity was increased to 113 MW for an increase of 98 MW

Incentives

18. To increase the capacity factor and availability of existing power plants, benchmarks can be set for each type of plant. If the plant achieves the benchmark, after an allowance period, to make repairs or schedule outages, then the plant will be expected to continue to achieve the benchmark. If the benchmark is exceeded the power plant can be rewarded with a bonus. If the power plant falls short of the benchmark the power plant will receive a penalty equal to the cost of the rental of reciprocating engines to replace the shortage of available capacity.

3.3.2 Expediting Projects in Expansion Plans

19. Each country in the region has developed expansion plans to meet increasing demand. Some projects may be in the engineering and construction stage, licensing stage,

planning stage, or the feasibility stage. Each project has a scheduled on line date that is used by each utility to determine dependable capacity to meet demand.

20. A review of the schedules of the projects in the expansion plans that are scheduled to come on line in the next few years, which may reveal an opportunity to expedite the completion and thereby increase capacity using a project that is already planned. Utilities that are building power plants under the expansion plan can be provided with a bonus to pay the constructors if the power plants are commercial prior to the scheduled date and likewise penalized for failure to meet the scheduled date for commercial operation. The bonus and penalty can be related to the cost of providing replacement power.

Incentives

21. There are two methods used in Power Purchase Agreements (PPA) for power plants operated by private companies that are used to expedite construction schedules and outage schedules. These are (1) liquidated damages for failure to meet construction schedules and (2) penalties for failure to achieve guaranteed availability under the PPA.

22. To expedite construction schedules, liquidated damages are included in the PPAs and are then reflected in the Engineering, Procurement, Construction (EPC) contracts to make sure that the power plants achieve commercial operation on time. EPC contracts may also have bonus provisions based on revenues earned by the Project Company by generating energy earlier than expected. The liquidated damages and bonus provisions help to focus the efforts of the constructor in sequencing the work, expediting equipment deliveries, and initiating startup and testing early in the commissioning process. Examples of liquidated damage provisions to meet a guaranteed schedule range from payments of $45,000 to $90,000 per day of delay. These examples of liquidated damage provisions are taken from projects in West Africa, the Middle East and South Asia. An example of the impact of bonus provisions on a constructor can be illustrated by a project built in northeastern Pennsylvania in the early 1990s where the constructor negotiated a contract to build a coal fired power plant in 27 months and targeted the construction schedule for 22 months. The constructor completed the project in 24 months and earned a bonus of a percent of the revenues earned by the plant for completing 3 months early.

23. Penalties for failing to achieve guaranteed availability under a PPA will motivate the Project Company to minimize scheduled outage time because scheduled outages can be controlled whereas unscheduled outages and forced outages cannot be controlled. Minimizing outage time can be accomplished by making spare parts available prior to the outage, using scheduling and management techniques to effectively schedule the outage activities and using quality control techniques to ensure repairs are done properly.

3.3.3 Transmission System Upgrades and Reduction of Losses

24. A computer model of the electrical system in Central America was used to run illustrative cases of the impact of selected changes that could be made to the system. The model is based on information that was gathered in 2004. Even though the information is not updated and can be incomplete, the results are still helpful to illustrate the impact of changes and to analyze some measures.

25. The measures selected to study the impact of changes to the transmission system were based on voltage profile and transmission line overloading. The corrective measures studied to improve the voltage profile included:

- Addition of capacitors.
- Effects of load tap changers.
- Addition of new generation.

26. The measure studied to correct transmission line overloading was the addition of a transmission line. All measures contribute to eliminating an average of around 3% of losses.

Table 27 – Transmission System Changes

Proposed Transmission System Change	Base Case	Addition of capacitor banks	Operation of the load tap changers	Connection of generating plants	Addition of transmission lines
Technical Losses (MW)	244.96	241.93	242.49	244.59	244.23
Imported Power (MW)	278.41	278.43	278.41	278.41	278.43
Generated Power (MW)	8007.34	8004.29	8004.88	8006.97	8006.59
Load (MW)	8040.79	8040.79	8040.79	8040.79	8040.79
Percentage of Losses (%)	3.05	3.01	3.02	3.04	3.04

Source: authors.

27. The results achieved come from specific measures, in particular:

- The addition of the capacitor bank reduces the need for reactive power from the generators, allowing the generators to increase capacity available for contingencies such as peak demand.
- The importance of adding capacitors at one of the substations of the Nicaraguan System has been identified by low voltage at three buses (4401, 4404, and 4407) which register voltage levels below 90%. A capacitor bank of 109.6 MVAR is installed at one of the buses (4407) and the voltage levels at three buses increased to above 94%. The recent cost of a 90 MVAR capacitor

bank installation at 230 kV was $4.5 million. A typical schedule for a capacitor bank is six months for manufacture and two months for installation.

- The location of the capacitor banks in the 230 kV transmission system in Nicaragua improved voltages with the consequent improvement in quality of service, and reduced the power losses of the transmission system. When the capacitor bank reduces the exchange of reactive power, it frees up capacity in the lines and possibly in nearby transformers. For example, in one of the adjacent lines, the load was lowered from 35.3% to 33.1% of line capacity.
- New transmission lines reduce system losses, avoid overloading and improve voltages. In the case for a new transmission line in Costa Rica, a load level of 101.8% was decreased to 56.7% with the addition of a parallel line. The voltages at the ends of the line before simulating the new transmission line were 94.8% and 94.0%. After insertion of the new line, voltages improved to 95.2% and 94.7%, respectively.
- In the transmission system of Costa Rica, the transmission line connecting two buses (5195 and 5003) is overloaded to 101.8% of capacity. To overcome the overload situation, another line was modeled to be constructed in parallel with the existing one. With this action the loading reduces to 56.7%. The estimated cost of a 230 kV transmission line is $120,000 per kilometer for a single circuit line and $180,000 per kilometer for a double circuit line. The schedule for design and construction of a typical 230 kV line, with right of way already procured is approximately two years.

28. The addition of a transmission line and the addition of a generating plant reduced losses by less than a megawatt. Operating load tap changers reduced losses by 2.5 MW and the addition of capacitor banks reduced losses by 3 MW. The test conducted for the purpose of this study provides a very conservative estimate of losses since the modeled system did not include sub-transmission and distribution systems. Yet, each alternative provided a significant improvement to transmission system operating characteristics by improving voltage conditions or reducing overloaded conditions.

29. One of the advantages of improved transmission system characteristics is a reduced requirement for the generators to generate reactive power. Reducing the requirement to generate reactive power can allow the generator to produce additional megawatts within the generator’s rating, as specified on a generator capability curve. For example a generator rated 125 MW at 0.85 lagging power factor can produce an additional 15 MW if the requirement to produce reactive power is reduced to 0.95 lagging power factor.

30. The value of this exercise is to show that making changes to the transmission system may not generate huge decreases in losses, but the improvement of transmission

does produce significant increases in electricity supply available to consumers (through less needs for reactive power generation for example). As a result, the contribution of measures linked to transmission improvements ought to be included in a broader emergency response design.

3.3.4 Integration of Backup Generation

31. Backup power generation is usually considered by large commercial or institutional facilities (hospitals, hotels, shopping centers, universities and industrial facilities) to provide a reliable source of power under blackout conditions on the grid. Some backup power generation is sized to provide electrical energy for the full load operation of the facility, while other back-up power supplies are sized for emergency, personnel safety and safe shutdown of the facility.

32. Industrial facilities, such as refineries, paper mills, steel mills, sugar mills, ports, pharmaceuticals and aluminum smelters build "inside the fence" power generation facilities to provide a source of reliable power for the process or to save on energy costs, producing electric energy at a lower cost than that delivered by the grid.

33. The advantages of such sources of distributed generation is that they can potentially supply electricity to the grid during a national emergency, above their traditional role as a back-up, or stand alone, capacity. The disadvantages of doing so include less centralized control of environmental emissions, costly operation of distributed generation and potential loss of native load for the utility.

34. As a short term measure, to take advantage of any back-up generators or "inside the fence" generation, an offer can be made to the owners of those generators to pay for fuel and capacity if the back-up generator is entered into the dispatch pool under a limited PPA. A PPA can be developed to compensate the owners for the additional maintenance, fuel and capacity in the short run in exchange for being subjected to dispatch and operation. Interconnection equipment would have to be installed which would be covered by the agreement.

35. Power purchase agreements can be crafted for a minimum capacity and a sunset date where back up generation would revert to the original on-site emergency service. The PPA would be limited in duration up to the time that plants being built under the expansion plans are built to replace the capacity of the backup generation to prevent the loss of native load for the local utility. Benchmark, bonus and penalty can be applied to backup generation that opts to be included in the dispatch pool.

Cost

36. The costs to implement the integration of backup generation into the dispatch pool would be the capital cost of the synchronizing equipment and protective relays so the backup generator can work with the system and the operating cost of more frequent maintenance and the cost of fuel. It is most likely that the existing backup generation operates on diesel, so the cost of fuel as a pass through would be approximately 9.5 cents per kWh based on diesel fuel costing $1.83 per gallon.[16]

37. A measure of the cost of maintenance and spare parts can be taken from the reported cost of renting high speed diesel engines in Costa Rica where the rental units cost 4 cents to 5 cents per kWh. Integrating the back-up generation is similar to renting generating units except they are already installed and after the rental period will not have to be relocated. The owners of these back-up generators will gain the benefit of a more reliable supply in their immediate area by allowing their units to be integrated into the dispatch pool so the cost could be less than the cost of the rental.

38. Prerequisites for deployment of using backup generation in the dispatch pool would be a minimum size of the unit that would make it economical to add synchronizing equipment and protective relays and the terms of a temporary power purchase agreement acceptable to the owners of the backup generators to allow their generators to be operated by dispatch which will increase maintenance and use of spare parts.

3.3.5 Sugarcane Bagasse Fired Power Plants

39. One source of on-site generation is the bagasse fueled power plants used by the sugar mills during the sugar cane harvest. The boiler specifications could be reviewed to determine an alternate fuel that could be used after the harvest is over and the power plant could be operated all year. Additional information required, to determine the cost and effectiveness of including on site generation in the dispatch pool, includes:

- Size and location of on-site generation
- Type of fuel used by the on-site generation
- Agreement of the owners to include on site generation in the dispatch pool

40. Analysis of the additional information will provide a measure of the effectiveness of such an approach. The same benchmark, bonus and penalty can be applied to bagasse plants that opt to be included in the dispatch pool after harvest operating on alternate fuel.

[16] The price of diesel fuel is subject to high volatility. This study anticipates that diesel prices will remain at a relatively high level in the two to five years to come. The price is assumed constant for the purpose of calculations comparing short term temporary alternatives.

Cost

41. The costs to implement the inclusion of the bagasse plants into the dispatch pool would be the capital cost of the synchronizing equipment and protective relays, the cost of modifying the boilers to burn an alternate fuel, the operating cost of more frequent maintenance and the cost of fuel. It is most likely that the alternate fuel will be light distillate oil (diesel) so the cost of fuel as a pass through would be approximately 9.5 cents per kWh based on diesel fuel costing $1.83 per gallon.

42. The operating and maintenance costs will be less than for diesel engines so the O&M cost will be less than 4 cents to 5 cents per kWh charged for diesel rentals and more likely be in the range of 1.5 cents to 2.5 cents per kWh.

3.3.6 Reduction of Non-Technical Losses with Advanced Metering Systems

Non-Technical Losses

43. Non-technical losses represent a significant difficulty for electric utilities. The primary causes of these losses include commercial loss and nonpayment loss. Commercial loss is frequently the result of electricity theft via illegal taps on power lines or tampering with power meters. Nonpayment loss is caused by an inability on the part of the consumer to pay full price for the electricity consumed. These non-technical losses represent an unnecessary energy waste that burdens electricity rates for consumers, results in lost revenue for utilities and causes increased carbon emissions in the environment.

44. One potential solution to these types of non-technical losses is the implementation of new power metering systems. This includes the establishment of either a prepaid electricity metering system or an integrated power system of smart boxes on distribution lines.

Prepaid Electricity Metering

45. A prepaid electricity metering system allows the consumers to buy credit from the power utility to use a specified quantity of energy. These credits commonly come in the form of encoded tokens which, when inserted into the appropriate slot in the meter, allow the consumer to utilize their energy credit. The meter then dispenses electricity until the

credit runs out. In addition, the meter alerts the consumer sufficiently in advance of the energy credit being exhausted so that the consumer can pay to recharge their energy supply. However, if the consumer fails to buy additional energy credits, the meter automatically disconnects the supply as soon as the credit store is used up[17].

46. Prepaid electricity metering offers several important benefits to utilities. Most significantly, the utility receives electricity payment about 45 days earlier than in the conventional billings system, effectively eliminating the risk of nonpayment. In addition, the utility can save considerably on operating costs associated with reading, billing and revenue collection. Obviously both of these factors improve the electricity utilities finances tremendously.

47. There are several barriers to the implementation of prepaid electricity meters. First, utilities may be discouraged with the large initial investment required, which includes the cost of equipment, marketing, establishing distribution channels and other management costs. Additionally, consumer behavior may play a role because of the difficulty in convincing existing customers who are satisfied with the post-paid system to switch to a prepaid system. In many cases, the payment, especially for smaller users, is on a flat rate basis and paying for actual energy used may be more expensive to the consumer. Finally, the uncertainty of success may act as a barrier since it may not be a viable option in all markets. The success of this system depends on the commitment by power utilities and for this they must be convinced of the real benefits of prepaid metering[18].

48. Such prepaid electricity metering systems have become increasingly common and can be found in the United Kingdom, South Africa, Argentina and New Zealand, among others. The South African case, in particular, is an example of the successful implementation of the prepaid electricity metering system. Eskom, the utility that provides 95% of South Africa's electricity has experienced success with the prepaid electricity metering systems. Starting in 1994, Eskom, to date, has over 2.6 million meters in operation. It currently costs Eskom, on average, 2,500 South African Rand (approximately US$248) for every new electrification connection they make. However, the installation of new prepaid meters has reduced steadily as certain projects have become prohibitively expensive to electrify. Many of Eskom's new customers live in new homes or shacks where there is no house wiring and thus, require additional investment on the part of the utility.

49. In regards to the problem of non-technical losses, Eskom has found that the prepaid metering system can be a useful tool in managing commercial loss and

[17] Pabla, 2004.
[18] Srivatsan, 2004.

eliminating nonpayment loss. By carefully analyzing consumption and purchase patterns, Eskom has been able to manage electricity theft by detecting usage anomalies, performing site visits and prosecuting trespassers. In addition, Eskom has also found that consumers have accepted prepayment because of the absence of fixed monthly charges and reconnection fees and a clear display of available credit that allows consumers to budget more effectively. Finally, the reliability of Eskom's prepaid metering system has been very good, with current meters exhibiting a failure rate of less than 2% per year, including customer induced failures.[19]

50. Although implementation and operation of improved metering and prepaid meters require a significant commitment from the power utility, both financial and over time, such system contribute to almost eliminating nonpayment losses. Additionally, the system allows for utilities to be able to better manage electricity consumption and detect theft. As a result, the prepaid electricity metering system is recommended for utilities that face long outstanding periods for their billings and significant amounts of electricity theft.

Integrated Power System

51. An integrated power system utilizes different electricity distribution system architecture when compared to many of the traditional fixed network AMR/AMI systems used in North America and Western Europe. Whereas the typical AMR/AMI system features an electric meter on the endpoint of the consumer's premises, the integrated power system system involves the physical removal of the electric meter from the customer's premises and the use of a separate unit that serves many customers. An integrated power system has been installed in Cartagena, Colombia.

52. In this system, the traditional electric meter is replaced by a module, which is placed on the electrical distribution structure alongside the premises. This module serves up to 12 premises and allows the utility to carefully monitor electricity consumption at the end-user level. The module is meant to be relatively inaccessible to the electricity end users and thus, is typically mounted on a pole top inside a substation enclosure or secure cabinet. Finally, the module is manufactured according to outdoor and military-like specifications to make it climate resistant and tamper proof.

53. The integrated power system is specifically designed for deployments that involve harsh climates, challenging topographic conditions or countries that have significant occurrence of non-technical electrical losses resulting from electric meter tampering or theft. The integrated power system runs parallel to the current metering system but

[19] "Frequently Asked Questions Related to Prepayment."
<http://www.eskom.co.za/live/content.php?Item_ID=192&Revision=en/0>

measures consumption at the line level, before it ever reaches the meter. This allows the system to bill in real time the actual energy being dispatched to the end user. The integrated power system then reports to the utility how much energy was dispatched to each end user, allowing the utility to compare against what they are billing in order to identify specific end user lines where electricity is being lost.

54. This system helps the utility to reduce its commercial losses by identifying areas where non-technical losses occur. The system is meant to act as a permanent solution by continuing to monitor electricity flows in real time and allowing remote suspension and reconnection of service if losses persist. This system is likely to be less expensive to install than a prepay system, but will push cash flow out and still has the difficulty of bill collection, even though it will have the remote disconnect-reconnect option. The integrated power system has several features that compare favorably with the traditional automated meter reading and Advanced Metering Infrastructure (AMR/AMI) systems. Integrated power system is specifically designed to provide significant information and protection of tamper and theft. In addition, the system is designed to accommodate challenging climates, environments and geographies because of its ability to utilize a variety of different communication technologies with its network also allows for easy disconnection and reconnection of non-paying customers as well as supporting both pre- and post-payment revenue models. Finally, the system eliminates the need to upgrade residential electric meters.

56. However, the integrated power system does possess some key disadvantages. The integrated power system measures on premises consumption via a distribution transformer that is located some distance from the premises. When this transformer is installed further than 10 to 12 meters away from the premises, there is a possibility that line loss could create an inaccuracy in measurement. Another issue that exists is that, at this time, the module firmware, a key element of the system, cannot be upgraded remotely and must be upgraded locally at each box, a labor intensive and time consuming process. Finally, the integrated power system is, at present, comparatively more expensive than other AMR/AMI systems. As such, it may be only practical to deploy this system selectively in areas that are most vulnerable to tampering and theft or with challenging topography.

57. The integrated power system is a potential solution to the problem of mitigating non-technical electricity losses and promoting energy efficiency. This system is designed for the express purpose of eliminating commercial loss resulting from tampering and theft and thus, is most viable in geographic regions where these problems are prevalent. A private company developing this system conducted 10 pilot trials with 7 distribution companies and the results showed an average improvement of 29.2% reduction in energy lost and the trial with the greatest improvement showed a reduction of 58% of energy

lost. This data suggests that the integrated power system can significantly help utilities mitigate energy loss because of the additional information gathering and tampering prevention this system provides.

Cost

58. The cost of a basic pre-paid electric meter tends to range between $10 and $50 per meter although feature rich meters may be much more expensive (around $200 per meter). Pre-paid meters' cost will vary depending upon:

- Technical specifications of the meter (1 phase or 3 phase; display; rating).
- Method of prepayment (cash, card, or code).
- Number of meters ordered (manufacturing and shipping costs).
- Communication (meters manually read or via telecommunications).
- Expected meter life and warranty.

59. Other factors to consider:

- Ability to tamper with meters.
- Payment by utility or customer for replacement or repair of damaged meters.
- Payment by utility or customer for initial prepaid meters and installation.
- Impact of prepaid meters on reduction of non technical losses.
- Cultural acceptance of prepaid meters.
- Dealing with theft or counterfeit if the prepaid meters are replenished with cash.
- Process for selling credits if the prepaid meters are replenished by cards or codes (similar to phone cards or by utility office).
- Cost of installation and training of the workforce to install the meters.

3.3.7 Addition of Capacity Using Reciprocating Engines

Diesel Fuel

60. Reciprocating engines (internal combustion engines) constitute a good back up power supply to the hydropower units that much of Central America uses for base load. Reciprocating engines have thermal efficiencies of 41% for the small high speed units (e.g.: 1MW of capacity) to upwards of 46% for the larger medium speed units (e.g.: 100MW of capacity). Boilers cannot meet this level of efficiency and gas turbines can be thermally competitive only in combined cycle and with natural gas or light diesel oil (LDO). Purchase and set up of the medium speed units built into a nominal 100 MW

plant will cost $ 800 to $ 1100 per kW and require about 30 months to purchase and install. They can burn the less expensive HFO and crude oil at an efficiency of approximately 46%.

61. The smaller high speed diesel units can be set up quickly, as they can be skid or container mounted with engine, generator and circuit breaker on the skid and require no foundation other than a site with stable soil. Large plants, up towards 90 MW can be established and operating in three or four months from receipt of order. Their downside is the price of electricity they produce due largely to their high fuel costs since these units must operate on diesel or LFO (or high level of subsidy in case diesel fuel price is subsidized). The temporary high speed units of 1 MW to 2 MW banked into a larger plant are being rented dry in Costa Rica for 4¢ to 5¢ per kWh. The fuel cost should be approximately 9.5¢ per kWh based on fuel costs of $1.83 per gallon. These plants are about 41% efficient.

Fuel Supply

62. Each 2 MW unit burns about 140 gallons per hour at full load. It would be expected that the units would be operating as peaking units for possibly two or three hours in the morning and about five hours in the afternoon, though peak load requirements differ by country. An increase in diesel rental units would require the import and transportation of additional quantities of diesel fuel oil and the resultant increase in capacity of port unloading capacity, storage tank capacity and tank truck capacity to move the fuel from the port to the power plant locations.

63. For a few such rental units, mobile tanker trucks connected by manifold for fuel supply may be adequate on a temporary basis, but with a plant much over about 20 MW, this proves to be impracticable as road tankers have a capacity of approximately 8000 gallons (at least in North America, to stay within highway load capacities).

64. For larger plants, steel tanks built on the site would generally be required. These tanks are of unlimited size in respect to the practical capacity used and can be erected and tested quickly. A plant of 100 MW will require about 50,000 gallons of diesel for 7 hours of peak operation noted above, though peaks are bell shaped generally so the plant would not likely be operating at full load for the entire period.

65. With oil requirements of this magnitude, there assistance is needed from various government entities to expedite the procurement and receipt of equipment and oil, expedite site locations and permitting of the plant including the oil storage facility, transportation of the oil from port or other interface to the plant, environmental

permitting and other such logistics required to get the plant up and running in the time expected.

3.3.8 Addition of Capacity Using Leased Power Generation Barges

66. The use of barge mounted electric power generation dates back to the 1940s and is a proven and reliable approach to providing electric supply, but is typically expensive. Barge mounted generation has been used as both a short term (emergency) supply source of electricity as well as a long term permanently installed power plant.

67. Electric generation barges are available for short to intermediate term rental or may be purchased (or leased) for longer term use. The barges also use a variety of equipment which yields a wide range of capacity outputs and can utilize several fuel sources. Due to the portability of power barges, there is an active market for the sale/lease/rental of barges which are operation ready needing only an interconnection to the grid to supply power. There is also an active market for the custom construction of barges.

68. The advantages of using power barges may include:

- Wide range of outputs using multiple machines allows for capacity supplied to be well matched to the needs (single or multiple barges).
- Barges may be added or removed if the need changes over time.
- Barges may serve base load, intermediate or peaking power needs.
- Time from decision to obtain added capacity to operation may be significantly quicker particularly when using currently operating units
- Construction of a new barge may begin simultaneously with permitting activities allowing for delivery of the power island in under a year.
- Construction delays are less of a factor for the power island as the barges are built in an industrial setting using experienced construction personnel.

69. The disadvantages of using power barges may include:

- Impact on production from storms.
- Consume valuable waterfront / docking areas.
- Space limitation adds operations and maintenance challenges.
- Environmental issues (emission and water pollution, wildlife) vary depending on barge equipment and fuel.
- May require transmission line, dock improvements, fuel storage or other on land costs which impact the cost per MWh generated.

70. The use of power generation barges in Central America is not uncommon and typically is oriented to light distillate oil, LDO. The extensive coastline and the location of electric demand load centers near the coast are supportive factors for the use of barges to meet short term or emergency supply of power. Gas turbines in a simple cycle configuration can also be considered for a fixed installation at a prepared land site. The equipment, if available, can be delivered and constructed in a similar time frame to be considered as a short term solution. In addition, if the generation is filling a short to interim requirement, the residual value of the power generation barge is higher than a conventional plant as it can be easily moved to another location for use. The cost to purchase power plant equipped barges currently in operation is widely variable with an indicative range being $500 to $900 per KW of capacity.

3.3.9 Addition of Capacity with Used Power Plant Equipment

71. Used power equipment may in some occasions provide good opportunities to lower investment costs while eliminating the manufacturing time. This option is examined briefly here, but merits upmost caution with regard to this type of equipment and does not indicate support for procurement of used equipment. Indeed, used equipment may generate higher unexpected operating costs and risks of failures that could impair the purpose of producing electricity in a reliable way.

72. The investment cost of used plants and equipment is significantly lower than the cost of new equipment due to wear and tear and due to warranty protection that is less than new equipment. Used power generation equipment that is selected for purchase must be thoroughly inspected by reputable third parties and tested for critical functions. The results of testing and any refurbishment or remanufacturing may provide some limited warranty protection. Inspection and testing are critical prior to purchasing used equipment and there are specialized companies that have the expertise to determine the condition of equipment. Most testing results are in a test report and often come with a verification certificate that details the functioning of each major piece of equipment. The cost of used power plants varies significantly and a sample of some used plants for sale resulted in a range of $33/KW to $1,000/KW.

73. Construction costs of used power generation equipment, including the cost of disassembly and shipping, approach the construction costs of building a new plant. The construction of used power generation equipment carries slightly less risk than building a new plant because it is known in advance that all of the parts will fit and that the plant will work.

74. Since the schedule for building a plant with used power plant equipment is dependent on the particular unit selected to be moved, it is not likely to be a short term solution.

3.3.10 Environmental Considerations in Rehabilitating Existing Thermal Plants

75. Bringing additional capacity on-line quickly through rehabilitation of existing thermal plants can help but requires a case-by-case assessment of power plants being considered. In evaluating individual power plants, the baseline reference for environmental standards should be the World Bank's Pollution Prevention and Abatement Handbook –"Thermal Power: Rehabilitation of Existing Plants", and primary consideration should be given to local environmental regulations.

3.4 Ranking of Measures to Increase Electricity Supply Capacity

76. One of the underlying assumptions is that the most effective means to reduce short term constraints on electricity availability, in terms of cost and schedule, is to improve the performance and make use of existing equipment. However, the actual cost and schedule will be made up of the summation of individual determinations necessary to identify which power plants can improve their performance, or be added to the dispatch pool. It is also difficult to determine the magnitude of the capacity that can be added to each system until the characteristics of each existing power generating unit has been identified and the feasibility of increasing capacity has been identified.

77. The other solutions that require the lease of temporary equipment for additions to capacity have also been reviewed and compared to some longer term technologies such as hydro and geothermal plants. The results of those rankings follow.

Table 28- Characteristics of Capacity Technology

	Expected Life	Construction Time (2) (3) (5)	Availability (1)	Capacity Factor (4)	Efficiency
High Speed diesel	20 years	90 days (rental)	95%	20%-30%	41%
Medium Speed diesel	20 years	24-30 months	95%	40%-50%	46%
Barge GT Plant, SC	20 years	12-18 months	94%	20%-30%	40%

Fixed GT Plant, SC	20 years	12-18 months	94%	20%-30%	40%
Fixed GT Plant, CC	20 years	24-30 months	90%	30%-40%	55%
Coal Fired Boiler	40 years	30-36 months	89%	40%-50%	35%
Hydro Power	50 years	36-84 months	89%	50%+	N/A
Geothermal Power	50 years	12-36 months	97%	80%+	N/A

Notes:

(1) North American Electric Reliability Corp. (NERC) 2002006

(2) Schedules have been towards the longer date for the past few years but should be retreating.

(3) From signing contract to commercial operation.

(4) Capacity Factor based on plant efficiency, demand curves and general availability of renewables.

(5) Geothermal construction time can be as low as 12 - 24 months with a proven source

Source: authors.

78. Only three of the technologies listed are appropriate for short term installation to add capacity (listed below). Other technologies take a longer term to implement, except geothermal if the field is already prepared for equipment installation.

- High Speed diesel.
- Barge GT Plant, SC.
- Fixed GT Plant, SC.

79. The decision regarding which technology to implement will have to be made on a case by case basis by evaluating the tradeoff between being able to have new capacity brought on line quickly to generate expensive electricity or to add capacity at a slower rate, but to have electricity produced at lower cost.

80. Peak electricity is always more expensive than electricity generated by base load plants and this fact is reflected in the operating costs of the short term technologies. The rankings of each of the short term technologies are ranked in terms of schedule, efficiency, operating cost and capital cost in the table below.

Table 29– Technology Sorted in Order of Installation Time and Thermal Efficiency

Technology	Installation Time		Thermal Efficiency	
	Rank	Time	Rank	Efficiency
High Speed diesel	**1**	90 Days (Rental)	**1**	41%
Barge Plant GT	**2**	12-18 Months	**2**	40%
Fixed GT Plant, SC	**2**	12-18 Months	**2**	40%

Source: authors.

Table 30– Technology Sorted in Increasing Order of O&M & Fuel Cost

Rank	Technology	Fuel Cost $/kWh	O&M Cost $/kWh	O&M & Fuel $/kWh
1	Fixed GT Plant, SC	$0.112	$0.0057	$0.118
1	Barge Plant GT	$0.112	$0.0057	$0.118
3	High Speed diesel	$0.109	$0.0255	$0.135

Source: authors.

Table 31– Technology Sorted in Increasing Order of Capital Cost

Rank	Technology	Installation Time	Capital Cost $/kW	Levelized Cost $/kWh
1	High Speed diesel	90 Days (Rental)	$500	$0.0163
2	Fixed GT Plant, SC	12-18 Months	$650	$0.0212
3	Barge Plant GT	12-18 Months	$900	$0.0293

Source: authors.

81. Capital cost was converted to $/kWh basis using assumptions of a five year lease 40% residual value, 15% interest rate and a 60% capacity factor. The terms of each agreement may be different such as lease or buy provisions, capacity of the unit which varies with technology, and the term of a lease. It is clear that high speed diesel engines can have the lowest capital cost but also have the highest operating costs. Unit sizes will also be smaller for high speed diesel engines than for the other short term technologies.

3.5 Ranking of Measures to Increase Electricity Supply and Characteristics Matrix

82. The rationale for the ranking of these solutions is based on anticipated cost, schedule, impact on capacity and ability to control the process. They are ranked in anticipated increasing cost and the schedule for implementation. The detailed rationale for the ranking is described as follows:

- Increasing availability of existing operating plants that have been identified as having low availability is a low cost effort completely within the control of the utility operating generation plants and can be implemented in a very short time frame.
- Increasing the capacity of existing operating plants that have been identified as having low effective capacity is also completely within the control of the utility operating electricity generation plants and can be implemented in a very short time frame. There will be some cost, depending on the necessary parts or construction that may be required for corrective maintenance. Rehabilitation of

units that have been retired or de-rated can also be considered. Impact on increased capacity is unknown until the plants with low effective capacity, or candidates for rehabilitation have been identified and potential improvements have been quantified.

- Expediting completion of plants and transmission lines that are currently being planned or under construction can be implemented immediately but the impact will be longer term, dependent on the construction schedules of each of the projects. This measure also depends on the cooperation of those outside the control of the utility and may include some cost if it is determined that financial incentives are necessary to accelerate schedules.
- Integration of the backup generation into the dispatch pool for peaking by offering PPAs depends on the cooperation of those outside the utility and also requires the cost for synchronizing equipment and protective relaying for each generator to be connected. There will also be the added cost of fuel which will most likely be high cost diesel fuel. However, the generating equipment is in place and the schedule will be determined by the time it takes to install the required interconnection equipment and the time it will take to negotiate the agreements. Impact on increased capacity is unknown until the capacity of the back-up generation evaluated as candidates have been identified and the cost of interconnection has been quantified.
- Increasing the availability of bagasse fueled plants for operation after the sugar cane harvest depends on the cooperation of those outside the utility. The cost will be dependent on the identified modifications to the existing boilers and the cost of the alternate fuel. The schedule will be dependent on the time it takes to make the modifications and to negotiate the agreements. This solution is limited to the regions where there are existing bagasse plants.
- Upgrading the transmission system by the addition of capacitor banks to reduce transmission system losses and increase the operating megawatt capacity of existing generators is within the control of the utility. Schedule and cost are dependent on the size and number of capacitor banks being installed. The potential increase in capacity can be determined from the transmission studies to identify the location and size of the capacitor banks to be installed.
- Installation of advanced metering systems to reduce non-technical losses can be an ongoing program with small incremental costs. Implementation of this alternative depends on the cooperation of the utility customers. Implementation will likely be gradual, and the benefits of improved metering will be more long term. However, in an emergency response design, steps to launch improvements in metering will help improve the overall resilience of the electricity system.
- Installation of high speed reciprocating engines to operate on diesel fuel on a temporary basis is a short schedule, but high operating cost solution. High speed

reciprocating engines are more efficient than combustion turbines, can be provided in relatively small unit sizes and can be installed in locations distributed around the system.

- Installation of leased power generation barges equipped with reciprocating engines or combustion turbines requires a longer schedule to deliver and install and uses high cost diesel fuel. Combustion turbines usually have larger unit sizes than reciprocating engines. Installation of the power barges is limited to water locations that have been prepared for the connection of the barge. One advantage of a power barge is the ease of relocating or removal when it is no longer needed, but high cost is a concern.
- Installation of fixed, combustion turbine (GT) plant, simple cycle (SC) at a prepared land site is estimated to have a schedule similar to the power barges and will have the same operating costs. The installation of fixed combustion turbines can have more options for location than power barges but does not have the advantage of easy relocation or removal when it is no longer needed. However, the high cost is a concern.

83. Each solution will have a cost to implement and the cost may be incentive payments, expediting costs, spare parts cost or the capital cost for the project. With limited resources there may be a threshold cost determined for the overall program and for each individual project. The threshold cost is represented parametrically on the table below by the yellow boxes on a diagonal to portray the concept graphically.

Table 32– Cost and time to implement different alternatives

High	**Rented High Speed diesel**	**Barge OCGT - Fixed OCGT**	**Used Equipment Power Plant**
Medium	**Increased Availability - Utilize Bagasse**	**Accelerated Construction**	
Low	**Transmission Capacitors - Backup Generators**	**Rehabilitation Of Existing Facility**	**Improved Metering**
$/kWh / time	**0-12 Months**	**12-18 Months**	**Up to 24 Months**

Source: authors.

84. These solutions require inclusion of environmental and social considerations, for which World Bank Guidelines and local regulations can provide useful standards.

Table 33– Characteristics Matrix

Rank	Short Term Fix	Actions Required	Benefits	Consequence	Cost and Schedule	Risk
1	Increasing Availability	Obtain data on availability limitations	Improves reliability of existing equipment	Cost of improved maintenance outages and parts for corrective	Possible low cost and short schedule depending on fix	Low

				maintenance		
2	Increasing Capacity	Obtain data on capacity limitations	Improves operation of existing equipment or rehabilitates retired or de-rated units	Cost of parts for corrective maintenance or rehabilitation	Possible low cost and short schedule depending on fix	Low
3	Expedite completion of Plants in the Expansion Plan under constructio n	Determine the effectiveness of expediting the schedule	Advances the schedule of projects or keeps a project on schedule	Cost of expediting efforts or incentives to contractors and owners	Cost of incentives, reduced schedule	Low
4	Integration of On Site Generation	Obtain data on existing on site generation	Makes use of existing operating equipment	Cost of connection equipment, high priced fuel and capacity charges under PPA	Possible low cost and short schedule	Low
5	Increase availability of bagasse fueled plants	Obtain data on allowable alternate fuels	Makes use of existing operating equipment	Cost of fuel and capacity charges un PPA, cost of equipment required to convert to alternate fuel	Possible low cost and short schedule	Low
6	Addition of Capacitor Banks	Update transmission system data	Reduces transmission system losses and can increase MW capacity of existing generators	Cost of capacitor installations	$4.5 million for 90 MVAR at 230 kV, 8 months	Low
7	Install Advanced Metering Systems	Obtain pricing, implementatio n schedule and technical data	Reduces non technical losses and can be used to control some loads	Cost of implementation and public acceptance	South Africa experience is $248 per installation. Cost can be stretched out over time	Low
8	High Speed Reciprocati ng Engines	Obtain pricing and available data	Fast implementation	High cost fuel and rental fees	High cost, short schedule Lease $0.04 to $0.05 per kwh plus $0.09/kwh fuel	Low
9	Leased Power Generation Barges, or Fixed Gas Turbine, Simple Cycle	Obtain pricing and available data	Large capacity additions possible	High cost fuel and rental fees or purchase costs, cost to prepare waterfront site, or land site	Medium cost and short schedule for used barges, $500 to $700/ kw; New fixed equipment $650/kw to $850/kw for simple cycle	Low
10	Used Power Plant Equipment	Obtain pricing and available data	Large capacity additions possible, reduction of construction and operating risk	Warranty less than for new equipment, schedule to implement dependent on plant	Medium cost and dependent schedule, not likely a short term remedy	High (mini -mal war- anty)
Depen ds on Applic ation	Environ- mental Restraints	Obtain information on environmental limitations	Acceptable waivers may provide capacity addition with existing plants	Short term deterioration of environment	Minimal cost and schedule dependent on application	Low

Source: authors.

CHAPTER FOUR
PRACTICAL RECOMMENDATIONS

1. A government or utility must act quickly when an electricity shortfall becomes apparent. It must create an electricity conservation strategy in a very short time — anywhere from hours to months — and then implement it. Good information is key to creating an effective plan.

2. The three major information requirements are listed below:

- Identify the kind of electricity shortfall, e.g. energy or capacity (what kinds of savings are needed, capacity or energy?). Is the shortage limited to certain peak times? If yes, what activities cause it? Example: are the in-line water heaters causing an 18:00 electrical peak?
- Estimate the probable duration of the shortfall (How long will the shortfall last?). Are we waiting for a new power plant? Transmission line?
- Establish a breakdown of energy consumption by end-use during the shortfall period (Who and what is using the electricity?).

3. The goal of the collected information is to allow the authorities to develop a list of measures and energy savings and select the most effective ones for further action.

4.1 Identify the Kind of Electricity Shortfall

4. A successful conservation strategy must save electricity at the time that there is actually a shortfall. Every crisis will be unique, but most will be either a shortfall in peak capacity or in energy (that is kilowatts or kilowatt-hours). In practice, the crisis will evolve (or more information will become available). What first appears as a shortfall in peak capacity may quickly change into a broader energy shortage (or vice versa). A supply shortfall may also be caused by administrative, rather than technical, reasons such as when generators choose not to offer power or try to manipulate the market.

5. Many conservation programs have impacts on one or the other, but not both. For example, it is often possible to reduce peak power by deferring agricultural pumping until off-peak periods. This action will cut the peak but not save any electricity (and might even increase its use). Many programs, to improve the efficiency of appliances, such as refrigerators and electric water heaters, will save electricity but have little impact on peak demand. Identifying the kind of shortfall will narrow the list of reasonable measures and simplify the development of a strategy.

6. Information needed:

- Size of shortfall. By how many percent does electricity demand exceed supply?
- Identification of times when shortages occur: time of day, season, drought? Or when in the future is the shortfall expected to appear?
- Load curves (electricity use by hour) for typical days in seasons with highest and lowest electricity demand (to assess the impact of lighting, water heating, industry, harvest, etc.).
- Does the shortfall include the spinning reserves?

4.2 Estimate the Probable Duration of the Shortfall

7. Strategies to save electricity in a hurry work best when there is a reasonably clear ending to the shortfall. In Central America, this may be when a power plant is completed (or repaired) or a transmission line is finished. The likely duration of the shortfall will shape the strategy to reduce demand. A 20% shortfall persisting for months will require different interventions than one lasting just an afternoon. In general, it will be possible to rely more on financial incentives and technological improvements for crises with longer advance warning or duration. Information required includes:

- Prediction of when critical shortfall is likely to end (and the event that will signal the end).
- Likelihood that crisis will continue or evolve into something different.

4.3 Establish a Breakdown of Energy Consumption by End-Use During Shortfall Period

8. It is difficult to save electricity that was not used in the first place but this is exactly what could be attempted if there is poor information on how (and when) electricity is used. The most reliable approach is to perform detailed customer surveys, including end-use monitoring, load surveys, appliance saturation surveys, and other data collection instruments. It is also important to know the largest customers. For example, about 1% of Tokyo’s electricity is used by the water and sewage treatment system. In California, utilities (in co-operation with the State Energy Commission) conducted load surveys of hundreds of customers. This, combined with appliance saturation surveys, give California planners a clear picture of the most important end-uses of electricity

9. Most data collection takes years to perform, and even longer to compile and interpret. Ideally data collection will be a regular activity. Reliable, up-to-date information in Central America will be scarce or non-existent but insights from even limited or incomplete data can make a difference.

10. Information needed:

- How much electricity is consumed by each sector?
    a. Residential.
    b. Commercial.
    c. Industrial.
    d. Agriculture (irrigation? Milling?).
    e. Government buildings and facilities?
    f. Certain regions with unusually high consumption? (e.g. hotels in tourist areas).
- What appliances and equipment are responsible and how much? This data will be crude at best. If any end use surveys have been conducted in one of the Central American countries, then it might be roughly applicable in the others. Major end-uses are:
    a. Lighting (residential, commercial, street).
    b. Water heating.
    c. Cooking.
    d. TV.
    e. Refrigeration.
    f. Water pumping & sewage treatment.
    g. Industry (including mining).
    h. Other.

11. Technical characteristics of end-users are also vital. For example, are most showers in-line, resistance-heated, rated at 2 kW. Or is most residential and lighting now done with compact fluorescent lights. It is also useful to compile data on customers with long-term, fixed-price contracts. These users – typically electricity-intensive industries — may find it worthwhile to shut down operations temporarily and re-sell electricity on the spot market if the price rises enough (and if their contract permits). These contracts are difficult to compile and tabulate because each is unique and many are confidential.

4.4 Define Whether Specific Electricity Pricing Measures are Needed

12. The price signal is the most important means of informing consumers of an electricity shortage. Electricity prices should rise to reflect its scarcity and most utilities already have interruptible power tariffs or Demand Response programs to exploit this price elasticity. These programs also provide clues as to how other customer categories will respond to higher prices.

13. Unfortunately, for many groups of customers, there exist barriers to quickly raise electricity prices. These barriers are caused by regulatory delays, technical barriers

associated with meters and meter-reading procedures, and uncertainty about what the actual electricity price is during the shortage. For example, most utilities in North America and Japan read residential meters once a month. If the shortage is expected to persist for less than a month, feedback caused by high prices can play at best a weak role in encouraging conservation. It is therefore critical to determine the technical and institutional constraints to which higher prices can be used to discourage consumption.

4.5 Develop a Ranked List of Measures

14. Hundreds of electricity conservation measures are possibly relying on behavioral changes and technical improvements in efficiency (or both). But usually there are resources to effectively promote only a small fraction of them. Factors to consider when ranking the measures include:

- Features of the shortfall: amount of conservation needed, duration, and advance warning.
- Target sectors, that is, residential, industrial, commercial, or agricultural.
- Appropriate mix of behavioral and technical changes.
- Staff and money available to implement programs.

15. This is the most difficult part of the process because it requires input from many different sources. Furthermore, the ranking requires subjective judgments, for example with respect to estimating the impact of campaigns to change consumer behavior. This, in turn, will depend on public opinion towards the electricity shortfall, the public's willingness to participate, and the credibility of the group promoting conservation. In practice, policymakers may have as little as a few hours to develop the list which will consist of only a few measures. Advance preparation is critical.

16. Ranking measures according to their cost-benefits does help to apprehend orders of magnitude and to fine tune expectations. As we can see from the box below, among the six measures described in the preceding chapters, the most cost effective measure is by far CFL replacement with costs which are six times lower than the next alternative in the ranking. The other appliance replacement alternatives rank 4th and 6th with costs, which under the given assumptions, are not very different from electricity generation expansion costs. These rankings do not include climate change aspects, which could affect their costs (e.g. externalities of carbon emissions are relevant) or potential access to concessional financing (e.g. for low carbon solutions such as appliance replacement programs).

Box 4 – Comparing the cost of adding electricity supply measures with savings from appliance replacement

In order to have comparable data we consider – like in the generation alternatives – a 15% discount rate in all cases. For the refrigerator replacement we assume a 15 year life, annual savings of 569 Kwh (replacing a mid 80s refrigerator for a new efficient one) and a cost of $500. For CFLs replacement we consider savings of 32.8 KWh/year (30 watts per lamp used 3 hours a day 365 days a year) 5 years lifetime and a cost of $2.5. For the electric shower we assume savings of 221 KWh/year at a cost of $208 and a lifetime of 10 years. Based on these data we calculate the levelized costs of the replacement (Table 1).

Table 1– Appliance Replacement Levelized Cost

	Refrigerator	CFLs	Electric Showers
Saving (KWh/year)	569	32.85	221.4
Cost ($)	500	2.5	208
Life (years)	15	5	10
Levelized Cost (KWh/$)	0.150	0.023	0.187

Source: authors.

We estimate the levelized cost of each alternative as the marginal cost of buying, installing, and maintaining the efficient device divided by its discounted stream of lifetime energy savings. The results for each appliance – in $/KWh - are presented in the last row.

These costs can now be compared with total costs of the different generation alternatives. A ranking based on increasing costs of generation and replacement levelized costs is presented in Table 2.

Table 2– Ranking of Levelized Costs

Alternative	$/KWh
CFL s	0.023
Fixed GT Plant, SC	0.139
Barge Plant GT	0.147
Refrigerator Replacement	0.150
High Speed diesel	0.151
Electric Shower	0.187

Source: authors.

These results are very sensitive to the assumptions considered. Fuel prices, discount rate and prices of the individual alternatives will all have significant impacts on total costs and relative ranking.

Fuel prices are a key element because they represent a very large share of generation alternatives while they do not enter at all in the costs of efficient appliances. For example an increase of 50% in fuel prices would turn all generation technologies more expensive than appliance replacement.

Environmental externalities were not factored in the calculation and would likely tend to burden further the costs of the electricity generation additions as opposed to demand-side measures which do not imply additional emissions.

4.6 **Institutional Measures to Consider**

17. Having a long term energy efficiency strategy in place can be of great help in devising and putting into practice an effective and efficient response to a crisis.

18. The international experience reviewed in previous sections shows that countries which had a strong energy efficiency tradition where best suited to cope with the crisis. California for example was able to implement over 200 different programs as a response to the crisis. Having a long term energy efficiency strategy in place can be of great help in devising and putting into practice an effective and efficient response to a crisis.

19. Specific institutional measures to consider include:

- Enforcing restrictions on imports of energy inefficient products and developing regional collaboration on energy consuming equipment information and customs standards.
- Strengthening energy demand data collection: residential appliance surveys, monitoring.
- Developing energy conservation programs focused on the largest electricity users.

Annex 1 – Case Study: Chile

1. Background

In the 1990-2003 period, the 5.8% GDP annual average growth was accompanied by a 5.1% growth of the total secondary energy consumption and, within this field, electric power increased by 8.2%.

Even though a series of Energy Efficiency[20] (EE) initiatives were implemented in the 90's, it was not until December 2005 that the Ministry of Economy, Promotion and Reconstruction issued Order No. 336 whereby the Commission for the "Energy Efficiency Country Program" was created. The main purpose of this Commission is to provide guidance to each of the Ministries in terms of specific actions, plans, policies and EE measures.

2. The 2007-2008 Energy Crisis

Three major factors contributed to the crisis

- The 2007-2008 energy crisis in Chile originated in a drought and the interruption of gas imports from Argentina. In 2007 gas reception averaged only 9% of the contracted 25 million cubic meters day. The lack of gas forced the use of diesel, increasing maintenance costs and failure rate in dual thermal plants.
- In 2007 – 2008 a drought took reservoir capacity down to 38% of its maximum level. In 2006, 70% of energy was generated by hydro plants while the share dropped to 53% in 2007.
- Failure of important power plants Nehuenco (11 months); Unit U-16 (2 months); Gasatacama Combined Cycle 2 (12 months, partial)

To deal with the price increases the government implemented the following measures:

- Stabilization of fuel prices through the injection of US$ 1.26 billion into Fuel Price Stabilization Fund
- Temporary reduction of specific tax on gasoline

[20] Within the scope of the National Energy Commission, a working unit called "Efficient Use of Energy" was created for the purpose of implementing the "National Program on the Efficient Use of Energy", which was financed with international funds. In this context, various initiatives for the promotion of EE in different areas of energy consumption were carried out, especially pilot programs and demonstrative projects. In addition, progress on regulatory and sector legislative tasks was given priority over the execution of individual projects.

- Electricity subsidy for the most vulnerable 40% of the population (direct reduction in the electricity bill)
- 2009 National Light Bulb Replacement Program
- Money subsidies for poor families

The measures for avoiding brownouts included:

- Month of April was included in peak hour measurement
- Rationing decree (reduction in voltage - hydro reserves)
- Energy saving campaigns (*Sigue la Corriente, Ahorra Ahora, Gracias por Tu Energía*)
- Extension of daylight savings time
- Flexibilization of water use for power generation
- Installation of back-up turbines and engines
- Conversion of combined cycle gas turbines to allow operation with diesel.
- Investment in diesel logistics
- Financial offers from generators for consumption reductions by regulated clients and agreements with non-regulated clients

Thanks to these measures there were no interruptions to the electric supply or interruptions to residential and commercial gas supply. Increases in domestic prices due to international fluctuations were mitigated and low-income families received support in order to cope with higher prices.

In order to ensure the long run stability and functioning of the electricity sector, the government of Chile has taken measures aimed at strengthening the role of the Public sector in the electricity system.

A new ministry of energy in charge of sector policy, plans and regulations was created. Personal in the Ministry increased by 146% since 2007 (from 62 to 153 in 2009) and the institutional budget was increase five-fold (from US$ 9.097.433 to US$ 47.720.193).

3. Energy Efficiency Country Program (PPEE)

3.1. General Strategy

Strategic Purpose: To build and consolidate a National Energy Efficiency System with the active participation of all related national players involved. This strategy is based on the following principles:

- Long-term commitment.
- Simultaneous implementation of initiatives and projects involving all sectors and players to create enough synergies to enable the necessary managerial, technological and cultural changes.
- High-level political and technical coordination.
- Integration of economic, energetic, environmental and social objectives.
- Flexible implementation.
- Combination of regulatory, promotion and educational instruments.

The Program is based on three fundamental principles:

1. Public-private cooperation and participation: The Ministry of Economy, a supra-sectoral institution, leads the program. In addition, the Notifying Committee was created for the purpose of achieving the active participation of all relevant sectors and players, as well as the Advisory Board,[21] in charge of providing guidance in terms of the PPEE's overall strategy, budgetary issues and how to obtain support for the program both from the private and international sectors.
2. Mix of policy instruments: Promotion, educational (including educational, training and social awareness instruments) and regulatory instruments. None of these instruments prevails over the other.
3. High-impact and highly profitable measures: The selection or combination of these measures should focus on making Energy Efficiency noticeable and an evident source of energy.

During 2005, the PPEE, together with 100 players, designed the development of the National Energy Efficiency System, which was included in an action plan. This system comprises thirteen basic and independent courses of action, such as:

- EE national policy and institutional status.
- Creation of an EE culture.
- EE legal and regulatory framework.
- National EE monitoring and supervision system.
- EE certification system.
- EE instruments for promotion and economic, tax and financial incentives.
- Incorporation of international EE mechanisms.
- EE sector policy and program on housing, buildings and construction.
- EE sector policy and program on transport.
- EE sector policy and program on industrial use (mining, agriculture and trade).

[21] The Board is made up of at least 8 but no more than 12 academic experts from both the public and the private sector.

- EE sector policy and program on energy transformation.
- EE sector policy and program for the public sector.
- Technological advances in terms of EE.

3.2. Courses of Action

The PPEE is divided into five essential areas and two transversal areas. Each of these areas promotes different projects, initiatives and promotion policies in connection with EE.

The technical areas are: the Public Sector, which includes the following subsectors: Street Lighting, Home Appliances, Construction and Housing, Industry and Mining. The Education and Regions sectors are transversal and cross all other areas of the program.

Each of these areas prepares intervention strategies based on the participation of the most relevant players, as well as strategies for the technical and economic assessment of the different sectors' energy consumption, the saving or EE improvement potentials and the technical, legal and institutional possibilities available.

a) Public Sector

According to a study published by the National Energy Commission in 2005, the Public Sector represents 1% of total energy consumption. Despite its low potential in terms of EE, it is a strategic sector within the PPEE given its exemplary role in society.

The five main principles of this sector are: EE criteria about government procurement; EE criteria about construction of public buildings, maintenance and reconversion of premises built; management of and incentives to saving; and EE in replacement and extension of street lighting.

The following activities are performed:

- **Energy Efficiency Procurement:** EE criteria are incorporated into government procurement through "Chile Compra" at the time of performing the public tendering.[22]
- A permanent training program including relevant information[23] was prepared for government purchasers.
- **Constructions based on sustainable criteria:** Development of the preliminary project "Sustainable construction design for the new Temuco airport in the 9th

[22] A PPEE's study carried out in 2005 concluded that 39.2GWh/year may be saved by incorporating EE criteria in the procurement of electric items made through "Chile Compra".
[23] Publication of manuals designed by EE experts of the University of California in Berkeley and Fundación Chile.

Region." A 42% saving was established if compared to the consumption of Concepción Airport.

- **EE regulations applicable to public works and maintenance:** Since 2006, the Ministry of Public Works has conducted a study on the incorporation of EE criteria to public works and maintenance thereof in order to issue reference regulations for the public infrastructure sector and create a basis for the generation of energy-efficient public works projects.
- **EE in Public Hospitals:** A public-private cooperation pilot project was prepared with the participation of the Ministry of Health and the Ministry of Economy, several public hospitals, the energy provider DALKIA and GTZ, the German Technical Cooperation enterprise. The purpose of this project is to introduce the Energy Contracting model or the third-party procurement through professional service providers into the public sector.
- **Optimization of energy resources:** The Budget Department (DIPRES) is involved in the "Design and Basic Proposal of an Energy Efficient system for the Management Improvement Program (PMG) in the public sector". Its purposes are the identification of economic incentives so that different services and state agencies optimize their energy resources; the design, justification and inclusion of such incentives in a management system for the efficient use of energy in public administration, in accordance with PMG guidelines and in compliance with the implementation of the ISO 9001:2000 standard.
- **Energy Efficiency in Teatinos 120 building:** In 2006, based on an EE diagnosis made in Teatinos 120 government building, lighting fixtures were replaced and the computers' configuration was changed. As of March 31 2007, the following progress was achieved: Change of lighting fixtures (52%) and computer configuration (94%). 100% fulfillment of these two measures would translate into a 6% saving of total electric power consumption. In addition, EE responsible persons were appointed for each service in the building. Training activities were made available to these individuals.

  Based on this experience, during 2008, the PPEE and the Public Building Program of the Budget Department implemented a comprehensive energy management program in government buildings.
- **Street Lighting:** By the end of 2005, the Inter-institutional Cooperation Agreement on EE in Street Lighting was executed. In order to fulfill the purposes of such agreement, a survey on street lighting was conducted, a national regulation based on Energy Efficiecy criteria was suggested and a street lighting manual was drafted.

b) Home Appliances

Within the Home Appliances technical area, the PPEE coordinates the initiatives for the creation of a National Energy Efficiency Labeling System for Home Appliances.

One of the most relevant initiatives is the implementation of the National Program of Energy Efficiency Certification and Labeling (P3E) that was launched in 2005 for light bulbs and refrigerators. These appliances were selected on the basis of 2002 Census and a study conducted in 2005 by the CNE (National Energy Commission) which indicated that about 60% of the electric consumption in residential areas is generated by the two appliances mentioned before.

c) Construction and Housing

The energy consumption of residential areas, including households, stores and offices, represented 28% of the country's overall energy consumption. In this sector, energy is mainly used for: heating, boiling water and cooking.

For the purpose of reducing energy consumption in this sector, the PPEE promotes a series of projects and initiatives to consolidate a 0.9% energy use reduction in this area. More specifically, the Ministry of Housing and Urban Planning (MINVU) issued the Regulations on Thermal Conditioning of Households.

d) Industry

In the industrial sector, the courses of action of the PPEE are focused on: reduction of production costs, compliance with environmental requirements, reduction of energy dependence, and improvement of overall competitiveness through EE.

The industrial sector has a huge potential. According to a study prepared for the CNE in 2004, the usable potentials for the Chilean industrial sector ranged between a 1.9 and 4.5% reduction of the annual energy intensity in a 10-year period.

The PPEE's strategy for the industrial sector considers both transversal and specific components. The former refer to measures, activities and projects applicable to the whole industrial sector. Two core elements within the transversal strategy are the CORFO Program of Preliminary Investment in Energy Efficiency (PIEE) launched by late 2006, and the Energy Efficiency Award granted together with the CPC to each of its branches since 2005.

Through the PIEE, up to 70% of the energy consulting services hired by companies can be jointly financed and, to guarantee the qualifications of the consultants, an Energy Efficiency Consultants' Registry was created, which comprises 21 certified consultants.

e) Mining

In energy terms, the last survey of the CNE evidences that the mining sector represents 35% of the electric power consumption.

One of PPEE's objectives for this sector is the execution of agreements within the framework of the Mining Sector Initiative on Clean Energy.

The following activities are performed:

- Mining Sector Initiative on Clean Energy (IMEL): Its purpose is to increase the use of non-conventional renewable energy sources (NCRE) and EE. The IMEL operates through the execution of voluntary agreements.
- Energy Efficiency Award.
- A characterization study for small and medium-size mining companies is underway, the findings of which promote the Clean Production Agreement signed by the sector at the end of 2006 and will translate into specific strategies for this segment of the sector.

The following goals have been set for 2010: to have basic information available for the mining sector, to homogenize the criteria about energy consumption metering in the area and to consolidate an EE increase in domestic mining production.

f) Education

For the PPEE, education is one of the key issues to meet the established objectives and goals.

In that sense, the PPEE, with the support of the Ministry of Education and the National Environmental Commission (CONAMA), performs activities in universities and elementary and higher education institutions under the School Environmental Certification System to implement one of the relevant guidelines of the SNEE.

Annex 2 – Case Study: Cuba

1. Background

The situation of the electric power sector in Cuba during 2004 and 2005, before the Energy Revolution, showed the following features:

- large number of inefficient home appliances in Cuban households;
- 85% of the population used kerosene to cook;
- residential electricity tariffs did not encourage any savings;
- there was a poor energy-saving culture both in the residential and the state sector;
- base generation with large and inefficient thermo-electrical plants, with an average of 25 years of operation, 60% of availability, frequent failures and high own consumptions;
- frequent blackouts; in 2004, there were 188 days with blackouts greater than 100 MW; in 2005, they reached 224 days; and
- high percentage of losses in transmission and distribution networks.

2. The Energy Revolution and the Transformations of the Electric Power System

These difficulties led to a strategy for the development of a safer and more efficient electric power system.

The strategy selected was to act not only from supply side but also from demand. Two objectives were established: i) improvement of the electric power system through the increase of the installed generation capacity and the reduction of losses in transmission and distribution networks; and ii) development of an energy-saving culture in the population.

The following courses of action were set for the purpose of achieving the objectives:

- Acquisition and installation of safer and more efficient generation equipment.
- Increase in the use of gas for power generation.
- Restoration of transmission and distribution networks.
- Promotion of an intensive research and development program on the use of renewable energy sources, mainly, wind and solar.
- Implementation of an energy-saving and efficient use program.

3. Programs

3.1. Demand

An advisory group was created in Cuba for the purpose of comprehensively coordinating and performing all the actions related to power efficiency for the identification of energy-saving projects in all sectors of the economy.

This advisory group is divided into the following working subgroups:

- Air conditioning and cooling
- Heat production
- Buildings
- Automation
- Electricity losses
- Driving force (electric engines)
- Lighting
- Residential, commercial and service sectors
- Audits and technical inspections
- Industrial sector
- General

The energy saving strategy defined covers the following courses of action:

- Implementation of a system of energy efficiency standards and labeling
- Design of a legal framework for the promotion of a rational and efficient use of energy in Cuba
- Change of the electricity tariff in the state sector
- Strengthening of power service companies
- Automation projects in the industrial and commercial sectors
- Installation of capacitor banks in low power factor customers
- Replacement of inefficient engines in the industrial sector
- Efficient use of air conditioning, heat production and cooling systems
- Increase in the use of power cogeneration
- Improvement of thermal insulation in buildings and industries
- Compulsory application of NC 220 in all new buildings
- Certification of new projects' energy efficient during the investment process
- Further promotion of the use of EE equipment in the residential sector; e.g.: solar heaters
- Development of a communications strategy.

In the power sector, these courses of action were implemented through the Energy-Saving Program in Cuba (PAEC*)*.

- **Energy-Saving Program in Cuba (PAEC)**

PAEC's objectives are the following:

- To reduce the system's maximum demand and the annual consumption growth rate according to the goals set.
- To develop better energy use habits in new generations to encourage the rational use of energy and environmental protection.
- To develop standards and a pricing policy that would guarantee the energy efficiency of all new electrical appliances used in the country.

The program is organized into different Working Groups:

a) **Standardization and Labeling Group:** it develops the following activities:
    - Standardization and labeling program
    - Clean Development Mechanism (MDL)
    - PAEC's web page
    - Procurement, import of energy efficient equipment
    - Development of new products
    - Implementation (acquisition, distribution)
    - Introduction of energy efficient equipment.

b) **Guide and Savings Motivation Group:** it develops the following activities:
    - Energy-Saving Program of the Ministry of Education (PAEME)
    - Training
    - Promotion
    - Work with mass organizations
    - Assurance

c) **Electric Power Regulation and Efficient Use Group:** the aim of this group is to guarantee that the exceptional measures for energy saving and the modification of off-peak loads are met. Its main activities consists in regulating electric power demand and consumption in the country's leading companies and providing consulting services in relation to power issues. Basically, it focuses on developing a greater awareness of the efficient use of energy.

As a result of PAEC's actions, the following programs are in progress:

1) **National Program on Energy Efficient Standards and Labels:**

   This program is carried out by PAEC together with the National Standardization Office (ONN), the Domestic Trade Ministry (MINCIN) and the Foreign Trade

Ministry (MINCEX). The aim of the program is to introduce EE rules, limits, testing standards and labels. The products selected during the program's first stage were: refrigerators and residential freezers; phase induction electric motors, residential electric fans and fluorescent lamps.

2) Program for the Rational Use of Energy in the Residential Sector

This is a nationwide program, conducted and financed by the national government. Through the Social Workers Program, inefficient home appliances are replaced by energy efficient equipment.

3) Program for the Rational Use of Energy in the State Sector

In the state sector, more than 100 inefficient water pumps were replaced by efficient water pipelines and sewerage and more than 500,000 40 W fluorescent tube lamps and electromagnetic ballasts were replaced by 32 W fluorescent tube lamps and electric ballasts.

A special Project was implemented in order to regulate demand and distribute the load among 1,720 selected services (large users). The actions performed in relation to these services were the following:

- 200 energy supervisions
- Introduction of the Energy Efficient Management Program
- Design and control of electricity consumption programs
- Training of the personnel in charge of energy control and subsequent inspections to test results.

As a result of these actions, while the electric power consumption in the overall economy grew 7.5% from 2006 to 2007, in the state sector such growth was 4% and in the selected services only 1.2%. These services account for 45.6% of the state consumption. The electricity intensity in the state sector fell from 0.16 GWh/MMP in 2005 to 0.13 GWh/MMP in 2008.

4) Communications Program

The strategy for EE communications policy focuses on the population in general and mass organizations. The media selected are the press, radio, television, billboards on avenues, neighborhood debates, conferences and festivals.

5) Savings Program of the Ministry of Education (PAEME)

The PAEME is the program executed by the PAEC and the Ministry of Education, whose main objective is to contribute through the National Education System to the development of a more responsible civil attitude in present and future generations and the awareness of the need to rationally use and save electric power and protect the environment. The specific goals of the program are:

- To promote energy-saving and rational use measures and to disclose the consumption ratios of home appliances.
- To contribute to cause professors, students and families in general, to get interested in knowing, applying and increasing the use of renewable energy sources.
- To analyze regulatory documents in force and apply them to different energy-saving lessons included in the syllabuses of the education process.

Annex 3 – Case Study: South Africa

1. Background

In South Africa electricity usage by consumers follows a particular pattern. People use more electricity during the early morning (from 07:00 to 10:00), consumption then reduces, only to increase again in late afternoons (from 18:00 to 21:00).This places a strain on national electricity resources as Eskom needs to generate significantly more electricity to cater for consumer needs during relatively short periods.

From small beginnings in 1991, starting with research, pilot studies and time of use tariffs, Eskom's DSM program has grown into a concerted national electricity-saving effort officially initiated in the last quarter of 2002.

The efficient use of electricity has become a national priority, a necessity for the future development of the South African economy and effective provision of electricity. Working towards these objectives is Eskom's Accelerated Energy Efficiency Plan that focuses on reducing electricity demand by 3,000MW by 2012, and a further 5,000MW by 2025.

2. Institutional Framework

Eskom is implementing DSM in South Africa through collaboration with the Department of Minerals and Energy (DME) and the National Electricity Regulator (NER).

3. Strategies

The 12 overarching elements of the energy efficiency strategy are to:

1. Set short, medium and long-term goals for energy efficiency that will support the country's economic growth.

2. Create national awareness that electricity is a valuable commodity that has to be used widely.

3. Promote effective energy use through appropriate legislation aimed at:

- preventing the importation and use of inefficient equipment
- Setting energy efficiency requirements for buildings.
- Achieving energy efficiency across natural resources used for generating electricity.
- Establishing mechanisms for funding accelerated energy efficient projects.
- Providing funding for appropriate energy efficiency projects.

4. Ensure effective collaboration between Eskom and all role players in the sector including the National Energy Efficiency Agency, the Department of Minerals and Energy and the National Energy Regulator of South Africa.

5. Accelerate the evaluation, approval and implementation of energy efficient projects.

6. Implement selected large efficiency projects.

7. Develop and implement "energy efficiency" tariffs applicable to end-users, including "time of use" tariffs for households. This enables householders to take advantages of tariffs that are lower at certain times of the day when demand for electricity across the network is lower. The usage cost is linked to Eskom production costs at that particular time. The tariff therefore reflects the generation cost.

8. Develop contingency projects to supplement the program such as the use of alternative energy sources for domestic heating and cooking.

9. Maintain savings achieved in the Western Cape during 2006, while implementing a focused roll out in KwaZulu Natal during 2007.

10. Position Eskom and government as leaders in the energy efficiency process by:

- Identifying, implementing and tracking projects that contribute towards an internal efficiency drive.
- Implementing employee programs to ensure energy efficient work sites and employee homes.
- Committing to energy efficient improvements in government buildings.

11. Using the government ASGIS-SA objectives to achieve advances in the industrial arena that provide the best short term benefits.

12. Ensure that the energy efficiency programme within Eskom is efficiently managed.

Action Lines

a) Residential Sector

The focus will be on rolling out programs for efficient lighting, solar water heating, installation of aerated shower heads and geyser blankets, thereby reducing residential consumption of electricity.

b) Industrial Sector

Demand market participation contracts, process optimization and the promotion of the use of energy efficient electrical motors will be of primary concern

c) Commercial Sector

Efforts will be concentrated on street lighting projects and the conversion of lighting, heating, ventilation and air conditioning systems

4. Programs and projects

- **Residential, commercial and industrial programs** - The main objective of this program is to transform the South African electricity market into an energy efficient industry. Figures 2 to 4 below show the identified areas that represent significant savings potential in each market sector.
- **Public education** - The primary objective of this program is to increase awareness about energy efficiency. The program includes a broad range of marketing and public relations activities, and feeds directly into programs in different income segments as well as residential, commercial, industrial and institutional program activities.
- **Schools program** - The objective of this program is to highlight the benefits and importance of using electricity efficiently to school pupils. DSM seek to increase the awareness of students and faculties on energy efficient measures through providing participating institutions with resources packs, including teacher, learner and electricity audit guides.
- **Stakeholder activities** – aimed at keeping DSM stakeholders abreast of DSM changes, objectives, and programs and also at outlining how to assist to promote the energy efficiency message.

4.1 Compact fluorescent lamp exchange

Compact fluorescent lamps (CFLs) offer consumers lighting through lamps that have a longer life and consume considerably less energy than conventional incandescent globes. As part of their strategy to introduce these globes, Eskom embarked on a national programme to exchange incandescent globes with CFLs in selected areas.

Since the program began in 2004 more than 18 million CFLs have been exchanged for incandescent globes. The national program was recently implemented in the Western Cape, Northern Province, Gauteng and Free State where four million CFLs were exchanged for incandescent globes.

The program has reached more than 315,000 households and continues to reduce the energy demand from the household sector.

4.2 Power Alert

Power Alert is a residential load reduction DSM project. Visual inserts in the form of Power Alert meters are broadcast (flighted) on SABC1, SABC2 and SABC3 on weekdays between 17h30 and 20h30. These Power Alert meters give an indication of the strain on the electricity supply and will urge people to switch off their appliances if the need arises. This is not a permanent intervention. The Power Alert meter creates real-time awareness and voluntary reaction by the public when broadcast.

The key indicators

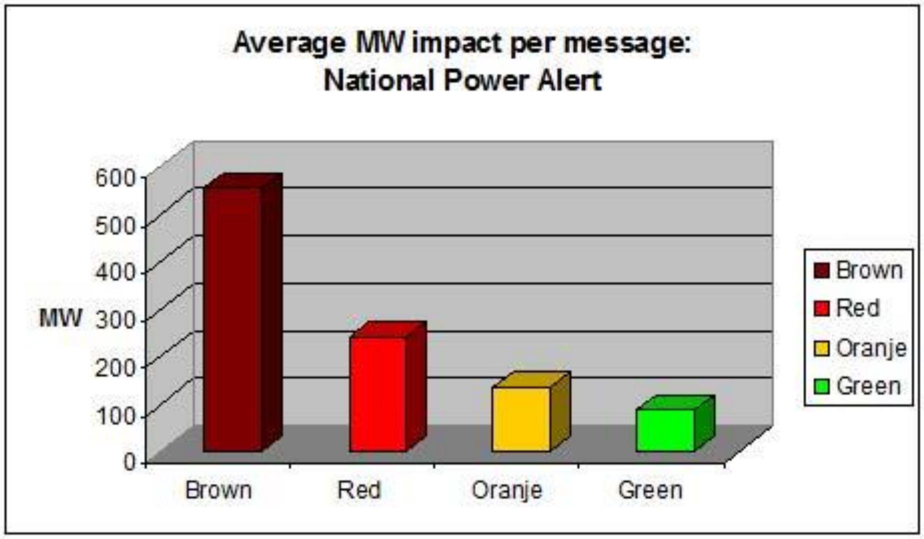
Four status levels occur, each calling for specific measures to be taken by consumers in all geographical areas. These are:

- **Green:** indicates that there is only limited strain on the system. Consumers are requested to save power as part of their everyday activities to achieve energy efficiency.
- **Orange:** the demand on the system is increasing. Consumers are prompted to switch off some non-essential power-consuming appliances. These include tumble dryers, dishwashers, pool pumps and unnecessary lights during peak periods.
- **Red:** strain on the system is increasing and load shedding is imminent. Consumers are asked to take action by switching off geysers, stoves, microwave ovens, kettles, heaters, air conditioning units and unnecessary lights.
- **Brown:** the most serious state indicates that there is significant strain on the national grid and that load shedding is being undertaken. Consumers are requested to switch off all appliances that are not absolutely necessary and rely only on essential lighting and their TV's (which, at this stage, indicate changed status as it occurs).

Savings achieved

Achieving the intended saving depends largely on the participation of the TV audience. This participation is driven by amongst other things, the frequency of the Power Alert broadcasts, and the general levels of awareness of the public. These levels of awareness are in turn influenced by "awareness advertising" or "awareness campaigns" as well as the frequency and severity of power interruptions.

The following graphs show the impact assessment for the National Power Alert project for July 2007 - March 2008 in South Africa.



4.3 Solar Water Heating Programme

The Eskom Solar Water Heating Program is driven by government which has set a target for renewable energy to contribute 10,000 gigawatt hours (GWh) of final energy consumption by 2013. Solar water heating could contribute up to 23% of this target. Eskom is supporting this drive through the large-scale introduction of solar water heating as it is one of the most effective renewable energy sources available.

4.4 Residential Load Management

Residential load management, a system that uses radio or ripple switches, allows municipalities to manage demand during peak periods without undue disruption. By using a wireless signal (radio) the geyser, the appliance which uses the most electricity in any home, is remotely switched off. After a short break in supply the geyser is switched on again -without the homeowner even realizing that it had been switched off at all.

Switches will be installed into homes by contracted technical teams over a period of two years. The task, taking about 30 minutes, will be performed at no cost to householders.

As the system simultaneously switch off thousands of geysers if this is required, the demand on the electricity network is significant. The network is used more efficiently and the possibility of major blackouts occurring is reduced.

Peak demand for electricity is reduced meaning that the existing capacity of the network is used more effectively.

4.5 Energy efficient motors

An estimated 100,000 motors keep South African industry turning. In the process they consume up to 10.0 GW of electricity (60% of the total industrial energy usage and about

57% of peak demand generation). It is the use of this electricity which, if substantially reduced, could play a pivotal role in reducing national electricity constrains that led to Eskom introducing its Energy Efficient Motors (EEM) Program offering users "instant subsidies" for trading in their old motors.

The Energy Efficient Motors Program is designed to create awareness regarding the vital contribution these motors can make to increasing the national electricity saving.

To encourage the purchase of new energy efficient motors, Eskom is offering subsidies on motors ranging from 1.1kW through to 90 kW. The 1.1kW units will qualify for a subsidy of R400 and, at the top of the range, the 90kW unit subsidy is R 3,500.

Annex 4 – Replacing Electric Showers in Costa Rica

In Costa Rica, 41.3% of the population (52.4% of urban and 25.6% of rural households) has electric showers. By income level, 75.6% of middle upper income households and 19.2% of popular households own electric showers.

The implementation of a program for heat recovery systems in electric shower – like the one developed by Rewatt from Brazil – would have a very positive impact in terms of energy savings. Based on the penetration ratio and the number of households we can estimate the total number of electric showers in the country at nearly half a million.

Table 34– Electric Showers in Costa Rica

Penetration ratio (%)	41.3
Households (1000)	1,198.0
Total Electrical Showers (1000)	494.7
Annual Consumption (kWh/year)	492
Number of Electric Showers	494.8
Total Annual Consumption (MWh)	**243.4**

Source: authors.

According the Residential Energy Consumption survey the average consumption of electric showers is 41kWh/month, with little variation by region or income. Based on this consumption and the number of electric showers total annual energy consumption can be estimated.

Using the costs and estimated energy savings of the Rewatt heat recovery system quoted by its manufacturer (450 Brazilian Reals) and residential tariffs in Costa Rica we can evaluate the economic impact of the installation of this device (see table below).

Table 35– Efficient Electric Shower Economic Impact Estimation

Cost ($)	208		
Energy Savings (%)	45		
Tariff ($/kWh)	0.1087	0.1960	0.2691
Annual Costs ($)	53.5	96.4	132.4
Annual Saving ($)	24.1	43.4	59.6
IRR (5 years)	-16%	1%	13%

Source: authors.

Costa Rica has a three block tariff for residential customers so we present the evaluation using each one of the blocks. As the table shows, savings range from $24 to nearly $60 a year depending on the tariff block. From a purely financial perspective the replacement seems to be efficient only for users consuming in the third block (over 300 kWh/month).

Table 36– Cost Analysis of Risk Mitigating Measures – Sensitivity Analysis

Base Case

	R CoC	**S** KWh/year	**C** USD	**n** years	Levelized Cost	Fuel Cost	Total costs	Rank
CFL		32.85	2.5	5	0.023		0.023	1
Fixed GT Plant SC		5256	650	15	0.021	0.118	0.139	2
Barge Plant BG	15%	5256	900	15	0.029	0.118	0.147	3
Refrigerator		569	500	15	0.150		0.150	4
High Speed diesel		5256	500	15	0.016	0.135	0.151	5
Electric Shower		221.4	208	10	0.187		0.187	6

Levelized cost of saving ($/KWh) = C*r/S(1-(1+r)^-n)

Cost of Capital (r)

	10%		12%		14%		16%		18%		20%	
	$/KWh	Rank	$/KWh	Rank	$/KWh	Rank	$/KWh	Rank	$/KWh	Rank	$/KWh	Rank
CFL	0.012	1	0.013	1	0.015	1	0.016	1	0.017	1	0.018	1
Fixed GT Plant, SC	0.134	3	0.136	3	0.138	2	0.140	2	0.142	2	0.144	2
Barge Plant GT	0.141	4	0.143	4	0.146	4	0.149	3	0.152	3	0.155	3
Refrigerator	0.116	2	0.129	2	0.143	3	0.158	5	0.173	5	0.188	5
High Speed diesel	0.148	5	0.149	5	0.150	5	0.152	4	0.154	4	0.155	4
Electric Showers	0.153	6	0.166	6	0.180	6	0.194	6	0.209	6	0.224	6

Investment Cost (C)

	-10%		+10%	
	$/KWh	Rank	$/KWh	Rank
CFL	0.017	1	0.014	1
Fixed GT Plant, SC	0.141	2	0.137	3
Barge Plant GT	0.150	3	0.144	4
Refrigerator	0.165	5	0.135	2
High Speed diesel	0.153	4	0.150	5
Electric Showers	0.206	6	0.168	6

Useful Life (n)

	-10%		+10%	
	$/KWh	Rank	$/KWh	Rank
CFL	0.015	1	0.016	1
Fixed GT Plant, SC	0.139	2	0.140	2
Barge Plant GT	0.147	4	0.148	3
Refrigerator	0.146	3	0.155	5
High Speed diesel	0.151	5	0.152	4
Electric Showers	0.180	6	0.197	6

Source: authors.

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