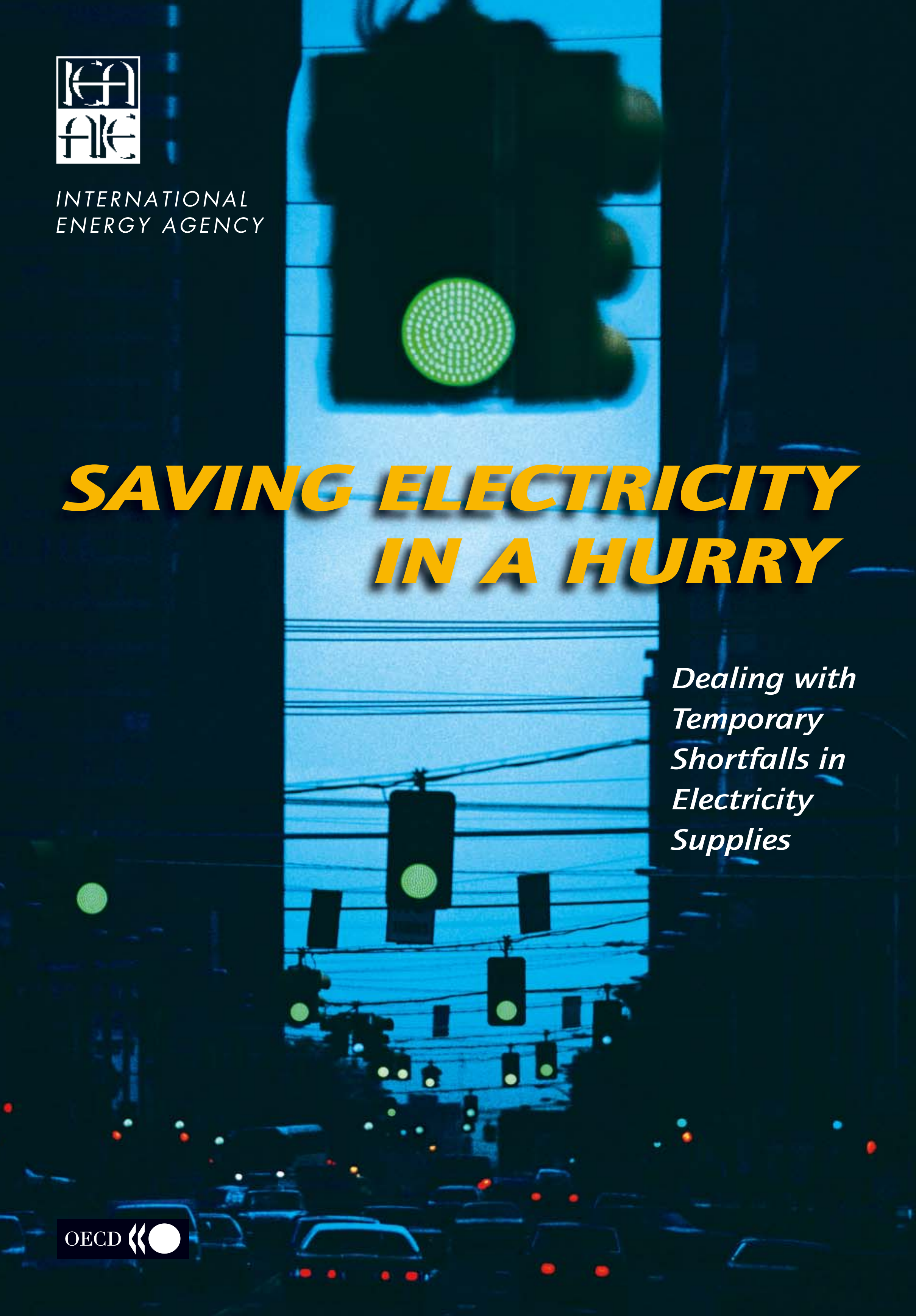

INTERNATIONAL
ENERGY AGENCY

# SAVING ELECTRICITY IN A HURRY

## *Dealing with Temporary Shortfalls in Electricity Supplies*

OECD

## INTERNATIONAL ENERGY AGENCY

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# FOREWORD

It is easy to understand the subject of this book – saving electricity in a hurry – but the reasons why one would want to do this and why this strategy deserves a book of its own are more complex.

This book describes why temporary shortages of electricity supplies occur even in the wealthiest countries with the most sophisticated electricity networks. Most shortages are local and minor and easily addressed. But, in other cases, the shortages persist for days, weeks, or even years and involve millions of people, and this is the target of this book. The reasons for these shortages are incredibly diverse: from forest fires to safety problems at power stations, from problems in electricity market liberalisation to heat or cold waves. These events can happen anywhere – and they do! The results are blackouts, brownouts and other curtailments on electricity consumption.

But there are alternatives. This book shows how to quickly reduce the demand for electricity to avoid the economic devastation brought by persistent power shortages. Electricity demand might appear inflexible but the clever use of mass media and other strategies can cut that demand 3% in only a few days to 20% in a few months and sustain those levels until the crisis has passed. When longer shortages are anticipated or there is greater time, it is possible to rely more on technical improvements in efficiency. This book describes how regions as diverse as Norway, California, Sweden and New Zealand achieved their savings and how other regions can use their experiences to successfully avoid major electricity shortages.

Thirty years ago, the IEA's original mandate was to help oil-consuming countries co-ordinate their oil stocks and consumption, especially when disruptions of oil supplies occur. Until recently, most of the IEA's activity has been devoted to increasing flexibility and improving transparency on the supply side. Now the IEA is applying the same principles on the demand side. Another IEA book, *Saving Oil in a Hurry*, reviews policies and measures to quickly reduce oil consumed in the transportation sector during a temporary disruption. This book, *Saving Electricity in a Hurry* is a natural extension.

This book deals principally with short-term measures; however, one of its most important conclusions is for long-term energy efficiency programmes. It shows how "saving electricity slowly" – another term first proposed for this book – provides the infrastructure to launch a crash programme to save electricity in a hurry. If economic common sense and obvious environmental benefits are not enough, the insurance against crippling electricity shortages provides yet another justification for maintaining aggressive energy efficiency programmes.

***Claude Mandil***
***Executive Director***

# ACKNOWLEDGEMENTS

This book was conceived and written by Alan Meier. He also first recognised the unique problem of "saving electricity in a hurry" and the special collection of strategies needed to respond to temporary electricity shortages. However, many other individuals played important parts in translating an idea into something that could be called a "strategy".

In June 2003, the IEA convened a workshop, "Saving electricity in a hurry". The participants in this workshop – mainly from regions that experienced electricity shortfalls – demonstrated that a global problem existed and that it was valuable to exchange experiences. They also provided a wealth of details on which this book relies.

Many IEA staff contributed to this book through research, analysis, and discussions; their role was critical in understanding the wider dimensions of electricity demand.

The IEA's Energy Efficiency Working Party – a group of officials responsible for energy efficiency in IEA member countries – also provided valuable comments and details about situations in their own countries.

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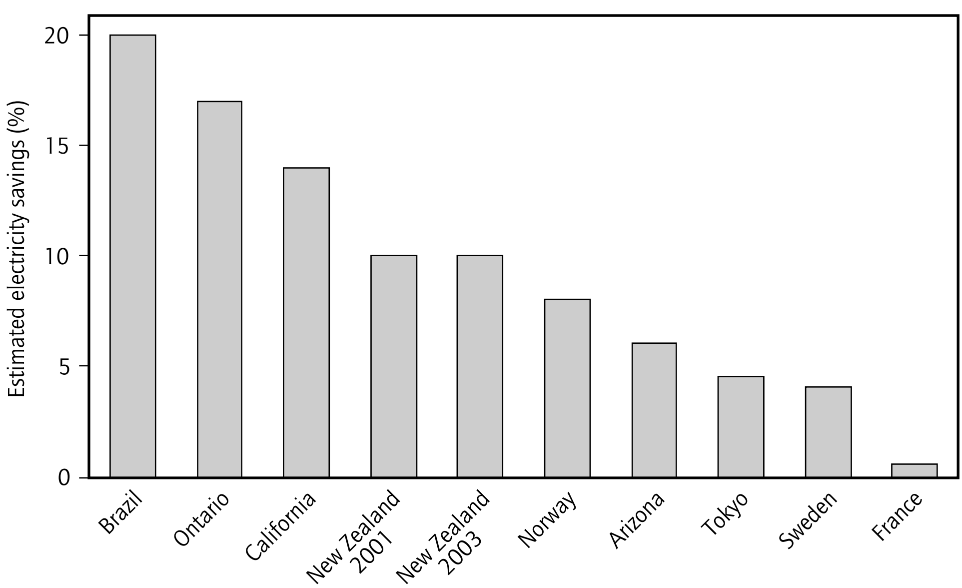
# EXECUTIVE SUMMARY

Temporary shortfalls in electricity supply – ranging from one day to many months – have occurred at one time or another in almost every country. During these crises, the infrastructure to deliver electricity to the customer remains intact but the utility cannot supply as much power as consumers wish. Such shortfalls might occur as a result of a breakdown in a key power plant, a drought, a heat or cold wave, or partial loss of transmission capacity. The end of the crisis is generally known, that is, the power plant is repaired, the rains replenish the reservoirs, the heat wave abates, or full transmission capability is restored.

One response to these shortfalls is to fix the supply problem as quickly as possible, such as by connecting temporary facilities or importing power. But some shortfalls are so large that drastic curtailment appears to be the only feasible means of still providing some electricity while maintaining the integrity of the electrical system. This book describes the experiences of several countries that chose a strategy of "saving electricity in a hurry" rather than suffer curtailments, indiscriminate blackouts and other consequences

*Figure ES-1*

*Summary of Estimated Savings Achieved in Regions through Programmes Designed to Save Electricity in a Hurry*

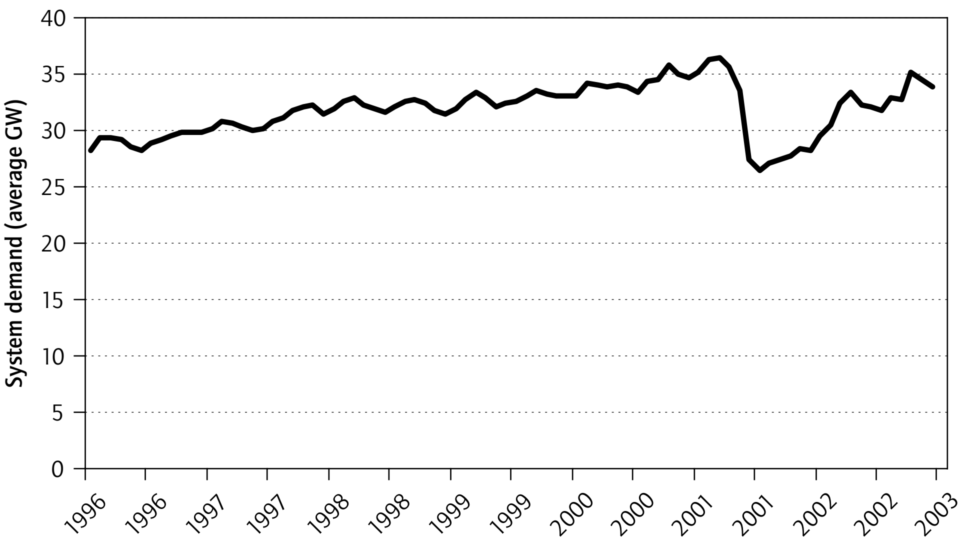


of electricity shortages. These countries include Sweden, Japan, Brazil, New Zealand and the United States. The shortfalls occurred in many different forms of electricity markets and for equally diverse reasons.

Countries have successfully cut electricity demand by 0.5 to 20% by saving electricity in a hurry (Figure ES-1). When confronted with a severe drought, Brazil cut its total electricity demand 20%, and sustained these savings for several months, without blackouts or causing major harm to the economy (Figure ES-2). Sweden cut its total electricity demand by about 4% for one day in anticipation of a cold wave that would have overwhelmed electricity generating capacity. In Arizona (United States), a fire at a key transformer facility cut available power; conservation actions sustained over six weeks reduced demand 6% and avoided blackouts.

*Figure ES-2*

*Electricity Demand in Brazil Before and After its Shortfall in 2001*




There are three major strategies to save electricity quickly:

- Raise electricity prices.
- Encourage behavioural changes.
- Introduce more energy efficient technologies.

The mix of the three strategies will depend on the time to prepare before the shortfall arrives, the anticipated duration of the shortfall, and the structure of the electricity markets. In fully liberalised electricity markets, the price mechanism will play the largest role in reducing electricity demand because experience has shown that higher electricity prices will stimulate conservation. A shortfall in a liberalised market is actually a "price crisis" which can be accommodated by normal market forces. In most current markets, however, there are administrative, political and technical obstacles to raising electricity prices quickly. The response in these countries must necessarily focus on behavioural and technical programmes to cut demand.

Programmes to reduce electricity demand quickly differ significantly from conventional energy efficiency programmes such as appliance efficiency standards, building codes and tax incentives (called "saving electricity slowly" in this book). First, the savings need only be temporary, that is, electricity use can return to traditional levels at the end of the shortfall. Second, it is acceptable to request consumers to make sacrifices and accept inconveniences for the duration of the shortfall. Finally, the shortfalls may appear and end so quickly that is impossible to draw on technical improvements in energy efficiency.

A mass media campaign can be surprisingly effective at quickly reducing electricity demand. Sophisticated media campaigns can be designed and launched in only a few days and reach a large number of consumers almost immediately. The messages must be carefully tailored not to blame the consumers for the problem and to convince them that individual actions will make a difference. Furthermore, the campaign must explain in simple terms to consumers which measures will save electricity (Figure ES-3). If the shortage occurs during peak hours, then the campaign must also explain *when* to save electricity. Sometimes consumers need to be educated before they can take actions. Many campaigns urged consumers to cut standby power use in homes and commercial buildings, but first they needed to explain what standby was and how it could be cut. Humour plays an unusually important role in encouraging consumers to conserve. Hundreds of measures have been used with success but nearly every campaign asked consumers to:

*Figure ES-3*

*Example of Advertisement During New Zealand's 2003 Electricity Shortfall*

- Re-set thermostats to reduce heating or cooling demand.
- Switch off non-essential lighting.
- Adjust schedules for the use of electricity-intensive equipment and industrial processes.
- Switch off office equipment or enable them to "sleep" in lower power modes.

These behavioural measures can be further encouraged by programmes that give consumers rebates for successful reductions in electricity bills. Each shortfall is unique so the appropriate actions depend on how electricity is used and when it must be saved. Regular collection of data related to energy consumption and savings will help a campaign focus on conservation measures that will save the most electricity.

When the shortfalls are expected to persist, technical improvements can supplement behavioural measures. The actions to raise technical efficiency often require an infrastructure to deliver or install. If an infrastructure already exists to "save electricity slowly", then it may be harnessed to achieve the short-term goal, too. Some measures include:

- Installation of energy-efficient lighting (especially compact fluorescent bulbs).
- Replacement of old equipment (ranging from refrigerators to traffic signals) with new, efficient units.
- Audits and improvements of key electricity-consuming equipment (such as municipal pumping and industrial compressed air systems).

Technical improvements take longer to implement than changes in consumer behaviour but they provide more reliable electricity savings. In addition, the savings will persist after the crisis has ended.

Electricity shortfalls often take place in a politically charged environment where many institutions have lost credibility. Politicians and high executives have lost their jobs during these crises. At the same time, these crises disproportionately influence the shape of future electricity policies and market structures. Effective resolution of temporary electricity shortfalls may encourage implementation of more stable long-term solutions to the needs of the electricity market.

# WHO NEEDS THIS BOOK AND WHEN?

Almost every part of the developed world has faced a temporary shortfall in electricity supply at one time or another. Such shortfalls might occur as a result of reduced hydroelectric supplies caused by a drought, a breakdown in a power plant, a heat wave, or partial loss of transmission or distribution capabilities. During these crises, the infrastructure to deliver electricity to the customer remains intact but the utility cannot supply as much power as consumers wish. The end of the crisis is generally known, that is, the rains replenish the reservoirs, the power plant is repaired, the heat wave abates, or full transmission capability is restored.

The traditional response to these shortfalls is to fix the supply problem as quickly as possible, often by bringing in or connecting temporary facilities. With enough advance warning – and good luck – a crisis will be averted. But some shortfalls are so large, or the temporary supply fixes so expensive, that the only outcome appears to be blackouts or unplanned curtailments.

It pays to avoid power shortages and even the threat of imminent blackouts. Even a single blackout can lead to deaths, injuries, and economic damage. The summer 2003 blackout in Ontario (and especially the mandatory reductions in electricity use in the weeks following it) led to a 0.7% reduction in Canada's total GDP during August (Statistics Canada, 2003). Continuing shortages, and the threats of blackouts, further undermine the economy by creating uncertainty and hidden costs of adaptation and preparation. At a personal level, people will become less productive in small ways; for example, they avoid using elevators (and may even refuse to visit upper floors of buildings). Companies will invest in expensive on-site electricity generation equipment, uninterruptible power supplies, and other mostly unproductive assets.

Many utility planners and government officials treat the demand for electricity as mostly fixed. When a shortfall occurs, the utility can disconnect some industries operating with interruptible contracts and perhaps wring additional reductions through Demand Response programmes. If the electricity market has been liberalised, drastically higher spot prices can be used to reduce demand. But what happens when these cuts are insufficient? For many planners and system operators, blackouts are the only solution. Is it possible to rapidly cut demand for electricity – at least temporarily – without causing lasting economic or environmental damage? This book examines the record, where regions encountered shortfalls and implemented rapid demand reduction programmes. The book's goal is to describe the extent to which electricity customers can also rescue an overwhelmed utility. Put another way, this books seeks to give the utility another tool with which to solve an electricity shortfall. This tool – rapid, short-term reductions in electricity demand – cannot be applied in every situation but it may be the best and cheapest tool, especially when combined with other strategies.

Who should read this book? Frankly, only a small group of specialists concerned with providing reliable electricity supplies and forecasting electricity demand should read this book immediately. But a second, larger group should skim through it and remember the book's primary conclusion – that it is feasible to cut electricity demand by as much as 20% in only a few months without destroying the economy – and then put this book in a safe place until a crisis arrives (when it should be read carefully). A second important conclusion of this book is that a modest amount of preparation can greatly accelerate the launching of a programme to save electricity quickly.

## What Kind of Shortfalls are Covered in this Book?

It is important to understand the boundaries of the problem addressed by this book. Many electricity crises cannot be solved by saving electricity in a hurry (or would be more effectively addressed by other strategies). This book offers solutions when the crises have the following features:

**The electricity supply infrastructure is basically intact**. Put another way, electricity can reach customers, but not as much as they wish. Thus, the ice storm in Quebec and Ontario in 1998, where hundreds of transmission towers were toppled, is not a candidate for saving electricity in a hurry. Similarly, the great French windstorm ("tempête") of 1999, which seriously damaged large parts of the transmission and distribution network, could not easily benefit from rapid electricity conservation measures. System-wide blackouts, such as occurred in the north-east United States, Italy and Scandinavia during 2003 are other examples where saving electricity in a hurry would not have avoided the situation. On the other hand, some of these strategies may be useful while the system is being restored. This was the case in Ontario (see the vignette in Chapter 2) after its blackout in 2003 during the process of recovery and re-establishment of the grid.

**An end to the shortfall is in sight**. The shortfall will end when the seasonal rains begin, the heat wave abates, or a power plant comes back on line. For practical purposes, the duration of the shortfall covered in this book is from one day to one year. Many of the programmes proposed in this book, such as mobilising consumers by calling on their civic duty, cannot be sustained for long periods. Other strategies must be used.

**The shortfall is larger or lasts longer than can be handled through the utility's standard Demand Response programmes.** Many utilities offer certain customer categories low-cost power at lower reliability. From experience, the utility can estimate the extent to which customers will respond by cutting demand. About 5% of a utility's total demand will typically be responsive to these measures.

**The shortfall may be a deficit in capacity (e.g., at the time of peak demand) or in total electricity consumption.** Some shortfalls may first appear during periods of peak demand and then spread to total electricity consumption.

The concept of saving electricity in a hurry applies to a small number of events in a year. But these events have such large economic consequences that, like an accident at a nuclear power plant, advance planning is justified. Furthermore, these crises often disproportionately influence future policies, so their long-term impact may be great.

## Developing Countries and Saving Electricity in Hurry

Rapidly-developing countries, for example China and India, suffer from chronic shortages of electricity when the electricity supply system struggles to keep pace with the country's growth. Saving electricity in a hurry does not apply directly to those situations because a clear end to the shortfall is not in sight, and the infrastructure is most likely not sufficient to deliver adequate amounts of power. Nevertheless, these countries may still benefit from many of the concepts described here, such as shifting municipal pumping operations to off-peak hours and scheduling vacations of staff in electricity-intensive factories to coincide with the weeks of peak electricity demand.

## Security Applications of Saving Electricity in a Hurry

Actions by terrorists or criminals could also create shortfalls in electricity supplies identical to those covered in this book. Power plants, transformer stations and transmission lines are potential – and highly vulnerable – targets for terrorists. Oil and gas pipelines, oil storage tanks and other major facilities upstream of the electricity grid are also prime targets. (Indeed, several attempts have already been detected and thwarted in various parts of the world.) These actions could disrupt the supply chain for a few minutes or even many months because these facilities are unique and not easily replaced.

As soon as the authorities determine the extent of damage and probable length of the shortfall, a demand-reduction campaign would begin. The goal is identical to that of electricity shortfalls caused by a non-hostile act: reduce demand in such a way as to cause the least damage to the economy. Mobilising consumers would probably not be difficult because utilities and governments would find it easier to request conservation as a kind of civic duty or act of patriotism.

## Reference

Statistics Canada (2003), "Canadian Economic Accounts", 28 November, www.statcan.ca.

# VIGNETTES OF POWER SHORTFALLS

## Introduction to the Vignettes

Nobody tracks electricity shortfalls and only a few such electricity crises have gained international attention (unless there is a blackout). This chapter lists some shortfalls and describes them. These descriptions have four purposes. First, the reader will gain an appreciation of the diversity of causes of the shortfalls as well as their complexity and dynamic nature. Second, it is important to understand the nature and chronology of the crisis (if only superficially). Third, a description here simplifies discussions of specific aspects in the following chapters. Finally, each vignette is a fascinating story in itself, with many lessons for other regions.

Some vignettes are short because the events are not directly related to saving electricity in a hurry. For example, the Presque Isle incident is presented to illustrate how a flood can temporarily cut power supplies and the economic impacts resulting from loss of power. Some vignettes are short because there is very little to report. The Swedish vignette – while an important example of saving electricity in a hurry – barely appears in the literature and required original research and interviews.

Table 2-1 summarises the shortfalls described in this chapter. This is not intended to be a comprehensive list of shortfalls; however, it does illustrate that the shortfalls happen regularly, for diverse reasons, and in all regions.

Other recent shortages have occurred in Chile, Australia, Italy, China and various parts of the United States, but we have not presented them here because of insufficient information or because they added no new insights.

## A Transformer Fire in Arizona

**Summary of Measures Taken**

- Frequent press releases and requests for conservation
- Extensive TV coverage of problems and need to conserve
- Specific instructions on measures to take and most important times
- E-mail messages to large customers and those already participating in conservation programmes

Estimated electricity savings: 6%
Duration of shortage: about six weeks
Advance warning: about two days

Table 2-1

## *Incidents of Short-term Supply Shortages*

| Date | Country/Location | Immediate Cause of Shortfall | Other Related Aspects |
|---|---|---|---|
| 2004 | United States/Arizona | Fire destroyed distribution station. | Forest fires threatened other transmission facilities. |
| 2003 | Norway | Drought, early and unusually cold winter. | High dependence on electricity for heating. |
| 2003 | Japan/Tokyo | Nuclear plants shut down. | Utility admits to preparing inaccurate safety reports. |
| 2003 | United States/ Presque Isle, Michigan | Flood damages cooling system of power plant. | Remote location prohibits substitution via transmission. |
| 2003 | New Zealand | Drought. | Low coal stockpile for main thermal station. |
| 2003 | Canada/Ontario | Power failure originating in Ohio, U.S. and affecting most of the northeastern United States and the Province of Ontario. | Slow re-start of nuclear power plants. |
| 2003 | Europe | Heat wave and drought lead to increased demand and reduced output. | |
| 2001 | Brazil | Drought and economic upturn causing increased demand. | Partial market liberalisation failed to increase electricity supplies. |
| 2001 | United States/California | High number of plants out of service, reduced imports. | Incomplete market liberalisation, shortage of natural gas, drought in nearby areas, market manipulation by independent generators. |
| 2001 | New Zealand | Drought. | |
| 2001 | Sweden | Cold wave and reduced hydro capacity. | Seeking to address anticipated Monday peak. |
| 1998 | New Zealand/ Auckland | Transmission line cut. | |

Phoenix, Arizona is one of the largest (and fastest-growing) cities in southwest United States. Two utilities serve the Phoenix area, APS (formerly called Arizona Public Service) and the Salt River Project (SRP). Most of the electricity is generated by remote power stations, so the city is particularly dependent on its transmission connections. The Phoenix area is served by four large transformer substations, which are owned either solely or jointly by APS and SRP.

On Sunday 4 July 2004, a fire burned parts of the 500 kV Westwing transformer station near Phoenix. The Westwing transformer station, which is jointly owned by APS and SRP, is approximately 30 years old, and hence did not incorporate the newest fire prevention technologies such as firewalls or active fire suppressing mechanisms. The fire caused a complete shutdown of the substation because there was damage in 5 of 14 transformers in two separate banks. Despite the age of the design, the transformer station was built to operate with the loss of or damage to one of its transformer banks but not two separate banks. (Ironically, the utilities were discussing retrofitting improved fire prevention equipment, but were still trying to resolve technical and cost barriers.)

With the Westwing station out of service, the two utilities were faced with a substantial reduction in their ability to import power into the Phoenix metropolitan area. They were able to reconfigure the power flow on the grid and to restore one of the Westwing transformer banks within a few days, but still faced a sustained 20% reduction in their import capacity, or about 10% of the total peak load (Jarman, 2004a). Since the accident occurred close to their summer peak, the actual shortage corresponded to roughly 10%.

Faced with a 10% reduction in their ability to supply electricity, the local utilities asked for the public's help to avoid outages. The first conservation request came on 5 July, one day after the fire, when APS issued a press release asking its customers to reduce their weekday electricity consumption between the hours of 4 p.m. and 6 p.m. APS indicated that this was a pre-emptive move to avoid the possibility of power outages. The request was accompanied by several suggestions to save energy: setting air conditioner thermostats at no lower than 28°C, turning off extraneous lights and appliances, reducing the use of swimming pool pumps, and shifting use of appliances such as clothes dryers, washers and dishwashers to evenings or weekends (APS, 2004).

The following day, 6 July, both local utilities – APS and SRP – as well as the Arizona Corporation Commission (the regulatory authority) extended the request for voluntary conservation to the entire Phoenix metropolitan area, and reiterated the energy saving suggestions. They also modified one recommendation regarding air conditioning by suggesting that everyone increase their temperature setting by 1°C rather than suggest a fixed temperature setting. (Presumably many people already had settings warmer than originally recommended and the utility wanted to extract further savings.) The utilities reminded customers that the higher temperature settings would not only help avoid a blackout but would also significantly lower their cooling bills. Fortunately, slightly cooler weather arrived at the same time as the most critical supply problems occurred.

Two days later, on 8 July, the crisis worsened when the transmission grid operator was forced to take two lines out of service to allow fire-fighting crews to combat wildfires; a common phenomenon in the region during the hot, dry summer months. This loss further strained the transmission system and the utilities came perilously close to outages. APS issued press releases on 8, 9 and 10 July to reiterate to the public that their assistance was critical in avoiding blackouts, and to update them regarding the progress toward restoring full system capabilities. One change was made in the requested weekend conservation hours: these releases now asked for conservation from 3 p.m. to 6 p.m. On 10 July, APS also issued a second press report, this time to inform their customers that a replacement transformer has been located and purchased, but that it was 2 400 km away and would take a few weeks to move the 180 ton unit to Arizona. The governor promised to expedite the necessary authorisations.

Between the purchase and installation of the transformer, another transformer fire occurred on 22 July at APS' 230 kV Deer Valley transformer substation. The second transformer fire caused a brief blackout for 50 000 customers. At the time, it was believed that this fire was a result of the additional stress placed upon the transmission system but later it was determined that the accident was independent (Welch and Taylor, 2004). Nevertheless, the incident reminded customers that conservation was still necessary.

Both utilities made public requests for voluntary conservation and, judging by the content and timing of the releases, apparently co-ordinated their efforts. However, APS appeared to be more active. APS issued nine statements between 4 July and 9 August. These messages were delivered in an inclusive, thankful tone that continually conveyed the impression that avoiding blackouts would depend on collective action in the community. Communiqués offered reminders of the nature of the crisis, thanks for the widespread support, frequent updates on status restoring the system to full capacity through incremental improvements and in the delivery and installation of the replacement transformer. On the other hand, SRP only issued three releases during the entire period from 4 July to 9 August. These tended to be simple and straight to the point – usually only reiterating the request for voluntary conservation, and offering the same suggestions for conserving energy. SRP appeared to rely more on direct contacts with its customers, especially its larger customers, through telephone calls, e-mail and other means.

The new transformer arrived on 31 July. It was installed and fully operational on 9 August. Thus, the shortage lasted for just over a month.

APS estimated that its customers cut demand 200-300 MW through conservation measures undertaken in response to its pleas. These savings correspond to roughly 6% of the utility's 4600 MW demand during that period, with further savings due to cooler weather. The impact was undeniable: the lights stayed on and the air conditioners continued to cool. "The voluntary conservation efforts kept the lights on" stated Steve Bischoff the Director of Construction, Maintenance, and Operations at APS (Jarman, 2004b). An APS spokesman also confirmed that the utility incurred virtually no additional costs as a result of the crisis, and that fact was solely attributable to the conservation efforts (Jarman, 2004c).

For over 20 years, APS has maintained a formal "Load Curtailment Plan" (Arizona Public Service Company, 2001), which it regularly updates. (This is required by the Arizona Corporations Commission.) The plan outlines the sequence of actions that APS will take when insufficient power is available. The steps before curtailment include delaying maintenance, suspending deliveries of non-firm power, starting spinning reserve, and internal conservation measures. The plan also includes a section entitled "Voluntary Customer Load Curtailment" and is shown below.

*5.2 Voluntary Customer Load Curtailment*

*5.2.1 Public Appeal*

*5.2.1.1 An advisory message procedure will be used when Company has advance indications that it will not be able to meet future peak loads. These messages will request voluntary load reduction during specific hours on specific days.*

*5.2.1.2 An emergency bulletin procedure will be used for instant notification to the public in the event there is no advance indication of a power shortage. These bulletins will request the immediate voluntary cooperation of all customers in reducing electric loads.*

*5.2.1.2.1 These bulletins will request all customers to reduce the use of all electrically operated equipment and devices, where possible.*

*5.2.1.2.2 Company will have a prepared statement to read which will give current information on the Power Supply Interruption, Fuels Shortage or Transmission Emergency.*

Clearly APS was prepared for an event similar to the Westwing transformer fire which allowed the utility to respond quickly and decisively to the shortage.

## Drought in Brazil

**Summary of Measures Taken**

- Electricity rationing
- Penalties for failure to cut consumption
- Extensive coverage of shortage by media
- Daily reports on reservoir status
- Distribution of conservation devices to the poor
- Strong national commitment to conservation
- Higher savings goal for public sector
- Fuel switching

Estimated electricity savings: 20%
Duration of shortage: about ten months
Advance warning: about five months

Hydropower is responsible for 80% of Brazil's electric power capacity and up to 90% of its total electricity production. Brazil has some of the world's largest dams, but reservoir capacity is relatively small. As a result, reserves are immediately affected by changes in the rain conditions. The Brazilian power sector is the most interconnected system in the world for its size. This makes the entire country uniquely vulnerable to a drought or other electricity supply shortfall.

The relatively low rate of investments in the Brazilian electricity industry in the period between 1995 and 2000 contributed to the deterioration in water storage availability in reservoirs. An unusually dry season in 2001, together with the recovery of the Brazilian economy in that year, set the stage for the 2001 electricity shortfall.

By May 2001, it was clear that drastic reduction in power demand would be necessary to avoid long-lasting electricity blackouts. The electricity supply crisis in Brazil was perceived by the entire society as a national calamity with unknown implications. Very rapidly a national debate developed concerning the options to avoid blackouts. Society quickly understood that the cost of doing nothing and accepting the long-lasting blackouts was unacceptable. Given this situation, the government formed a special commission to manage the energy crisis (Câmara de Gestão da Crise de Energia Elétrica-CGE). Special power was given to the committee, which was directly linked to the presidency.

The CGE immediately established a package of programmes to both encourage and require energy conservation. These programmes included:

- Increases in electricity prices for some customer categories.
- Nationwide public awareness of the crisis.
- Utility rebates and energy efficiency.
- Electricity rationing.

Rationing electricity or mandating reductions in consumption are the most drastic forms of conservation. Until Brazil began its programme, no country or region had used these conservation strategies.

The CGE 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 Table 2-2. The amount of energy savings was different according to the demand segment. In addition, penalties and incentives were introduced to promote the reduction in demand. First, consumers who did not reach their mandatory saving targets were subject to interruption of supply. Second, the tariffs for electricity consumed in excess of the quota[1] 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 taking more then 500 kWh.

*1 In general the quota corresponded to 80% of the amount of power consumed in June 2000 (one year before the beginning of the rationing programme).*

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 then 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).

Table 2-2

*Energy Saving Targets in Brazil by Sector*

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

Besides the general rules described above, several additional measures were adopted in the different demand segments. These programmes are summarised in Table 2-3. Utilities and the federal government initiated an intense information campaign in all media on how to save electricity. Energy savings alerts were given on TV every day to promote consumer awareness of the results of the saving efforts. In parallel with the information campaigns, all consumers received formal notification concerning their respective energy targets. Consumers were formally threatened with disconnection if they did not reach the specified reduction in energy demand.

These measures had immediate effects on the residential consumers' habits. One newspaper reporter captured the radical changes in behaviour sparked by the electricity shortage:

*"... I've even disconnected the lights illuminating the little statue of the Virgin Mary in my living room," said Aurora Nascimento Fonseca, a jittery 81-year-old who lives on a small pension.*

*All across the country, in fact, the rationing plan and the penalties that go with it have set off a mad scramble to find ways to save electricity and money. Just try, for example, to buy a fluorescent bulb, flashlight, generator, gas-powered lantern, batteries or even candles.*

Table 2-3

*Major Electricity Measures and Programmes in Brazil*

| Sector | Measure |
|---|---|
| **Residential** | Mandatory reduction or disconnection, 20% less than previous year for customers using more than 100 kWh/month, plus bonuses for savings by small consumers. |
| **Residential** | Government purchase of 5.6 million compact fluorescent lights (CFLs) for poor people. |
| **Residential** | Removal of unnecessary household freezers. |
| **Commercial** | Mandatory 20% reduction in customer electricity consumption through curtailment of night-time activities, rearrangement of schedules, efficiency improvements, fuel switching, cogeneration. |
| **Industry** | 15% reduction compared to previous year. |
| **Public** | 35% reduction in lighting. |
| **All** | Massive media campaign informing public of the crisis and measures to reduce it. |

*"The demand for fluorescent lighting has shot up 1 000 percent in the last couple of weeks," said Eulalia Cardoso, a weary saleswoman at a hardware store where customers were lined up at the door. "We can't keep up with the requests, and neither can our suppliers. As soon as a new stock comes in, it immediately sells out." (The New York Times, 2001)*

National sales data confirm this description. Sales of CFLs by one company jumped from 14 million in 2000 to 50 million in 2001. At the same time, sales of incandescent lamps during 2001 were about half that of the previous year (Geller, 2003).

While large reductions in power demand were possible with less use of air conditioning and lighting, middle and upper class consumers rapidly discovered unexpected opportunities for cutting demand. One of the main forms was to switch off the family freezers. Millions of consumers had purchased freezers during the high-inflation period of the 1980s and earlier 1990s. (The freezers allowed consumers to purchase most of their food at the beginning of the month before their salaries became worthless at the end of the month.) Inflation had fallen significantly during the late 1990s, so consumers no longer needed to use this inconvenient strategy. Since a typical freezer consumes 100 kWh/month, switching it off represented alone a significant savings, possibly even the entire 20% demanded. Another important form of savings was through widespread adoption of compact fluorescent lamps. The federal government distributed 5.6 million compact fluorescent lamps to poor families, but millions more were purchased by the Middle Class.

The CGE decided to demand an effort even more robust from the public sector. Utilities received directives ordering the reduction of about 50% in public lighting points. All public events like shows or soccer games were prohibited from using electricity from the network. Opening times of banks and other public agencies were changed to avoid using power for lighting.

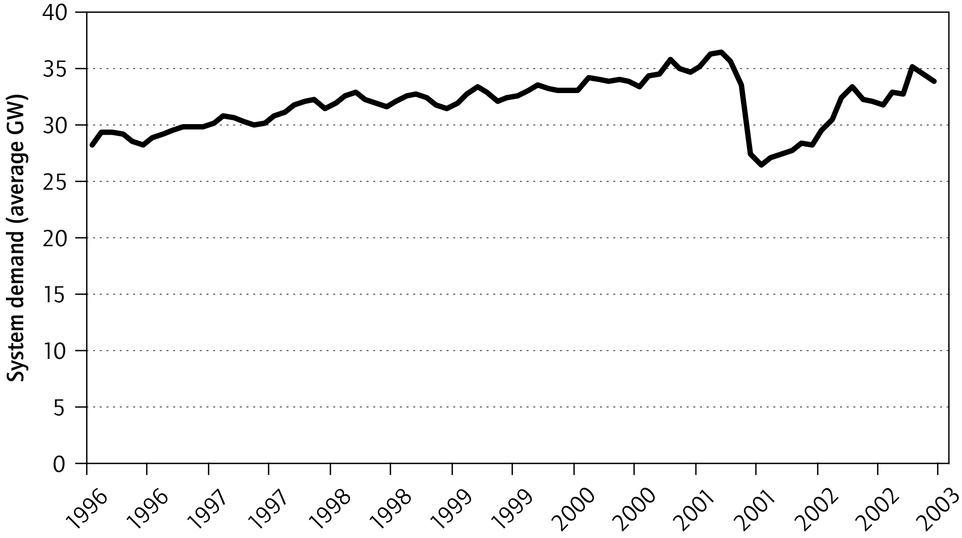
The commercial sector also promptly responded to the energy savings restrictions. The sector rapidly discovered plenty of saving opportunities. The most important measures were: i) increasing the average temperature of their central cooling systems; ii) changing the opening times; iii) adopting efficient lighting systems; and iv) replacing electric-based equipment by gas-based equipment. Besides the energy savings, the commercial sector responded by investing in on-site generation. Between 2001 and 2002, the imports of on-site generation equipment reached two billion dollars. Most of this amount was for diesel-based generation equipment. Some shopping centres and supermarkets accelerated their cogeneration projects.

The potential for energy savings in the industrial sector were less important than in the other sectors. Most of the savings in this sector were obtained by reducing the rate of production. The rationing programme was followed by a temporary reduction in economic activity. Several marketplaces developed in the country to permit bilateral power trading to unload surpluses and ease shortages. Companies able to save more than their target were allowed to sell this excess savings to other companies having difficulties reaching their target. These marketplaces proved essential in giving flexibility to firms to respond to the rationing programme. Some electricity-intensive industries were able to increase their profitability by selling power instead of products. This was especially true for the aluminium and copper industries.

This broad campaign had an immediate impact. The target of 20% was practically obtained in the first month of the rationing programme (see Table 2-4). In July 2001, the savings surpassed the targets. Surprisingly, the residential sector achieved the highest energy savings. The power demand in the residential sector in December 2001 was 23% less than the demand in December 2000. The figures for the commercial and industrial sectors were 16.3% and 11.9%, respectively. Figure 2-1 shows the evolution of demand over time and the country's rapid reduction in demand after rationing began.

Figure 2-1

*Evolution of Electricity Demand in Brazil*




*Source: Brazilian Power System Operator, ONS.*

Table 2-4

*Savings by Region in Brazil*

| | Reduction from 2000 (in %) | | |
|---|---|---|---|
| | Southeast/West | Northeast | North |
| **June** | 19 | 19.7 | 0* |
| **July** | 21.7 | 21 | 9.8 |
| **August** | 19.5 | 18.9 | 18.5 |
| **September** | 18.6 | 16.1 | 20.2 |
| **October** | 17,3 | 13.9 | 18.9 |
| **November** | 15.2 | 12.6 | 19.5 |
| **December** | 9.91 | 8.17 | 8.22 |

** The North began rationing only in July.*
*Source: Brazilian Power System Operator, ONS.*

The savings in power consumption, together with a normal rainy season in the summer of 2001-02, contributed to almost average storage levels in the reservoirs. The level of the reservoirs in the main load region of the country (southeast and centre-west) increased from 20% in September 2001 to 70% in March 2002. Given this improved situation, the government decided to terminate the rationing programme at the end of February.

## California's "Perfect Storm"

**Summary of Measures Taken**

- Over 200 different programmes involving all sectors
- Rebates to customers who used less electricity than in the previous year
- Public Awareness Campaign
- Extensive – daily, on the front page – coverage in the media
- Rebates for purchase of efficient appliances and equipment
- Business partnerships
- Updated efficiency standards
- Higher electricity prices to some consumers

Estimated electricity savings: 14%
Duration of shortage: about nine months
Advance warning: about 12 months

California's electricity crisis of 2001 is often referred to as a "perfect storm", where many serious, but individually manageable, events occurred at the same time and together created an unimaginable catastrophe. These events included a bungled transition to a liberalised electricity market, bankruptcies of the major utilities, a drought, a shortage of natural gas, and policy deadlocks between regional and federal authorities. Freak events, such as seaweed clogging the cooling intake pipes for a major nuclear power plant, also contributed to the crisis. This book offers no interpretation or explanation of the origins of the crisis – the interested reader should consult the numerous analyses, such as that by Bushnell, (2003) for a detailed history – but will cover some highlights as they relate to the response on the demand-side. This description relies heavily on excellent analyses and reporting by Goldman *et al*. (2002), The Flex Your Power Annual Report (FYP, 2002) and Lutzenhiser (2004).

California entered the crisis with an unusually strong energy efficiency infrastructure. In 1974, a state agency – now called the California Energy Commission – was established with specific responsibility for energy efficiency. It was the first state to develop comprehensive energy efficiency standards for buildings and these have been frequently upgraded since then. California also created the first appliance efficiency standards in the late 1970s, starting with refrigerators. Later, the federal government pre-empted most of the authority for appliance standards[2]. At the same time, California's electricity prices were (and remain) among the highest in the United States.

California utilities (both investor-owned and municipal) have also administered large energy efficiency programmes since the late 1970s. Funding fluctuated between $200 and $400 million a year, mostly depending on regulatory guidance. These programmes included rebates for efficient equipment and buildings (beyond minimum standards), energy audits, design assistance and training. These programmes targeted all sectors and both peak demand and energy savings.

Many events shaped public perception of the crisis and its response. One of the earliest events began in May 2000. San Diego Gas & Electric Company, the utility serving the city of San Diego (SDG&E) underwent deregulation earlier than the larger utilities. It had made no long-term electricity supply contracts, expecting the prices to continue falling. In fact, the spot price rose sharply, forcing SDG&E to raise prices to its customers. San Diego customers were both shocked and angry because they had been assured that de-regulation would lead to lower electricity prices. The utility claimed that the regulatory authority had prohibited it from making long-term contracts. Californians throughout the state were alarmed because they could see that the two principal utilities were poised to enter the same operating environment. San Diego's rates were soon lowered and capped by the regulatory authorities, but all agreed that this was only a temporary solution.

California's electrical system is heavily interconnected with those in the neighbouring states. As a result, California's problems spread throughout the western United States. The Northwest states (Washington, Oregon, Idaho) suffered perhaps more than California because of a severe drought combined with the loss of traditionally low electricity prices.

[2] *This pre-emption is not comprehensive and, in 2004, the California Energy Commission established its own efficiency standards to address standby power and external power supplies. California's continuing electricity crisis has been one justification to lead the country – and federal authorities – in new efficiency regulations.*

In June 2000, a series of rolling blackouts and power emergencies occurred throughout the state as the grid operator (the California Independent Service Operator, or CAISO) was forced to shed loads to protect the entire system. Californians first experienced the confusion and inconvenience of widespread blackouts and uncertain electricity supplies. Firms with interruptible power contracts suffered even more. Ordinarily, interruptible contracts are limited to certain industries and firms with electricity-intensive operations who understand the risks and benefits (and have planned accordingly). California utilities had been operating an interruptible programme since the mid 1980s, representing about 5% of total load. A diverse group of customers, including hotels, offices, supermarkets, and even electricity-sensitive industries, had purchased interruptible power. Since no interruptions had occurred for years they treated this power as if it were firm. These customers were totally unprepared for curtailments. Chaos resulted as elevators suddenly stopped working, hotels were totally blacked out and factories were idled.

Finally, prices for natural gas climbed sharply in November 2000. Pacific Gas & Electric Company and SDG&E delivered both electricity and gas to customers, so nearly half of California's residential customers received a combined gas and electric bill. The electricity portion of the bill did not change during the early part of the crisis – indeed the rates were frozen as part of the de-regulation agreement – but the natural gas portion doubled. Most consumers looked only at the combined bill and assumed that they were already feeling the impact of higher electricity prices when in fact the high price of natural gas was responsible. Consumers were confused and angry because this aspect received relatively little attention[3].

These (and many other) events were widely covered in all media, both in California and in the United States as a whole. Television, newspapers and magazines carried conflicting explanations of the causes of the crisis and experts offered widely different solutions. Federal and state authorities publicly blamed each other while neighbouring states sought to isolate themselves from California's problems. In a short time, the majority of the traditional sources of authority or information (such as the utilities and government regulatory agencies) had lost most of their credibility. This meant that no existing institution could take responsibility for starting and running a massive conservation campaign.

[3] *This confusion also resulted in the curious situation where consumers mistakenly responded to high natural gas prices by conserving electricity. Economists will have a difficult time disentangling consumer response during this period.*

In January 2001, California Governor Gray Davis, declared a state of emergency, thus signifying the official start of the electricity crisis.

Gradually a consensus evolved that conservation would be a necessary part of any solution to California's (and the entire west coast's) electricity crisis. In spite of disagreements about all other aspects of the electricity crisis, the state legislature quickly allocated over half a billion dollars to fund conservation programmes. These expenditures supported a wide range of activities, from rebates for more efficient appliances to LED traffic signal replacement. The budgets, with projected power savings for the first and second summers, are shown in Tables 2-5 and 2-6.

*Table 2-5*

*State of California Appropriations for Major Demand-side Programmes and Projected Savings in First and Second Years*

| Measure | 2001 Funding ($ million) | Savings (MW) | |
|---|---|---|---|
| | | September 2001 | July 2002 |
| Summer Peak Initiative | 67.0 | 124 | 124 |
| Appliance Rebates | 50 | 58 | 100 |
| Commercial Lighting Retrofits | 35 | 37 | 60 |
| Low-income Weatherisation and Appliance Rebates | 45 | 8 | 12 |
| **Total** | **197** | **227** | **296** |

Many of these programmes, especially those operated through the California Energy Commission, aimed to reduce shortages beyond the summer of 2001 (since the crisis was not expected to end with the summer). The estimated savings grew rapidly from the first year's 375 MW to 985 MW in the second summer. Altogether, California taxpayers and utilities invested some $1.3 billion in 2001 in energy efficiency, demand response and on-site generation initiatives. Similar programmes were launched in neighbouring states, especially in the Northwest.

In February 2001, California's governor, Gray Davis, announced the formation of "Flex Your Power", to accelerate California's conservation activities. The Flex Your Power campaign raised public consciousness and awareness of the electricity crisis through a co-ordinated series of TV, radio, newspaper and billboard advertising and promotional material. It encouraged conservation behaviour (for example, turning off lights, turning up the thermostat) rather than promoting energy efficiency investments. Flex Your Power also provided educational information about conservation strategies and financial incentives. An unlikely person was selected to run Flex Your Power – a veteran organiser of many political campaigns – but this background established Flex Your Power's approach: a carefully-managed campaign, relying heavily on public relations, aimed at convincing the consumers to "vote" for electricity conservation during the summer of 2001.

*Table 2-6*

*California Appropriations (and Estimated Power Savings) for Programmes Operated by California Energy Commission*

| Measure | Funding ($ million) | Estimated Power Savings (MW) September 2001 | July 2002 |
|---|---|---|---|
| LED Traffic Signals | 10.0 | 6 | 8 |
| Innovative Programmes | 48.0 | 34 | 95 |
| Demand Responsive Buildings | 48.0 | 122 | 186 |
| Cool Roofs | 23.9 | 2 | 20 |
| State Buildings and Public Universities | 5.5 | 51 | 51 |
| Water/Wastewater | 16.3 | 53 | 56 |
| Municipal Utilities | 40.0 | 45 | 59 |
| Agriculture | 87.1 | 30 | 35 |
| Local Government Loans | 49.5 | 1 | 5 |
| Real Time Meters | 34.0 | 31 | 470 |
| **Total** | **362.3** | **375** | **985** |

The Flex Your Power Campaign began operations with a receptive audience. One survey found that 56% of the public felt that electricity prices, cost, supply and demand were the most pressing issue facing California in July 2001. It had risen from 0% in 1999 and now ranked far above the second most pressing issue, schools and education, at 9%. The Flex Your Power campaign also needed to treat the reasons for conserving very delicately. Table 2-7 shows the diverse – and somewhat contradictory – reasons consumers gave for conserving. Consumers distrusted the energy suppliers and blamed them for overcharging (and were eventually proven correct). This anger, however, needed to be channelled into constructive actions.

*Table 2-7*

*Most Important Motivations for Conserving*

| | |
|---|---|
| Very important to stop energy suppliers from overcharging | 79% |
| Using energy resources wisely | 78% |
| Keeping bills down | 77% |
| Trying to avoid blackouts | 77% |
| Doing our part | 69% |
| Qualify for utility rebate | 33% |

Flex Your Power had an additional challenge: it needed to explain to consumers the concept of peak power demand and then how to reduce it. Few consumers – and almost no residential customers – paid time-of-use rates, so they were unfamiliar with peak demand. This educational process needed to occur while reminding consumers of the other goal of saving electricity at all times.

## • The 20/20 Utility Rebate Programme

Through an executive order, Governor Davis established the "20/20" utility rebate scheme. The 20/20 programme 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. 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.

The 20/20 programme was a logistical challenge to implement. The governor announced the programme with little (or no) consultation with investor-owned utilities. The utilities needed to re-programme all of their billing operations within a few months to capture the necessary information and then to include the rebates. Table 2-8 shows the participation rates, electricity savings, and the total rebates.

*Table 2-8*

*Participation, Savings, and Costs of the 20/20 Rebate Programme*

| Customer Type | Customers Receiving Credit (%) | Electricity Savings (GWh) | Total Rebate ($ million) |
|---|---|---|---|
| Residential | 33 | 3 021 | 134 |
| Non-residential | 26 | 2 237 | 153 |
| Total | 32 | 5 258 | 286 |

It is difficult to estimate precisely how much savings can be attributed to the 20/20 programme and how much occurred during the critical peak hours. Natural variation in energy use ensures that about 20% of the customers will use 20% less energy than the previous year; thus the impact is actually smaller than it appears. On the other hand, customers who saved electricity, but failed to achieve the 20% threshold, are not included in the savings. Regardless of the exact savings, the important feature of the 20/20 programme is the simple way in which it linked individual actions to solving the regional problem.

## • Other Programmes to Conserve Electricity

It is impossible to describe the over 200 programmes established to reduce electricity consumption; some, however, deserve special mention. These include:

- Co-ordination of pumping schedules with California Department of Water Resources, which briefly curtailed as much as 300 MW.
- Electricity saving in state office buildings, which achieved about 20% cuts.
- Transformation of markets for energy-efficient appliances such that they became widely available (and were purchased).
- Distribution of over eight million compact fluorescent light bulbs.

Detailed descriptions of many other programmes are available in the Flex Your Power report (FYP, 2002).

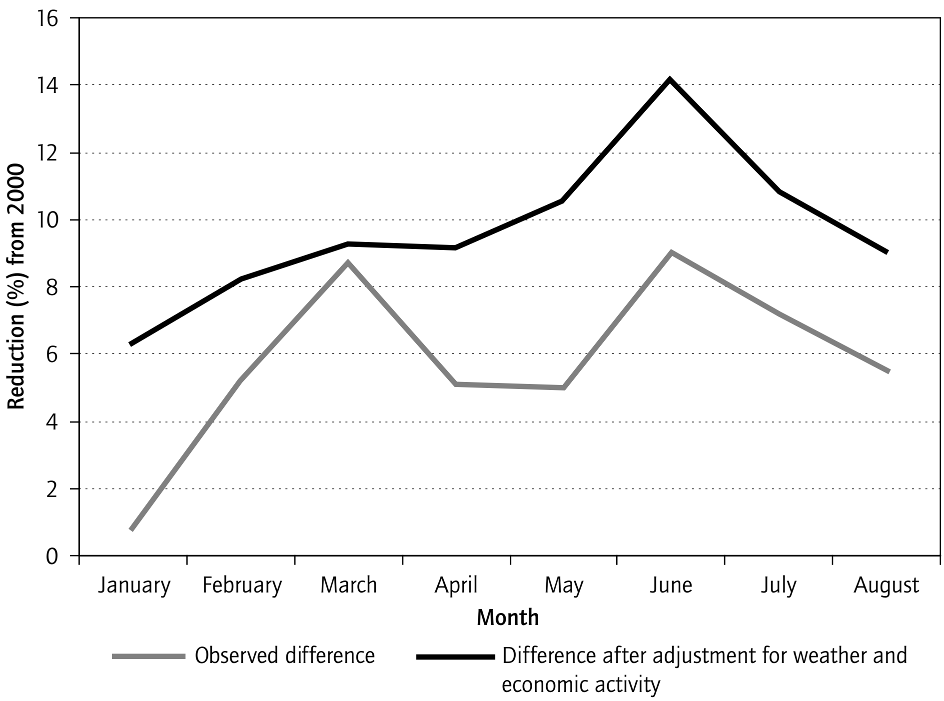
California was able to create a crash programme (and quickly spend $1.3 billion) because it already had an infrastructure in place to "save electricity slowly". Existing programmes could be rapidly expanded by simply increasing – often by a factor of ten – the amount of subsidies and rebates available. The utilities and government agencies already had lists of participating manufacturers, stores and services; these groups could be easily invited to participate in new programmes. The Energy Star efficiency endorsement programme was also valuable because it had already identified a group of high-efficiency products. The rebate programmes could easily just use the Energy Star endorsement as the criterion for eligibility.

## Results

The electricity supply situation in the summer of 2001 was about as bad as originally feared. However, electricity demand was significantly lower than expected, both in terms of electricity consumption and peak demand. Figure 2-2 shows the monthly differences between 2000 and 2001, along with a difference adjusted for temperatures and economic activity. These savings reflect only the electricity flowing through the California grid authority, CAISO.

*Figure 2-2*

*Observed and Adjusted Savings in California's Monthly Peak Electricity Use between 2000 and 2001*




*Source: California Energy Commission.*

The actual savings in March and June exceeded 8% and, in June, corresponded to a savings of 5 570 MW. This reduction needs to be adjusted for differences in weather and economic activity in the two years. Experts generally agree on the direction of the adjustments but differ on the size of adjustments. In 2001, California's economy took a sharp turn downwards – the Silicon Valley bubble finally burst – but summer temperatures were about the same as in 2000. After adjustment, the estimated savings were always higher – perhaps as much as 14% – than the actual savings.

About 13% of California's electricity is controlled by municipal utilities, most of whom faced milder shortages (and some had comfortable surpluses to export). They also mounted conservation campaigns, but they resulted in slightly lower savings. In addition, the Pacific Northwest states (Washington, Oregon and Idaho) cut electricity use substantially.

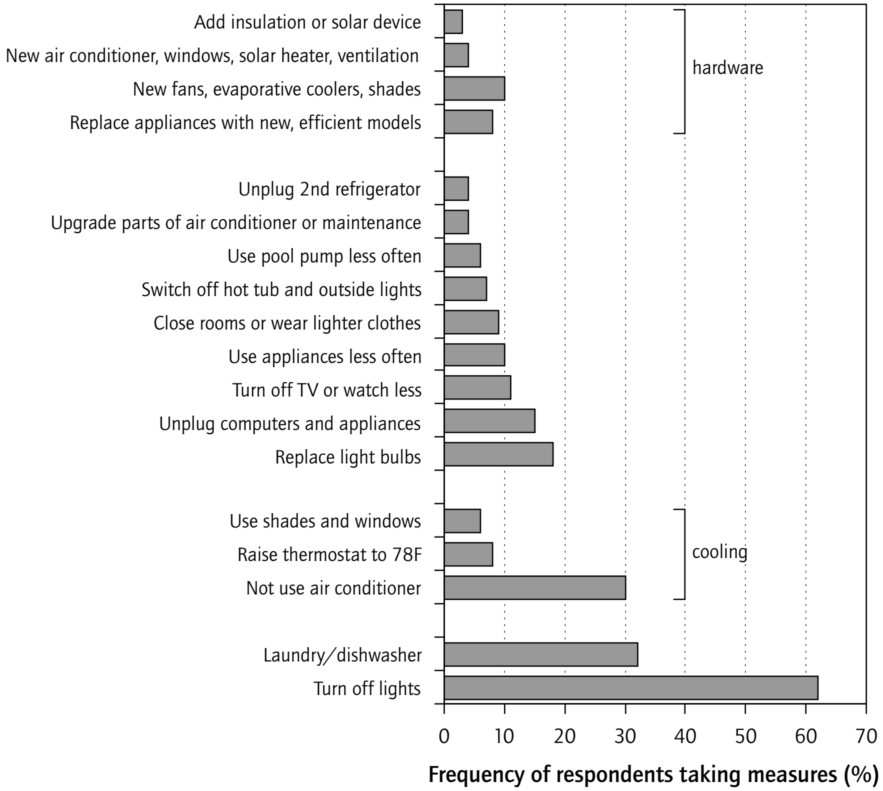
A survey of consumers found that almost 80% of all consumers undertook one or more measures to cut electricity demand. However, most of the savings occurred in a smaller group of consumers (about 37%). The types of measures taken by residential consumers are shown in Figure 2-3. The four measures at the top of the chart involve purchases of new equipment, while the remainder involve changes in behaviour.

Behavioural changes dominate the list but efficiency improvements are significant (especially when considering the relatively short time period involved). Goldman (2002) estimated that about 25-30% of the 4 200 MW of customer load reductions observed in summer 2001 can be attributed to savings through energy efficiency or onsite generation projects, which are likely to persist for many years.

California's electricity problems did not end in September 2001. The supply side still remains in disarray, but California continues to invest in demand reduction measures. New, stricter building standards were approved which, for the first time, were aimed at reducing peak demand. A special new minimum efficiency specification focusing on peak power use was also approved for air conditioners. New regulations establishing minimum efficiency for a wide range of small electronic devices have also been adopted. Finally, metering has been improved and greatly extended; this will allow utilities to communicate better with their customers, establish rates more closely reflecting costs of service, and generally encourage more efficient operation.

*Figure 2-3*

*Conservation Measures Taken by California Households*




*Source: Adapted from Lutzenhiser, 2004.*

# Europe's Hot Summer

**Summary of Measures Taken**

- Maximum use of interruptible contracts
- Public requests to conserve through mass media

Estimated electricity savings: 0.5% (in France)
Duration of shortage: about three weeks
Advance warning: about one day

Heat waves and drought affected large areas of Western Europe during June, July and August 2003. They first became an electricity problem in late June when Italians switched on air conditioners and fans and reached into their refrigerators in record high numbers. Faced with extraordinarily high demand[4] and diminished hydro capacity, the Italian national grid operator ordered the first power cuts in over 20 years (CNN, 2003). (These rolling blackouts are called "spots of the leopard" in Italian.)

Some weeks later the exceptional meteorological conditions started to affect the energy situation in France and Germany. Temperatures stayed between 35°C and 40°C (and were even higher in some cities). Evening cooling was often not feasible because night temperatures remained above 25°C for several weeks. More than 10 000 persons in France alone died prematurely as a consequence of the high temperatures (and air pollution due to ozone peaks).

Electricity shortages arose because of increased demand and constrained supply. On the demand side, consumers switched on air conditioners and fans, while refrigeration systems were required to work exceptionally hard. Electricity demand in France was 8-10% higher than in previous years. On the supply side, utilities faced constrained operations. Most northern European utilities are winter peaking and shut down generation facilities in the summer for maintenance. Capacity was further limited because many of the rivers had exceeded their mandatory temperatures, so power plants were not permitted to exhaust heat into them. Additional nuclear power plants were shut down because the temperatures in the control rooms rose to 50°C, the level beyond which control devices are no longer guaranteed. Other nuclear plants were shut down because the effectiveness of the core cooling system was uncertain at high temperatures. As a result of this situation, the price of electricity on the spot market reached 1 000 euros/MWh on 11 August.

Facing this unexpected situation, the French government took several measures to reduce demand. First, it invoked all possible interruptible supply agreements. These were not particularly effective because they were designed to cope with winter peaks. Next, it strongly urged residential customers to reduce electricity use. The French agency for energy efficiency, ADEME, took charge of announcements to the mass media and provided additional information about the kinds of measures consumers should take. Similar appeals were made in Italy and Germany.

[4] *Italy, Greece, Spain and parts of southern France have only recently become summer peaking.*

On 14 August the French agency in charge of electricity network transport (RTE) registered a decrease of 200 to 300 MWe on the level of the demand forecast the previous day. This reduction was presumably a result of behavioural changes in households and other customers (Moisan, 2003). Since demand was roughly 58 GW, this corresponds to a reduction of about 0.5%. Savings in Italy and Germany are not known.

On 21 August the French government decided to launch a programme to prevent such electricity problems in case of future heat waves including energy conservation (in addition to several more publicised measures dealing with public health).

## New Zealand's Three Electricity Crises

**Summary of Measures Taken**

- Intensive media campaign with suggested measures
- Establishing individual goals for all consumers
- Consumer hotline
- Web site with real-time reservoir information
- Rebates to some customers for successful conservation

Estimated electricity savings: 2001: 10% 2003: 10%
Duration of shortage: 2001: about three months 2003: about six weeks
Advance warning: 2001: about one month 2003: about one month

New Zealand has experienced three separate electricity crises since 1998. The first, involved the loss of electrical service for over a month in Auckland's Central Business District. This is an example of a catastrophe so large that even drastic strategies to conserve were insufficient. It also shows the economic and social consequences of long-term blackouts in a developed country. The second two crises were anticipated shortfalls in electricity caused principally by droughts. These two shortfalls are excellent examples of where saving electricity in a hurry made a critical difference in the outcome and avoided blackouts.

### • Auckland Power Supply Failure 1998

Auckland is the largest city in New Zealand and the nation's commercial centre. Electricity is provided by Mercury Energy Ltd. A series of four power cable failures, struck the utility in February 1998. Auckland's Central Business District was particularly hard hit (Ministry of Economic Development, 1998). On the evening of the fourth failure (20 February) Mercury Energy announced,

*"The situation has deteriorated to the point that now the company believes it can no longer supply the Central Business District with electricity. This raises Civil Defence and public safety issues which may lead to a declaration of a Civil Defence Emergency. Mercury Energy is notifying all essential service providers and asking them to come immediately to an emergency meeting at Mercury Energy headquarters. After the conference Civil Defence will decide whether a Civil Emergency is declared."*

Ultimately, a Civil Emergency was not declared, but people were urged to stay out of the Central Business District.

On 26 February Mercury Energy announced rotating power cuts and called for ongoing power savings. On 8 March a series of demand-side management initiatives were announced, including a buy back scheme and a new information and awareness programme.

On several occasions the utility announced completion of repairs, only to discover another problem or experience another failure. Additional cable failures and brief system outages continued through May, about three months after the first blackout.

The Auckland blackout probably influenced New Zealand's attitude towards electricity reliability, power shortages and blackouts, which had not been forgotten by the time the next electricity crisis arrived.

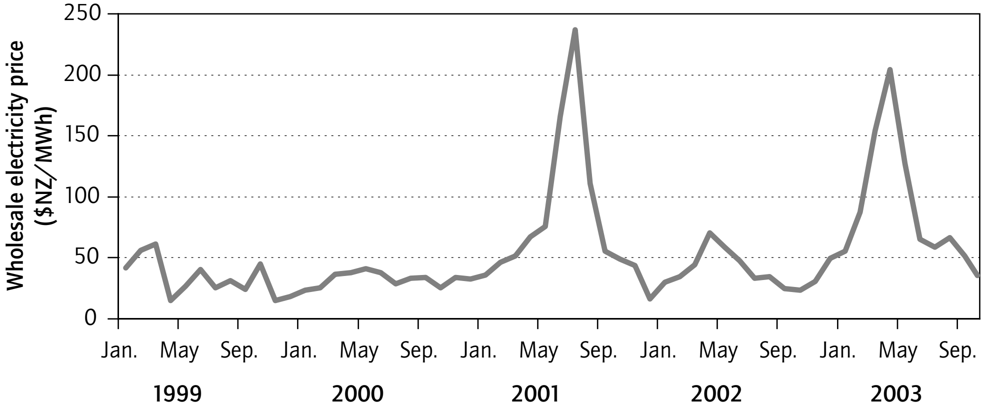
## ● The 2001 Power Crisis

New Zealand relies heavily on hydro for its electricity. Over 60% of its electricity comes from hydro but reservoir storage is relatively small. Electricity demand had been growing at an average of between 2% and 3% per annum, reflecting a vigorous economy and improving standard of living (Infratil and Morrison, 2001).

In 2001, New Zealand experienced its worst drought in over 50 years. Very low hydro flows began before January and then continued at very low levels through the winter. In June, an early cold snap struck the country, resulting in record high levels of electrical demand – about 4% higher than the previous year. The combination of low inflows, declining hydro storage and increased demand resulted in dramatically higher spot electricity prices. Figure 2-4 shows the monthly average electricity prices since 1999. The run-up in electricity prices began in June and reached NZ$0.29/kWh in June (compared to 4 cents/kWh in April).

*Figure 2-4*

*Average Monthly Wholesale Electricity Prices in New Zealand, 1999-2003*




*Source: New Zealand Electricity Market (2005).*

In June, the government announced that a "modest" hydro supply risk existed. It acted to assist the industry and consumers by convening industry meetings and promoting conservation. In early July, the Minister of Energy publicly raised the hydro supply risk to "moderate". The drought continued to worsen – and electricity spot prices continued to rise – such that by the end of July, the government was forced to intervene more strongly. It called together electricity stakeholders to meet every week until the threat of a shortage had passed. The government created an energy audit scheme for commercial and industrial premises run by the Energy Efficiency and Conservation Authority.

Also in late July 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. This campaign was created and operated by the government. It also called for 15% savings in the public sector.

The conservation campaign, and especially the "10 for 10" programme, achieved its goals. Conservation and energy efficiency campaigns saved over 450 GWh of hydro storage, equal to about one-third of the estimated 1 350 GWh of hydro storage in mid-July.

In mid-September, the Minister of Energy announced the end of the electricity shortage and terminated the weekly meetings of stakeholders.

## • The 2003 Drought

The circumstances of winter 2003 closely paralleled those in winter 2001: a severe drought accompanied by high electricity demand. An additional factor was low coal reserves at the main thermal stations used to cover dry winters. There were already signs of another dry winter by March 2003 and by April it was clear that there was a high risk of winter power shortages. At that time, the Energy Minister confirmed the fears of another dry winter and high power prices. He announced that a new power-savings push would be on the way.

In May, the Winter Power Task Force was formed by the industry's Grid Security Committee. It immediately launched the Target 10% campaign. The campaign's main message was that the country needed 10% power savings. The 2003 campaign differed from the 2001 campaign in that it was organised and run by industry participants (rather than the government).

The Target 10% campaign relied heavily on mass media to disseminate the conservation message quickly. Celebrities and other nationally known personalities reminded the audience of the drought, the need to conserve, and specific measures to take. Humour played an important role in many advertisements but all kept to the theme of asking New Zealanders to work together now so as to avoid compulsory shortages later. Some advertisements featured prominent members of minority groups in order to mobilise the entire population. Other advertisements appeared in the print media (see Figure 2-5), again stressing the need to work together.

The Target 10% campaign established a Web site to provide all energy consumers and the public with the latest information about the progress in electricity savings. The site contained tips on how to save power at home and at work, results of power savings so far, power news, and links to other helpful sites.

Once again, the government set a 15% electricity savings target for the public sector. Energy Minister Pete Hodgson conceded that achieving 15% savings might require reduced working conditions in government agencies, such as reduced air conditioning or heating, but promised that public servants' health and safety would not be compromised. The electricity savings were monitored by the Energy Efficiency and Conservation Authority (Hodgson, 2003).

***Figure 2-5***

*Advertisements from New Zealand's Target 10% Campaign*


*Source: Target 10%.*

Some large industrial customers with long-term contracts (at low rates) found it more profitable to shut down operations and re-sell their electricity in the spot market. The amount of electricity made available through this process is not clear, however, because the details of the contracts were generally confidential.

The goal of 10% savings was achieved in early June, only one month after the Target 10% campaign began. The combination of power savings and strong rains in late June removed most of the threat of a shortage. By July, the equivalent of 3,000 GWh of electricity was held in hydro storage reservoirs, which was 98% of the average for that time of year. The wholesale power prices returned to the lowest level since January 2003.

When the power crisis was over, it was acknowledged that an early response by industry and voluntary savings had been effective. Several retailers provided financial incentives for electricity savings to consumers, or made contributions to charities in proportion to total savings by their customers.

# Norway's Drought and Early, Cold Winter

### Summary of Measures Taken

- Extensive media campaigns urging conservation
- Daily reports of reservoir levels
- Creation of subsidy scheme for household electricity conservation measures
- Fuel switching
- Electricity-intensive factories shut down operations and re-sold electricity on spot market

Estimated electricity savings: 8%
Duration of shortage: about four months
Advance warning: about two months

Norway relies almost exclusively on hydroelectric facilities for its electrical generation. Until recently, these supplies were plentiful and the country was a net exporter to neighbouring countries, including Denmark and Sweden. Electricity has generally been cheap, so it has been used in buildings for heating and spawned numerous electricity-intensive industries.

Norway's electricity consumption fluctuates with economic activity and the severity of winter but, overall, has grown at about 2% per year. Increases in reserves have not kept pace with consumption and in about 2000, consumption overtook available supplies. This shift from a net exporter to importer was partly obscured by mild winters and wet summers (ICF Consulting, 2001).

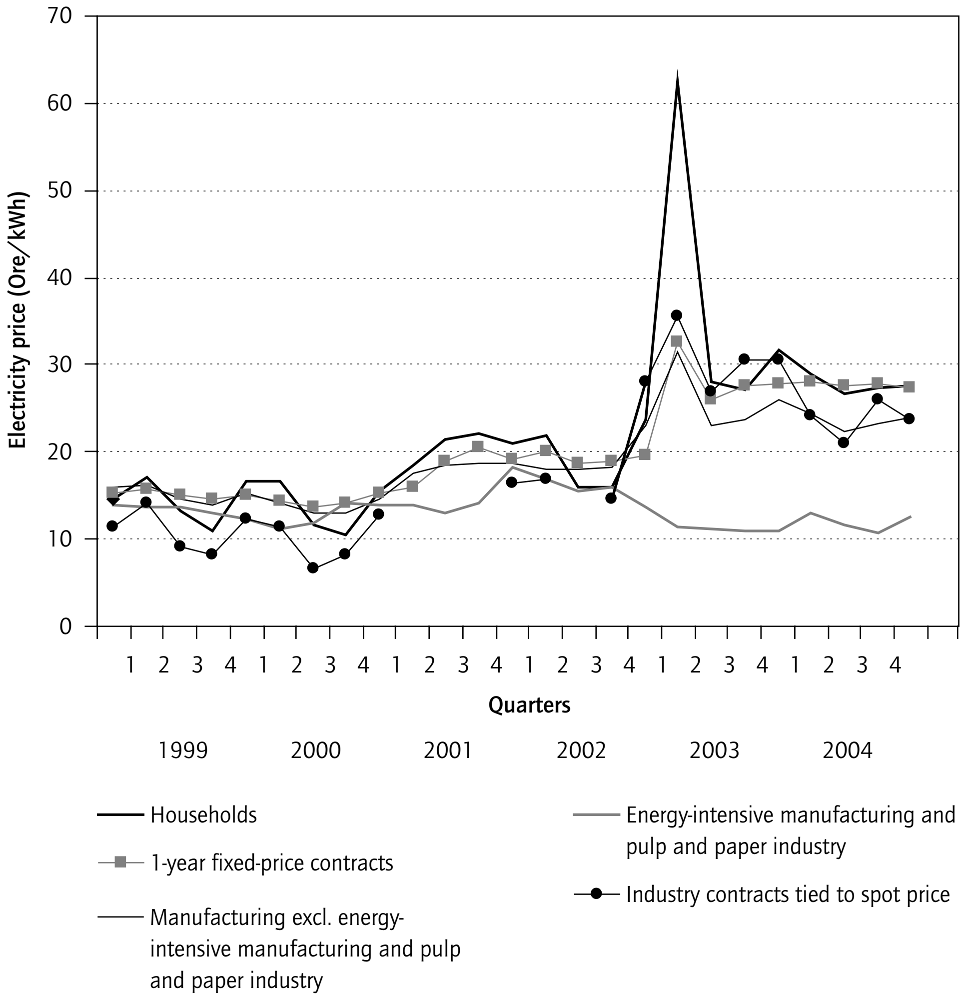
Norway was one of the first countries in the world to liberalise its power markets in 1991. Shortly thereafter, in 1993, the Nordic Power Exchange (Nord Pool) was established by the major utilities in Norway and Sweden. The liberalisation now extends to retail customers, including residential. Over time, most Norwegian utilities had begun to buy large fractions of their needs on the spot market (whose prices in 2001 had continued to fall). The heavy reliance on the spot market made Norwegian residential and commercial customers extremely vulnerable to spikes in electricity prices. Industrial customers relied more on long-term contracts and were therefore less vulnerable.

The summer of 2002 was unusually dry and was then followed by a cold autumn. These conditions led to a shortage of electricity at the end of 2002.

Prices rose rapidly in the retail markets (see Figure 2-6) but the increases were greatest for households, who basically paid the spot price. Industry and large customers were shielded from the full rise by long-term fixed-price contracts. However, the apparent rise in prices seen by households was buffered by the taxes and other fees tacked onto the electricity bill (see Figure 2-7).

*Figure 2-6*

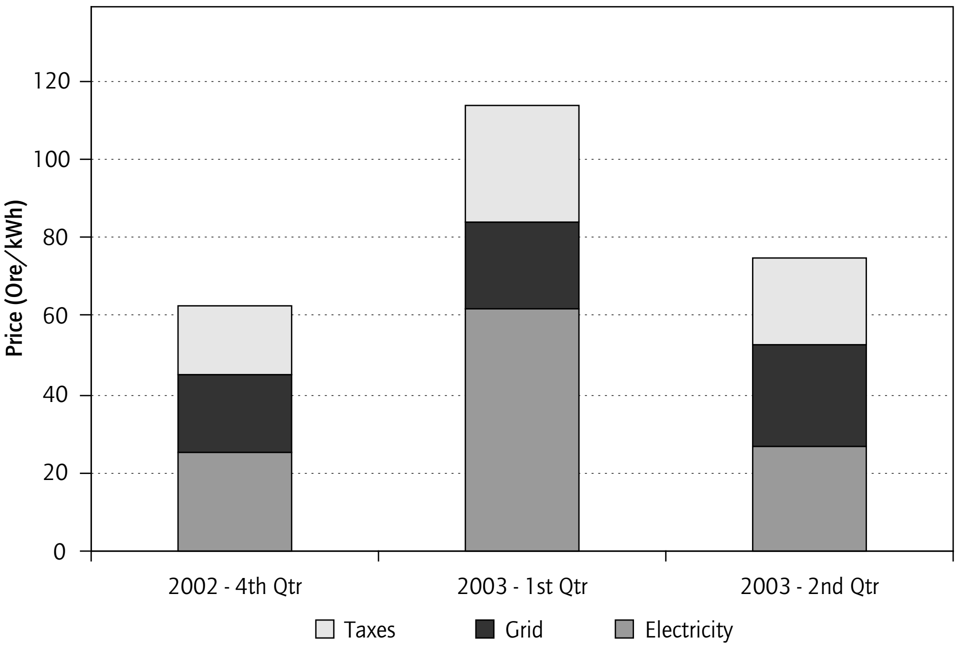
*Average Electricity Prices (Excluding Taxes) for Major Sectors in Norway*




*Source: Statistics Norway, 2005.*

*Figure 2-7*

*Composition of Household Electricity Prices in Norway*




*Source: Statistics Norway, 2005.*

By coincidence, the Norwegian conservation agency, ENOVA, had just been established. One of its first actions (and planned before the crisis) was an intensive media campaign to urge consumers to conserve, mostly by preventing wasteful energy use. One television clip showed a hot steamy shower running with nobody in it, while another showed a car being filled with petrol; then the hose falls out and sprays petrol all over the ground. Nobody is present to switch off the flow.

The shortfall became a political crisis as the prices rose and consumers complained. An old woman was thought to have died from cold because she was afraid to use expensive electricity. One description of the crisis went :

*"For Norwegians, most of whom had become quite dependent on electricity for heating purposes, this was a totally new situation. Many were not able to pay their electricity bill. Others turned down the indoor temperature to levels far too low to maintain a sound living. Needless to say, this situation was discussed in newspapers almost daily during the winter, and radio and television ran*

*discussion programmes on the theme several times a week. There was also a lot of aggression in the debates against politicians and energy utilities. This was based on the fact that there had been a substantial export of electricity in a situation where early during the year it had become clear that Norway would not even be self-sufficient. In any case, the important issue of rational use of energy had become a hot topic in Norway...." (Aarlien et al., 2005)*

The Norwegian government firmly supported a market-oriented solution to the crisis. It stated that the market should – and could – handle the situation through the price mechanism.

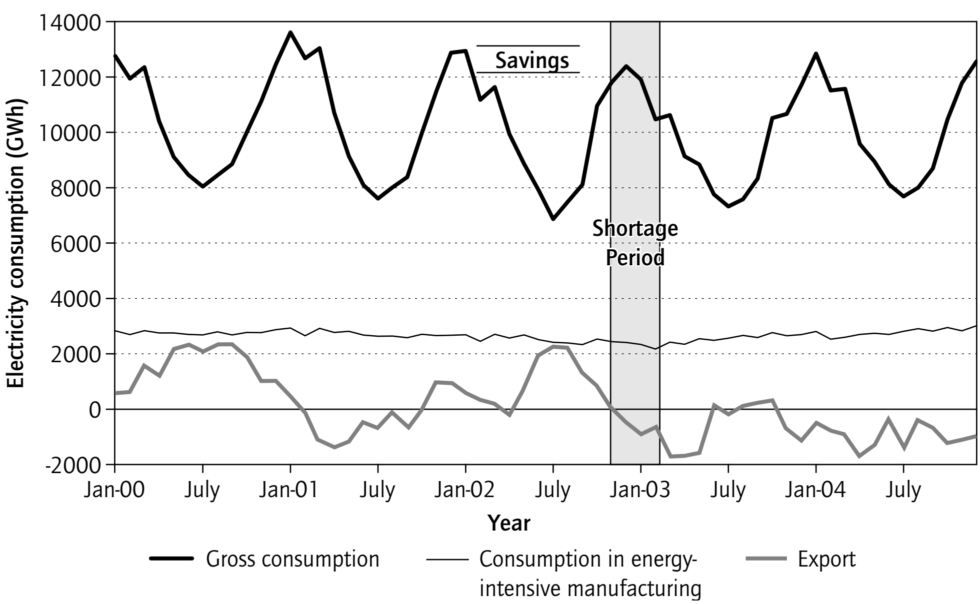
Nevertheless, the Ministry of Petroleum and Energy launched an electricity savings programme called the Household Support Scheme. The programme offered investment aid to households for three technologies:

- Air-to-air heat pumps
- Wood pellet stoves
- Energy management systems

The government subsidised 20% of the total cost (capped at about $700).

*Figure 2-8*

*Norway: Production, Consumption and Export*




*Source: Statistics Norway, 2005.*

Unfortunately, the programme 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 (in particular the free-rider analysis). Manufacturers of products excluded from the list – such as makers of efficient windows – also complained. Whenever the Prime Minister spoke about energy conservation, he specifically mentioned the Household Support Programme and heat pumps as a remedy for high heating bills. Advertisements for heat pumps appeared in newspapers and on television every day.

ENOVA was obliged to create the entire programme in less than two months. This may have been one reason why it designed the applications to require as little paperwork as possible and to maximise communication through the Internet. ENOVA also designed minimum specifications for the technologies. The heat pumps must be equipped with inverters (for variable speed operation) and use an HFC or natural refrigerant (rather than R-22 which was scheduled to be phased out in Norway one year later).

These programmes, and especially the heat pump programme, sparked an unexpectedly large consumer response. Heat pump sales jumped from below 5 000 units per year to over 50 000 units in 2003. Distribution channels changed during the crisis, too, from contractors specialising in refrigeration and heat pumps to department stores and electric appliance stores. The heat pump became more of a commodity.

At about the same time, ENOVA established a hot-line to answer consumer questions. This, too, proved to be very popular. Other conservation programmes were under way by different groups. The Ministry of Petroleum and Energy launched its own campaign to conserve, involving television, newspaper and direct mail. Newspapers and television stations reported the reservoir levels every day.

Local utilities initiated their own programmes. For example, the Stavanger utility began reading meters once a month (instead of quarterly). More frequent meter readings helped the utility estimate annual costs and then average the utility bills more accurately over the year. A second benefit was that customers received more frequent feedback about their energy use and conservation. Many of the utilities had special contracts with customers owning dual-fuel boilers. In return for lower electricity rates, these customers were obliged to switch to oil when requested by the utility, thus making more electricity available. Manufacturers of aluminium and other electricity-intensive processes typically had long-term, fixed-price contracts with the local utilities. Several of these firms discovered that it was more profitable to temporarily shut down operations and sell the electricity on the spot market (and did so).

The remainder of the winter proved to be relatively mild and by March 2003 electricity prices had fallen almost down to pre-crisis levels. Overall, the electricity savings were roughly 8% compared to the previous year (and after adjusting for differences in the severity of the winter). The crisis ended, but the long-term problem of electricity demand rising faster than new capacity continues.

## Ontario Recovers from a Blackout

**Summary of Measures Taken**

- Appeals for conservation by government and utililties on radio, TV and in newspapers
- Shutdown of government offices
- Closure of electricity-intensive industries
- Electricity curtailments

Estimated electricity savings: 17%
Duration of shortage: about two weeks
Advance warning: none

On Thursday, 14 August 2003, the Canadian Province of Ontario (along with much of northeast United States) suffered a massive blackout. This was the largest blackout in the history of North America, involving over 50 million people and 60 GW of electrical load. In Ontario – whose grid is controlled by the Independent Electricity Market Operator (IMO) – about 24 GW of load was affected.

The electric utilities in Ontario took immediate action to return their generating stations to service. Much of the IMO-controlled grid was restored within about 13 hours, and most customers were re-connected within about 30 hours (IMO, 2004). By Friday 15 August 2003, around 60% of the generating capacity, including hydroelectric stations, a significant portion of fossil station capacity and some nuclear capacity, was reconnected to the transmission system. As a result of the blackout, the IMO suspended the Ontario electricity market and implemented the Ontario Power System Restoration Plan (OPSRP).

However, it soon became evident that insufficient generation capacity would be available through much of the following week. A number of problems delayed the re-starting of nuclear power plants in Ontario (See Figure 2-9). Although 4 of 12 nuclear units were supplying power within six hours of the blackout, a week later this had only been raised to 7 of 12. (By contrast, nearly all hydro plants were continuously available and the majority of the fossil plants returned to service within 24 hours.) The impact was more severe in Ontario than in the United States because the Province relies on nuclear power for about 40% of its electricity supply. The Government of Ontario declared a Provincial emergency – the second in history – on Thursday evening.

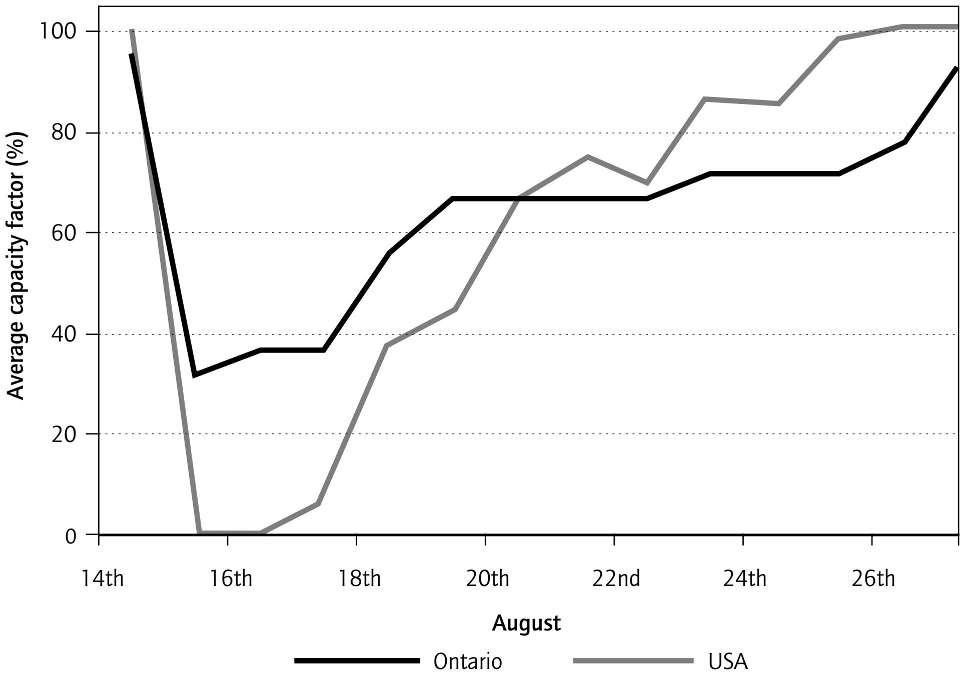
Pre-existing emergency load curtailment plans were implemented, although these plans needed to be constantly revised in the face of rapidly changing system conditions and newly identified priority loads. (Most of these adjustments were made to accommodate priority loads such as public transport, hospitals, water treatment plants and refineries.) The power shortfall was so great that rarely-used measures were implemented, including controlled rotational load shedding. Implementing an effective rotation of load shedding was initially challenging since load was still being restored from the blackout. Nevertheless, rotating blackouts were not needed after the first 24 hours.

In light of uncertainties regarding the extent of the supply shortfall, the degree to which customers would voluntarily reduce load, and a weather forecast that promised increasingly high temperatures through the following week, the Government of Ontario requested a 50% reduction in consumption from all commercial and industrial customers. This request was issued through the media, along with suggestions on measures that should be taken. Energy-intensive industries – such as automobile manufacturing and refining – complied by simply shutting down operations rather than face unpredictable curtailments. Other businesses and industries reduced shifts or maintained partial operation but shut down energy-intensive activities.

Provincial and federal governments shut down all non-essential operations. Almost half of all Canadian federal employees work in Ontario. About 60%

*Figure 2-9*

*Capacity Factors of Nuclear Plants in Ontario and the United States after the 14 August Blackout*




*Source: IEA analysis based on data from US Nuclear Regulatory Commission, Ontario Power Generation, and press reports.*

of federal employees were absent during the second half of August. Ontario's provincial government employees stayed home too; their absentee rate was 45%.

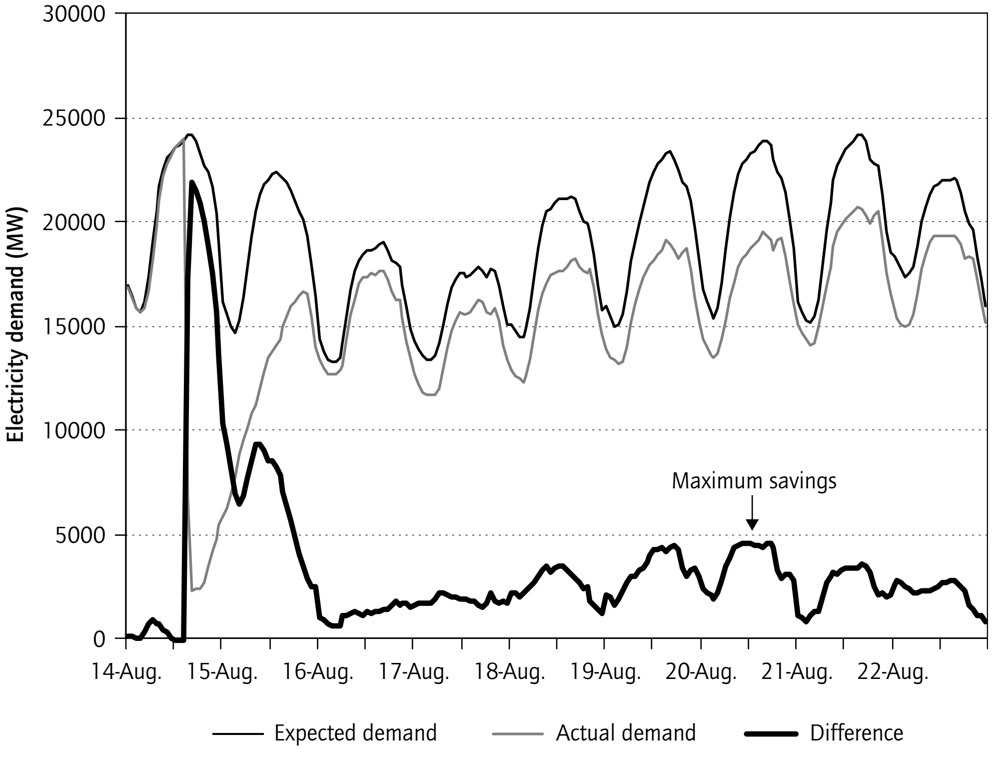
A 50% reduction in consumption was not achieved. Forecast and actual loads in Ontario during the eight days after the blackout are shown in Figure 2-10. The maximum reduction in demand of about 17% – corresponding to over 4 GW – occurred on 20 August. The total amount of energy reduction during the week following the blackout was 494 GWh.

No thorough study of the savings has been undertaken. Anecdotal information (Spears, 2003) suggested that the industrial and commercial sectors provided disproportionately more reductions than the residential sector. Households consumed about 40% of Ontario's electricity but appeared to have been responsible for only about a quarter of the saved electricity. However, it has to be noted that more than the normal number of residents would be at home during the crisis, because of shutdowns by the government and companies.

Generating capacity was fully restored by 29 August 2003. Canada's GDP (not just Ontario's GDP) fell 0.7% in August. The decline was blamed mostly on the commercial and industrial production curtailment as a result of the blackout.

*Figure 2-10*

*Actual and Forecast Load after the 14 August Blackout*




*Source: IMO, 2004.*

# A Flood-damaged Power Plant at Presque Isle

**Summary of Measures Taken**

- Major industries closed for duration of the shortage
- Localized blackouts for short periods after flood, followed by frequent warnings of potential blackouts
- Press releases appealing for conservation, including preferred times
- Heavy coverage by local media, including requests for conservation

Estimated electricity savings: not available
Duration of shortage: about ten weeks
Advance warning: about one day

The Presque Isle Power Plant is located in Michigan's Upper Peninsula on the southern shore of Lake Superior. The Presque Isle plant is a 618 MW, coal-fired, nine unit generating facility located in the town of Marquette (population 20 000) where the Dead River flows into Lake Superior.

On 14 May 2003 the Silver Lake Dam failed, triggering failures in other dams downstream, and eventually sending water, mud and debris into the circulatory systems at the Presque Isle Plant. The flood damaged motors, gearboxes, switching equipment and transformers. Ironically, the dam failed because of design and construction errors to a recently-added emergency water release system designed to protect the dam structure in the event of a "maximum probable flood". (It failed after a heavy, but not extraordinary, rainfall.)

The Presque Isle power plant was completely out of operation for about three weeks, from 15 May to 8 June, when the first generating unit returned to service. Additional units were gradually brought into service; all units were returned to service at the end of July 2003. Portable generators were also brought in to provide temporary power. The shortage lasted about ten weeks, but was most severe for about one month and then slowly diminished as the units were brought back into service.

The southern shore of Lake Superior is an unusually remote part of the United States and has limited transmission connections to neighbouring utilities. The Presque Isle plant represents about one-half of the installed generation capacity. Two nearby iron ore mines account for approximately 300 MW of power demand, or half the output from the plant. These mines employ over 1 200 people, almost 7% of the area's workforce.

Wisconsin Electric Power Company (WEPCO) was the utility most affected by the Presque Isle shutdown. It issued the first warning of the potential for rolling blackouts on 15 May 2003. As the scope of the crisis became clear, WEPCO, Upper Peninsula Power (often referred to by its familiar name Uppco), other nearby utilities and the transmission operator in the area co-ordinated their efforts to ensure the reliability of service. WEPCO immediately curtailed electricity to the iron ore mines, which were then forced to cease operation. The mines remained closed for about five weeks, at a loss of $11 million to the mine owners and tens of millions of dollars of damage to the local economy (Cleveland Cliffs Inc., 2003; Marquette County, 2003).

WEPCO began requesting conservation efforts from their customers on 18 May. This request was echoed by the neighbouring utilities and the story was widely followed by the local print and television media. WEPCO issued press releases on 18 and 30 May, and its sister company, Edison Sault, issued similar pleas on 16 May, 19 May and 19 June (WE Energies and Edison Sault, 2003). The neighbouring municipal utility, Marquette Board of Light & Power also participated in the co-ordinated effort, issuing similar requests. The magnitude of the disaster was easy to convey to the public through both aerial photos and close-ups. In this sense, the utilities had no difficulty convincing the consumers that a crisis existed.

Through the local media, the utilities implored their customers to conserve power as the grid was in an exceptionally fragile state. Conservation suggestions included switching off unused appliances and delaying chores such as dishwashing, laundering and cooking until after 21:00. There is no official estimate of the electricity savings that occurred through conservation; they would make little sense when WEPCO's largest customer was not drawing power. Curiously, Uppco reported only a 3% reduction in their 2003 electricity sales compared to 2002 in spite of the Presque Isle accident. It attributed the reduction to mild weather and conservation efforts.

# A Cold Monday in Sweden

**Summary of Measures Taken**

- Requests for conservation broadcast on radio and TV
- Newspapers carried expanded explanations of the problem

Estimated electricity savings: 4%
Duration of shortage: one day
Advance warning: three days

In February 2001, a cold wave caused electricity demand in Sweden to approach available capacity. On Friday, 2 February, demand at the morning peak amounted to about 26 700 MW, which was just 100 MW below the maximum capacity (ERA, 2002). (This was approximately 700 MW higher than the peak consumption during the previous winter.) The cold wave covered much of Sweden, Norway and Finland. The temperatures in central Sweden were 10°C below normal and even lower in Oslo and Helsinki. As a result, it was impossible to import additional power from neighbouring countries. On that Friday, the electricity price averaged 440 SEK/MWh but rose to four times that during the peak hour (Svenska Kraftnät, 2001).

On Friday morning, Svenska Kraftnät – the entity responsible for matching supply and demand – was reasonably certain that it could meet Friday's peak. The weekend would not be a problem because demand falls during the weekend when industrial and commercial customers shut down. However, the situation for Monday was grim. The weather forecast for Monday, 5 February, predicted even lower temperatures. That, combined with the Monday start-up by the industrial and commercial customers, would create a demand in excess of available capacity.

Svenska Kraftnät ordered an extra 1 000 MW to be made available on the spot market for Monday. At the same time Svenska Kraftnät requested all electricity consumers to either conserve or postpone consumption on Monday morning, that is, during the time when industry was gearing up and temperatures were expected to be at their lowest. This appeal was broadcast on television and radio, and was published in weekend newspapers. Meanwhile, power traders arranged for the purchase of up to 850 MW at the price of 2 000 SEK/MWh – over four times the Friday price – for delivery on Monday morning.

The call for conservation was a great success: peak demand on Monday morning was about 1 000 MW less than anticipated and there were no blackouts even though Monday's weather was even colder than predicted. This corresponds to roughly 3.5% savings beyond those already expected by industry but not taking into account the lower than expected temperatures.

Svenska Kraftnät was amazed by the result. A survey indicated that about 45% of consumers had reduced their electricity consumption (or at least had taken measures to cut use). The industrial customers also responded to the much higher electricity prices. Unfortunately, it was not possible to determine how much savings were caused by each group (and why). Industry's reaction to higher prices cannot be responsible for the entire savings because only about 25% of industry sees a spot price.

The unexpected magnitude of the conservation caught the market by surprise and had unintended consequences. The traders were forced to sell the surplus power for 200 SEK/MWh on Monday, at one-tenth of its purchase price. Afterwards Svenska Kraftnät decided that it would be more restrictive in the future with appeals to the public and that use of an announced "code red" compared to possible purchases on the spot market posed a dilemma. In any event, Svenska Kraftnät' wanted to keep this instrument as they regard blackouts as a bigger problem than disturbing the market.

Since then Svenska Kraftnät established a Web site as a means of communicating with its customers in case of a future shortage. The Web site displays total electricity demand and shows three possible electricity supply conditions – "normal", "strained situation" and "a warning that a power shortage may be announced".

# Nuclear Plants Shut Down in Tokyo

**Summary of Measures Taken**

- Frequent paid appeals and voluntary discussions on TV
- Print media reminders and requests
- Utility staff visited thousands of customers to request conservation
- Leadership by example in government buildings
- Re-negotiation of interruptible contracts with large customers
- Shifting and rescheduling of factory production
- Web site showing current demand

Estimated electricity savings: 4.5%
Duration of shortage: about three months
Advance warning: about eight months

Tokyo Electric Power Company (TEPCO) is the largest privately owned electric utility in the world. It serves roughly 27 million customers in the city of Tokyo and in other cities in the Kanto region. Peak demand is about 64 GW and occurs during the summer when consumers switch on air conditioners in response to high temperatures and humidity. Seventeen nuclear power plants supply about half of its electricity.

In the late summer of 2002, a whistleblower revealed that TEPCO had falsified results of numerous safety inspections, going back over at least a decade. This revelation followed several accidents (ranging from minor to fatal) related to nuclear power plants and fuel reprocessing in Japan. As a result of these events, the credibility of the Japanese utilities – indeed, the whole industry – was seriously eroded. In September 2002, TEPCO announced that, in order to restore the public's confidence in nuclear power, it would shut down all its nuclear power plants. The plants would be gradually shut down with the last plant ceasing operation in April 2004. These plants would remain closed until the host communities were satisfied that the plants had fully complied with all safety regulations. At the same time, the president of TEPCO accepted responsibility for the problem and announced his resignation.

Even with 17 nuclear plants removed from the grid in the winter of 2002-03, TEPCO did not face an immediate crisis because winter demand was far less than its summer peak. In December, for example, demand was expected to be about 51 GW, which matched TEPCO's available capacity without its nuclear plants. The situation was expected to improve a little in April as warmer weather arrived but would then deteriorate when consumers began switching on their air conditioners. TEPCO anticipated a peak demand of about 64.5 GW in 2003, with only 55 GW of capacity available to meet it, that is, a shortage of about 15%.

Starting in late 2002, TEPCO took many measures to obtain capacity to meet the summer peak. It began negotiating for additional supplies from neighbouring utilities. These transfers were limited, however, for two reasons. First, there is relatively little transmission capacity between Japanese utilities. TEPCO, along with all utilities to the east of it, operates at 50 Hz. The largest utilities (in the western region) operate at 60 Hz, so transfers are technically impossible except from a few plants able to supply power at both frequencies or able to convert power from one frequency to another. Less than 1 GW could be obtained from the utilities in the 60 Hz region through these plants. Next, TEPCO began advancing the start date of new thermal power plants and adjusting schedules for maintenance on existing plants. In addition, it re-started mothballed thermal power plants[5]. These measures still did not provide sufficient capacity because many of the plants had uncertain reliability since the old plants had not been operated recently and new ones had not been thoroughly commissioned.

In January 2003, TEPCO began encouraging consumers to conserve electricity. The government also began its own campaign. Media efforts were gently urging consumers to use electricity wisely but not specifying what conservation measures should be taken.

The scope of the crisis became clearer in the early spring when TEPCO announced that all its nuclear power plants would be closed before the end of April. With the looming threat of power cuts, manufacturers began reviewing their production schedules. Toshiba, Hitachi and Kobe Steel created plans to increase production at night or on weekends when electricity demand is lower. Some of these measures were in response to TEPCO's moves to adjust load contracts with its largest customers.

Other factories sought to cease production entirely during the critical period – late July – by scheduling all holidays for that time. Kirin and Asahi Breweries studied the possibility of increasing production at plants outside TEPCO's grid. Honda Motor considered changing its production schedule to

5 *This rapid re-starting of oil-fired power plants created an unexpected demand for oil (IEA, 2003).*

boost output from September onwards if power cutbacks were required in July or August. Nissan Motor drew up a blueprint to use less electricity in areas that would least affect production (Rahman, 2003). Other companies switched off air conditioners or set them at a higher temperature. Some companies, such as NEC, went so far as to carry out drills to prepare staff for power cuts. The extent to which these plans were actually implemented was not determined.

TEPCO gradually shifted to more specific requests for conservation, describing the kinds of measures to take. In May the government expressed further concern for the situation and urged greater conservation efforts. TEPCO staff personally visited thousands of customers and urged them to conserve electricity. Concurrently, METI formed an “energy-saving team” of around 1 350 women from the Kanto region, headed by the popular young actress Mayu Tsuruta. The team visited local companies and shops and asked them to co-operate in energy-saving measures. These women had visited a total of 13 500 premises by the end of May (Kimura, 2003).

In June, TEPCO started a Web site where it displayed demand and available capacity in real-time and updated every hour. For the first time, the utility’s load curve was made public. TEPCO offered daily television information about the electricity situation (see Figure 2-11).

*Figure 2-11*

*A TEPCO Spokesperson Explains the Electricity Situation*

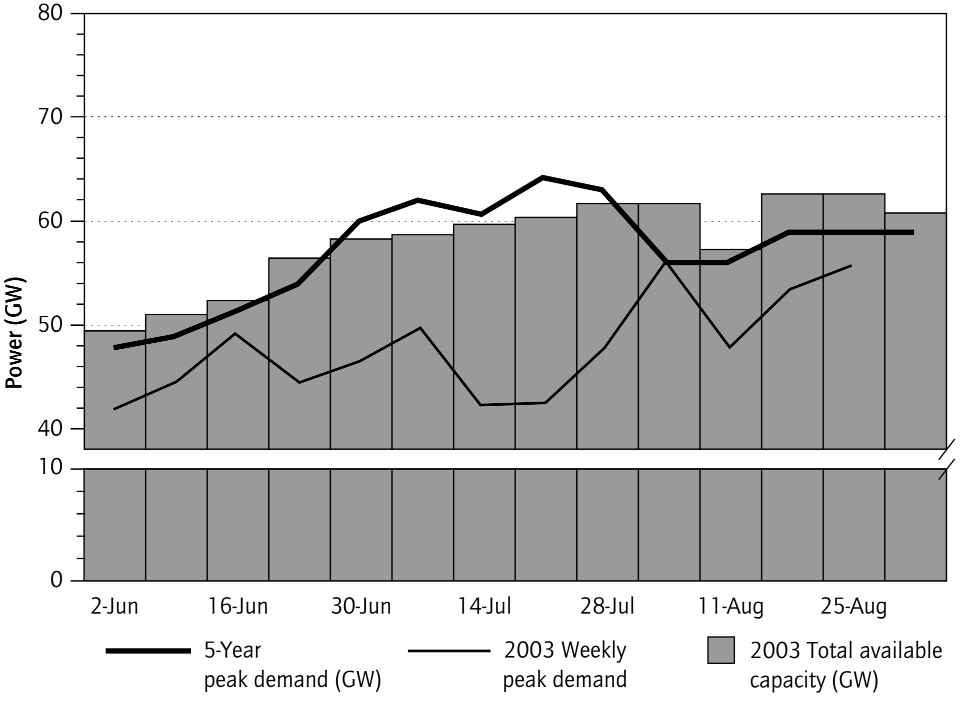

*Source: TEPCO.*

In fact, the critical month of July proved to be among the coolest in history. Electricity demand was far below expectations. Electricity demand never exceeded about 57 GW during the summer, significantly less than the 2001 peak of 64 GW. At the end of July, TEPCO brought back on line another mothballed fossil-fuel power plant and it announced the end of the crisis for the time-being. In early September, TEPCO declared the crisis had ended.

TEPCO estimated that it achieved roughly 1.4 GW savings through adjustments in its load contracts with industrial and other large customers and 1.3 GW in other conservation (TEPCO, 2003). The combined savings, 2.7 GW, represents about 4.5% of TEPCO's peak demand (at 60 GW).

*Figure 2-12*

*Supply and Demand for Tokyo Electric Power Company During Summer 2003*




*Source: Adapted from TEPCO, 2003.*

A detailed assessment of the conservation response is difficult because the savings are obscured by the effects of the extraordinarily cool summer. Some evidence suggests that TEPCO's programs were more successful than estimated. A survey conducted by the Center for Consumer Studies at Dentsu Inc. (the largest public relations firm in Japan) found high levels of reported conservation actions (Dentsu Inc., 2003). According to the survey, eight in ten respondents claimed to have taken measures to reduce electricity use. Dimming the lights was the most popular method (about 77% of respondents), but almost 60% claimed to have raised the thermostat settings on their air conditioners and almost 50% claimed to have reduced the operating hours of their air conditioners. Participation rates appear to be higher than those observed in California (see Figure 2-3). TEPCO was also successful in enlisting conservation actions from the industrial and commercial sectors. The number of respondents reducing air conditioning use – if it is accurate and not simply a consequence of the unusually cool summer – may have translated into more than 1.3 GW savings.

These savings may have prevented blackouts. Figure 2-12 shows the course of the electricity supply and demand during the summer of 2003. For most weeks, TEPCO had more than adequate capacity to meet demand. However, for the week of 16 June, the energy savings roughly equalled the difference between actual demand and available capacity; without conservation, a blackout may have occurred.

## Vignettes Conclusions

The vignettes show the diversity in the origins of electricity shortfalls: they occurred in tightly regulated and liberalised markets, in winter peaking and summer peaking systems, and in both large and small utilities. No particular generating technology appears immune from supply shortfalls. Size of the utility is no assurance of stability, either. Shortfalls occurred during periods of peak demand and in total electricity use.

Nevertheless, these events have common features. The parameters of the shortfalls – notably the size and duration – changed as the crisis unfolded. Droughts appear first as a slight downturn in rainfall or safety problems appear first at one plant and then spread to others. Chain reactions are also possible. The Arizona shortfall demonstrated how one technical failure stressed the system, which then created a second and third failure. Another common – but not universal – feature is the intensely political nature of electricity shortfalls. A politician's career is often at stake by the way he or she deals with the crisis.

Several shortfalls appear to have been a convergence of two or more problems. California's electricity crisis is often attributed to "the perfect storm", that is, a combination of bungled de-regulation, drought, a shortage of natural gas, accumulated maintenance problems, manipulation of the market by certain players, and rapidly rising demand in neighbouring regions with traditional surpluses. Even Tokyo's crisis was a combination of irregularities in maintenance, political differences about the role of nuclear power plants, and Tokyo's high demand for electricity during the summer. These unfortunate combinations of events are easy to identify in retrospect but difficult to forecast with confidence.

Weather plays a key role in the electricity shortfalls. On the supply side, droughts and floods are often the proximate causes of shortfalls because they reduce generating capacity. These shortfalls typically first appear during periods of peak demand in the winter or summer. On the demand side, unusually severe cold waves and heat waves increase demand for heating or cooling. These episodes, with or without supply difficulties, can cause shortfalls.

## Electricity Savings

The estimated savings of the programmes are listed in Table 2-9. These estimates were compiled from local studies or are IEA estimates. Regions achieved savings of 0.5 to 20%. These savings were obtained after as little as three days after the conservation campaign began and they persisted for anywhere from a few hours to several months. Some programmes continued to save electricity even after the crisis had ended. In most cases, the programmes avoided significant blackouts entirely.

These estimates are uncertain because it is impossible to measure energy savings directly; instead, one must calculate the difference in consumption between the crisis period and a base period. Nearly all the estimates include an adjustment for differences in weather between the crisis and base periods. These adjustments are based on historical data and are usually accurate in the typical range of weather occurrences. Adjustments for extreme weather, however, have greater uncertainty because there are less data for rare events. So the estimates of savings during Sweden's cold Monday or Tokyo's cool summer have greater uncertainty than events occurring in normal temperature ranges. Regions with diverse climates, such as California, France and New Zealand need to use weighted averages (though an unchanged weighted average can still conceal large local variations). When the shortfall spans several months, then corrections for economic activity also need to be included. In most cases, the cumulative effect of these adjustments is relatively small; the gross energy consumption profiles displayed in the vignettes are convincing on their own.

*Table 2-9*

*Summary of Estimated Electricity Savings*

| Location | Savings (%) | Approximate Duration | Approximate Advance Warning |
|---|---|---|---|
| Brazil | 20 | 10 months | 5 months |
| Ontario | 17* | 2 weeks | none |
| California | 14* | 9 months | 12 months |
| New Zealand | | | |
| 2001 | 10 | 3 months | 1 month |
| 2003 | 10 | 6 weeks | 1 month |
| Norway | 8 | 4 months | 2 months |
| Arizona | 6 | 6 weeks | 2 days |
| Tokyo | 4.5 | 3 months | 8 months |
| Sweden | 4 | 1 day | 3 days |
| Europe-France (August 2003) | 0.5* | 3 weeks | 1 day |

* *With significant blackouts or involuntary curtailments*

The impact and cost-effectiveness of these programmes employed to achieve these savings are described in Chapter 5.

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# A STRATEGY TO SAVE ELECTRICITY QUICKLY

A government, utility or responsible authority 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. This section describes the steps to establish an electricity conservation strategy and the specific measures to support that strategy.

The major steps in developing a strategy to quickly save electricity include:

- Identify the kind of electricity shortfall, e.g. energy or capacity (what kind of electricity needs to be saved, peak power or base load?).
- Estimate the probable duration of the shortfall (How long will the shortfall last?).
- Establish a breakdown of energy consumption by end-use during the shortfall period (Who and what is using the electricity?).
- Develop a list of measures and energy savings and rank them by appropriate criteria (Which measures are available and what should be done first?).

In practice, political exigencies may necessitate bypassing – or giving superficial attention to – some of these steps. Those persons responsible for *preparing* emergency plans (in anticipation of crises) would certainly be able to follow this procedure.

## Identify the Kind of Electricity Shortfall

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.

Many conservation programmes 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 programmes 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.

## Estimate the Probable Duration of the Shortfall

The crises covered in this book are typically shortfalls with reasonably clear endings. For example, the shortfall ends when the seasonal rains return, the heat wave abates, or a power plant is restored to operation[6]. The Arizona crisis ended when the transformer was delivered and installed; meanwhile, the public could observe progress because television stations carried almost daily status reports of how the huge piece of equipment was slowly transported across the desert. Chronic supply problems or uncertain directions of market reforms may not have such clear end points. The approaches described in *Saving Electricity in a Hurry* apply to both situations but probably are most suitable for shortfalls persisting for one day to about one year.

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[7]. In general, it will be possible to rely more on financial incentives and technological improvements for crises with longer advance warning or duration.

## Establish a Breakdown of Energy Consumption by End-use During the Shortfall Period

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 kinds of data collection. 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.

[6] *Unusual weather events – drought, heat waves, cold waves – eventually end, but the aspect that often causes a crisis (their severity) may also be linked to their exceptional duration.*

[7] *Droughts – even those that are supposed to happen once every 50 years – have the unfortunate habit of happening again in the following year (or soon afterwards). Both New Zealand and Norway experienced this phenomenon. Ideally, the possibility of a reccurrence also should shape the response but, in practice, nobody has the luxury of planning beyond the present crisis.*

Most of these activities take years to perform, compile and evaluate so they cannot be done when confronted with a crisis. Ideally data collection will be a regular activity. In California, utilities (in co-operation with the State Energy Commission) regularly conduct load surveys of hundreds of customers. This, combined with appliance saturation surveys, gave California planners a clear picture of the most important end-uses of electricity[8]. The shortfall in Norway (during the winter) was very different and showed how each country's situation (both with respect to consumption and detailed data) is unique. In practice, reliable, current information will be scarce and one must begin with a simple breakdown of electricity use by sector and some back-of-the-envelope estimates[9].

Some customers have the ability to switch boilers (and other equipment) from electricity to oil, gas or wood. These users provide an important opportunity for electricity conservation but the combined potential is rarely tabulated. Norwegian utilities often give discounted rates to customers who have the ability to switch fuel (and will do so when requested), so the tabulation is relatively simple.

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.

## Can Electricity Prices Rise Quickly and for whom?

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 programmes to exploit this price elasticity. These programmes also provide clues as to how other customer categories will respond to higher prices.

Unfortunately, for many groups of customers, there exist barriers to quickly raising electricity prices. These barriers (which are discussed in Chapter 6 "The Role of Prices") are caused by regulatory delays, technical barriers

8 *Ironically, in anticipation of market liberalisation, some of these information collection activities ceased or became proprietary in the years leading up to California's electricity crisis.*

9 *Liberalisation of electricity markets makes even a "simple" sectoral breakdown more difficult to establish because there are more suppliers, with differences in definitions of customers, and proprietary claims on data.*

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.

## Develop a Ranked List of Measures

Hundreds of electricity conservation measures exist. They rely on behavioural 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 behavioural and technical changes.
- Staff and money available to implement programmes.

This is the most difficult part of the process because it requires input from many different sources. Furthermore, the ranking requires subjective judgments, especially with respect to estimating the impact of campaigns to change consumer behaviour. 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.

## The Next Steps

Every electricity shortfall is unique and, beyond these initial steps, those unique features will dominate the shaping of an effective strategy. Translating a list of conservation measures into electricity savings is the crux of saving electricity in a hurry; it will be discussed in detail in Chapter 4, "Measures to Save Electricity Quickly ".

## The Final Step: the End of the Shortfall

Many shortfalls have a clear termination, for example, when the drought ends, the heat wave abates, or a key power plant is restored to operation. It is tempting to declare an end to the crisis as soon as this happens. (Politicians like to do this.) It is an excellent opportunity to publicly thank customers for their participation. Other shortfalls have ambiguous terminations, especially when the shortfall had several causes. In these cases a more cautious strategy may be justified to prevent an immediate (and embarrassing) recurrence. While thanking customers for their sacrifices, the authorities also want them to continue their newly-learned behaviours. One veteran recommended, “Never declare victory” (McGuire, 2003) but simply make a transition to traditional energy efficiency programmes.

## Saving Electricity Slowly

Most governments (and many utilities) have energy efficiency programmes already under way. These programmes target specific sectors, seasons and times of the day. The programmes are justified because of their cost-effectiveness to consumers, benefits to load management, equity considerations, and energy security. Examples include:

- Minimum efficiency levels in building codes.
- Minimum appliance efficiency standards, energy labels, and rebates for purchase of efficient appliances.
- Load management programmes, including time-of-use tariffs, interruptible rates, etc.
- Weatherisation programmes.
- General information campaigns to encourage energy conservation.

These programmes “save electricity slowly”; that is, they rely on gradual replacement of buildings and appliances with efficient products and other actions taken as part of normal business. Saving electricity “slowly” does not mean that it is an inferior programme – indeed, “slow” conservation will generally be cheaper than actions to save electricity quickly – but these programmes do not specifically address a temporary electricity shortfall.

The distinction between saving electricity in a hurry and saving electricity slowly is sometimes only a matter of the intensity of the programme. The “hurry” programmes will seek to transform the market sooner than the “slow” programmes. This may be achieved through accelerated replacement of equipment, rebates, saturation advertising and other crash promotion programmes. Saving electricity in a hurry relies more heavily on measures that are *reversible*. In other words, people may revert to their former habits once the crisis has passed (and this is acceptable). Technical efficiency improvements and other save-electricity-slowly policies will play a larger role the longer the advance warning of the shortage or the longer the shortage is expected to persist.

The infrastructure established by programmes to save electricity slowly is valuable because it can be used to "ramp-up" and support programmes to save electricity quickly. A crisis programme can be launched and put into operation more quickly by borrowing knowledgeable staff, offices, mailing lists, contractor networks and other expertise. In California, for example, it was possible to launch an aggressive programme to offer rebates for efficient appliances by rapidly expanding an existing utility rebate programme (about tenfold). Utilities in Arizona were able to rapidly contact key customers by e-mail from lists they had assembled from traditional programmes. The value of the saving electricity slowly programmes must not be ignored because establishing relationships with retail networks, mailing lists, and familiarity with markets requires months or even years.

## Summary of Strategies

Every electricity shortfall is unique but the initial steps to prepare to deal with them are similar. It is vital to understand the dimensions of the shortage – the amount of shortfall, duration and timing – to be able to develop programmes large enough to deliver the necessary savings. A broad list of possible conservation measures – along with their potential savings - is essential to identify those measures likely to save electricity. Higher electricity prices should be the first measure on the list, but only if they can be applied and consumers will actually be in a position to respond to them. Finally, the crisis demanding to save electricity quickly may require co-ordination with programmes to save electricity slowly.

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# MEASURES TO SAVE ELECTRICITY QUICKLY

Somebody needs to take an action in order to reduce electricity use. This chapter describes the technical aspects of those actions. A later chapter (Chapter 5) describes how to mobilise energy consumers to adopt these measures.

Buildings are typically the largest consumers of electricity – nearly 60% of total use in developed countries (IEA, 2004a). For this reason, buildings are the most important target for electricity savings during a shortfall. The goal is to quickly cut as much as possible a building's electricity use while maintaining the health, comfort and productivity of its occupants until the crisis has passed. This goal differs significantly from traditional conservation activities that seek to permanently lower energy use and are implemented at a more leisurely pace and without sacrificing comfort. Similarly, most building science research has focused on effective technologies to "save electricity slowly" which might occur during design, construction or through retrofits, rather than temporary savings implemented quickly.

Most buildings are designed, constructed and operated with certain expectations about the levels of services, i.e. desired interior temperatures, humidity, illumination, ventilation, operation of elevators, and so on. A modification to cut electricity use 20-60% is a major perturbation in normal operating conditions. Some of the consequences are predictable through such tools as building energy simulation models but others are too complex to model or easily foresee. In many cases, a holistic perspective is needed to predict the implications of the perturbation on energy use, indoor environment and building materials.

There is a wide range of measures available to save electricity quickly. The measures most quickly implemented typically require the energy consumer 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 operations. Such measures are attractive because they can be implemented almost immediately and cost almost nothing. On the other hand, changes in behaviour or operating practices may be difficult to sustain.

Alternatively, efficiency improvements can be made to the energy-using equipment. These improvements result in the consumers receiving the same services but with less electricity consumed. (These are sometimes called "technical fixes".) Efficiency improvements include adding insulation, replacing appliances, upgrading efficiency of motors, and eliminating leaks in heating, cooling or compressed air systems. The end-user – the consumer, employee, customer or occupant – may not even be aware that improvements have been made. Efficiency improvements require investments that take time to implement but once made lead to sustained lower energy use.

In practice, many measures lay between pure investments in increasing efficiency and changes in operations and behaviour. Even a simple modification of an industrial process, for example, requires careful preparation, down-time, observation, and possibly new monitoring equipment. The installation of some efficient lighting systems – especially compact fluorescent lights – results in different illumination characteristics which may be perceived as a reduction in services. The purpose of this chapter is to illustrate the spectrum of measures available, covering both behavioural changes and technical improvements.

## Operational Changes: "Switch it off"

The average person switches electric devices on and off hundreds of times a day[10]. These devices include lights, TVs, computers, stereo equipment, elevators, copiers, power tools, microwave ovens, and so on. Many of these actions are nearly instinctive and do not even correspond to a direct need; that is, switching on a light even though ambient conditions are adequate or opening a refrigerator before deciding what to remove. In a building, custodians, secretaries and other staff often switch on lights, copiers, printers, coffee-makers, fans, etc. as part of their daily routine before anybody actually needs them[11]. Perhaps more devices stay on even after the need for their services has actually ended. These are all opportunities to save electricity merely by delaying switching on until the need arises and switching off after use. Annotated lists of operational changes leading to energy savings for the major sectors are presented in the tables below. These lists are not in any way comprehensive and the annotations are intended to expose unique aspects of each measure.

[10] *People have a poor sense of this number. For the next hour, count the number of things that you switch on or off. Try to distinguish between those that you explicitly switch (such as a room light) and devices that switch on automatically as result of a sensor or timer (such as the light inside the refrigerator that switches on when you open the refrigerator). In this way it is possible to appreciate the importance of behaviour and energy use. At the same time, many activities with the highest energy consumption are invisible or operate independently of behaviour. Any device, for example, controlled by a thermostat or clock will not be directly affected by these actions.*

[11] *And, in some cases, nobody uses these devices all day.*

## Operational Changes to Conserve Energy in the Residential Sector

The residential sector is typically the most important target of conservation campaigns. This is only natural because the residential sector consumes so much electricity – about one third of total electricity use in developed countries (IEA, 2004b) – and because so many measures are available. In addition, the same person receives the message, carries out the measure, and experiences the consequences. Table 4-1 lists some of the most frequently recommended operational changes to save electricity in homes. They are listed in no particular order because the actual savings are heavily dependent on local conditions.

Small, almost inconsequential differences in behaviour can lead to large differences in energy use (and potential savings). For example, hand dishwashing habits were closely examined in a recent European study (Stamminger, 2004). Energy consumption for the same group of dishes ranged from about 1 to 12 kWh depending on the person. The study was able to identify three distinct personalities: the super dishwasher, the economiser, and the carefree dishwasher. Curiously, the cleanliness of the dishes bore no correlation to the personality. The study also compared groups from different countries. On average, the test-washers from Germany and the United Kingdom used significantly less energy and water than their Spanish and Turkish counterparts. (However, the Spanish were the ones who got their dishes cleanest of all.)

Many of the measures target standby power use (IEA, 2001). 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 not doing anything. It is an attractive operational measure because consumers easily understand the waste and they are not intimidated by unplugging most appliances.

## Operational Changes in Commercial Buildings

The major uses of electricity in commercial buildings are lighting, ventilation, cooling and office equipment (personal computers, displays, etc.), so these end-uses are the primary targets for conservation actions. Commercial buildings also contribute disproportionately to summer peak demand. The overall goal is to maintain productivity of staff, sales of goods, customer service or whatever is the purpose of activities in the building. Some common measures are listed in Table 4-2.

Table 4-1

## *Measures to Reduce Residential Electricity Use Quickly through Operational Changes*

| Measure | Comments and Examples |
|---|---|
| Switch off unneeded lights inside home | This measure can start immediately and "signals" a commitment to neighbours and friends. Actual savings may be small. In New Zealand, citizens were recommended to darken the rest of their homes while watching TV. |
| Switch off computers and peripherals when not deliberately logged on | Computers and their peripherals can easily draw 500 watts when all devices are switched on. A large portion of this can be eliminated even if modem and CPU must remain switched on to maintain a network connection. In California, customers were urged to switch off all computers not actually in use. |
| Unplug video and audio equipment | An audio/video entertainment centre may draw 25 watts even when switched off. New Zealand urged consumers to switch them off at the outlet. |
| Take shorter showers and fewer baths | The electricity needed to sustain a moderate-flow shower averages over 10 kW and baths consume even more energy. This conservation measure applies only where water is heated electrically. |
| Practice more efficient dishwashing | Use less hot water while hand-washing dishes. Rely more on an automatic dishwasher which (when full) uses less energy than hand-washing. |
| Raise/lower indoor temperatures | Warmer indoor temperatures in the summer and cooler temperatures in the winter cut electricity use by several percent (or more). This measure applies only where cooling and heating are done electrically. |
| Switch off outside decorative lighting and reduce "security" lighting | Outside lighting for decoration (including Christmas lights) may have a combined power of several hundred watts operating continuously or for large parts of evenings. If controlled by a time clock, their operating schedule can be restricted or lights can be switched off. |
| Lower water heater storage tank temperature | In homes with electric resistance storage heaters, lowering the storage temperature can cut standby losses by 100 kWh per year (or more). This may result in more occasions when the tank runs out of hot water. |

*Table 4-1 (continued)*

| Measure | Comments and Examples |
|---|---|
| Unplug miscellaneous equipment with standby except when being used | In homes with more than two televisions, one unit is likely to be used only rarely. Many small devices – especially those with external power supplies – draw power even when switched off. Each charger draws 0.5 to 2 watt. Chargers for mobile phones, portable tools, small radios, etc., are all candidates for unplugging. This measure requires constant vigilance. |
| Shorten pool filter pump cycles | Swimming pools require filter pumps (0.5 to 2 kW) operating several hours a day. Cycle time can often be shortened without sacrificing sanitary conditions. Owners may need to request the pool maintenance contractor to make this adjustment. |
| Unplug hot tubs | Most hot tubs and spas are electrically heated and consume 2 000 to 6 000 kWh/year. California urged people to unplug them for the duration of the crisis. |
| Use alternative fuels for heating and cooking | Some homes have back-up heating systems relying on wood or oil. Norway and New Zealand urged consumers to increase their use during the crises. Others can switch from microwave ovens to conventional gas stoves. |
| Unplug waterbed heater | In some regions of the United States nearly 10% of homes have heated waterbeds, each consuming 500 to 1 000 kWh/year. During the summer these can be unplugged (though an insulation pad may be needed). |
| Practice more efficient clothes washing | New detergents make it possible to wash clothes with much less hot water (or none if the water is soft, as in Japan). Californians were urged to hang their wet laundry rather than use their electric dryers, saving as much as 1 000 kWh/year. |
| Unplug freezer or second refrigerator | Brazilians were urged to unplug their freezers and Californians were urged to abandon their second (or third) refrigerators. A refrigerator or freezer draws 400 to 1 000 kWh/year. |
| Correctly regulate hot water circulation pump for boiler | In France, it was found that correctly regulating the boiler so that the circulation pump is controlled by the ambient thermostat reduced the boiler's electricity consumption by a factor of 3.6, producing an average energy saving per household of 227 kWh/year. This change required about five minutes to perform. |
| Dry clothes on clothes line rather than with clothes dryer | Many laundry areas are no longer configured for convenient line-drying. |

*Table 4-2*

## *Measures to Reduce Commercial Building Electricity Use Quickly through Operational Changes*

| Measure | Comments and Examples |
|---|---|
| Raise/lower indoor temperatures and shorten operating hours | This is already standard practice in many buildings; the difference here is that the temperature adjustments are much larger, and the restrictions in operating hours more severe. There are also opportunities to "pre-cool" buildings to minimize peak demand. |
| Reduce indoor lighting levels | This includes both de-lamping and manual operation of switches. |
| Restrict office equipment use | This measure will be perceived as greatly inconvenient if not implemented thoughtfully and with approval of occupants. |
| Enable power management features on all computers and related equipment | Nearly all displays and copiers already have Energy Star sleep features and can be configured to power down on their own with little inconvenience. Computers are more difficult to configure and may require close co-ordination with company's IT staff. |
| Shift computer back-ups to day-time and shut down all possible computers | Information Technology (IT) staff prefer to perform back-ups and maintenance during the night; however, higher-bandwidth connections and hardware have made day-time back-ups less inconvenient. Many companies already perform backups during lunch hour. |
| Consolidate servers and shut down unneeded equipment | Studies in Switzerland and Japan have shown that consolidation in servers is technically feasible. The consolidation saves electricity but saves more in avoided purchase and maintenance costs. |
| Reduce elevator and escalator service and speed | This measure was encouraged in Japan and California and linked to slogans like "walk up one floor and down two floors". Some new escalators switch themselves off when not in use and speeds of elevators can be automatically varied depending on the demand. |
| Reduce ventilation rates (and amount of fresh air) | Potentially an important opportunity to cut energy use, but adjustments to ventilation systems can have unexpected consequences. |
| Cut outside display lighting | Symbolism is important. MacDonalds in California co-operated by switching off its "golden arches". In Japan, the Tokyo Tower's decorative lighting was switched off during the crisis. |
| Reduce outside "security" lighting | There is no evidence that crime increased as a result of reduced security lighting. |
| Switch off unneeded equipment | One university discovered laboratory vacuum pumps that had been running over a decade for no apparent reason. |
| Patrol building to switch off all unnecessary lighting and equipment | Equipment that has already been switched off is habitually switched on again and then users forget to switch it off. The University of Cardiff in the United Kingdom found that vigilance was essential to cut campus power use. |
| Schedule whole company to take vacation and shut down all but essential operations | Canadians in Ontario did that in government offices. Beijing forced over 6 000 enterprises to take week-long "vacations" during the period of peak power demand. |

People responsible for these measures fall into three broad categories: maintenance and operations staff, administrators, and all employees. The custodial staff must change air temperatures, ventilation rates and other aspects related to building services. Computer technicians will be needed to change times of computer backups or consolidate servers. Administrators must make decisions regarding overall operations, scheduling holidays, etc. But all employees are responsible for hundreds of smaller actions, such as switching off personal computer equipment or nearby lights. These distinctions become important when planning the campaign to cut electricity use quickly.

A significant amount of office equipment remains switched on during the night. A survey of eleven offices in San Francisco and Washington D.C. found that only 44% of computers, 32% of monitors and 25% of printers were turned off at night (Webber *et al.*, 2001). It requires a combination of education, some technical modifications and constant vigilance to increase rates of equipment shutdown.

Office servers deserve special attention. Oki Electric Industry Co. of Japan reorganised its internal computer systems with the goal of halving its current 3 400 office servers. Maintenance and updating requirements were the primary reason for the consolidation but the company also expects to reduce annual electricity consumption by 7.5 million kWh. Servers use electricity 24 hours a day. In addition, servers need to be kept at a constant temperature throughout the year to ensure stable performance, so the consolidation will also result in air conditioning savings. Oki's situation may be extreme in the number of units involved, but similar studies in Switzerland and Denmark have also shown large savings potential through server consolidation. Non-energy benefits may overwhelm the electricity savings but a crisis may be needed to overcome internal administrative obstacles.

Many of these measures can be implemented quickly. After the Ontario blackout, commercial electricity customers were asked to cut power demand immediately (Natural Resources Canada, 2003). Hudson's Bay Company – a chain of department stores – applied a combination of measures described in Table 4-2 literally hours after requests for cutbacks were broadcast. The chain achieved an average of 32% savings in its 103 Ontario sites. Some stores cut consumption by more than 50% in the week following the blackout. Thanks to a real-time tracking system, the Head Office was able to identify stores with insufficient cutbacks. Energy managers then met with merchandising managers to discuss methods of reducing unnecessary lighting levels and other conservation measures.

No single operational measure is likely to provide large savings but a collection of them will result in substantial savings. Hospitals and nursing homes were particularly hard hit by the Ontario blackout. One chain of hospitals/nursing homes increased the air temperature by 3°C in central chillers, urged staff to wear light clothing, switched off lights, closed curtains on sun-exposed windows, switched off computers (or put them into sleep mode), disconnected small appliances and encouraged staff to bring lunches that did not require heating. Outside the buildings and in parking lots, it switched off lights (offering escorts in dimmed parking areas). The hospital asked their patients to switch off their TVs between 3 p.m. and 8 p.m., and encouraged the "down two, up one" elevator philosophy (i.e. not using elevators unless travelling more than two floors down or more than one floor up). The chain saved an average of 12% during the week that followed the blackout. More cooling and ventilating savings would have been possible except that the windows were sealed and could not be opened to allow natural ventilation.

During the Tokyo electricity crisis, the Ministry of Economics Trade and Industry (METI) used its own headquarters as an example. The measures taken included:

- Set all thermostats (for air conditioning) to 28°C.
- Switch off all unnecessary lights, including 75% of lighting in corridors and entrance halls.
- During lunch break, turn off all lights in the Ministry except in those areas where they are necessary for work purposes.
- Reduce elevator operation by about 40% during regular hours and 50% during the lunch break.
- Encourage staff to use stairs to access nearby floors (two up, three down, etc.).

During the lunch break on 26 May 2003, a power-saving campaign was conducted throughout the Ministry and the impact measured. By turning off all lights, electrical office appliances and air conditioners, a saving of around 30% was achieved. Visitors to the METI buildings noted these conditions and it is not clear if these measures enjoyed wide support among METI staff.

## Operational Changes in Industry and Other Sectors

The goal for industry is to cut electricity use without sacrificing production output or quality. Factories must operate with even more sensitivity to time of use than commercial and residential customers. It is not always possible to maintain production when large cutbacks are required. For example, when the utility at Presque Isle, Michigan lost over 50% of its generating capacity, the mining processing facility was forced to shut down for six weeks until power was restored. Certainly, this is an extreme case: if smaller cut-backs are needed (and possibly with more advance warning), sufficient conservation measures are often feasible.

Industrial customers can take many measures similar to those found in commercial buildings; indeed, many factories contain large areas devoted to office activities. But industries also have savings opportunities in specific processes. Improved housekeeping and greater vigilance can often yield immediate savings. Some examples are described in Table 4-3. There is considerable overlap among housekeeping, routine maintenance and retrofitting.

A unique option for industrial customers with long-term, fixed-price, electricity contracts is to close down operations altogether and re-sell the electricity on the spot market. If the price differential is large enough (and the consumption large enough) the profits made through re-sale will exceed profits made through normal operation. Electricity-intensive industries (aluminium-smelting and other production based on electrolytic operations) in New Zealand, Norway, and the US Pacific Northwest (adjoining California) all closed facilities in order to re-sell electricity. The potential electricity savings are huge. The aluminium smelters in the Pacific Northwest ceased production and freed-up 5 GW of capacity for use by other consumers. (This single action probably prevented California from experiencing a much worse crisis.)

During a crisis, government operations are nearly always requested to save more than the public as a whole. Table 4-4 lists some measures available to governments. The operational measures closely resemble those for commercial buildings because so much of a government's energy use is in commercial buildings. The unique aspects of government operations are in water pumping, sewage treatment and street lighting. Housekeeping measures often yield surprisingly high savings but they need a crisis to accelerate action.

Table 4-3

*Measures to Reduce Industrial Electricity Use Quickly through Operational Changes*

| Measure | Comments |
|---|---|
| Implement measures to conserve electricity in commercial buildings where appropriate | Large parts of many factories closely resemble commercial buildings. |
| Shift production to off-peak periods | Some breweries in Tokyo re-scheduled shifts to minimise demand during peak periods. |
| Eliminate leaks in pressurised air systems | Pressurised air is responsible for 7% of industrial electricity use in Germany, equal to the consumption of the entire German train network (Agricola and Radgen, 2003). Most systems are very leaky and waste much of the energy used to pressurise the system (Rosenberg, 2002). California supported inspections and tune-ups of compressed air facilities in factories. |
| Replace belt drives on motor systems | Friction losses in motor belts represent up to a 10% loss in motor output (Nadel et al., 2002). Cogged V-belts can halve these losses and are easily retrofitted to many motor systems. They cost 20-30% more than standard V-belts, but their extra cost is recovered over a few thousand operating hours. |
| Schedule mandatory vacations and factory shut-downs during critical period of shortage | Many factories in the Tokyo area elected to shut down production entirely during the period of peak summer electrical demand rather than stagger vacations through the summer and operate at reduced output. |
| Shift production to factories outside of crisis area | At least one brewery and one electronics company in Tokyo planned to shift operations to outside Tokyo during the critical period. |
| Switch fuel from electric heating to fuel heating | Many small commercial boilers have dual-fuel capability and can be switched relatively quickly; however, the conversion may be constrained by air pollution regulations. |

Table 4-4

*Operational Measures to Reduce Municipal Electricity Use Quickly through Operational Changes*

| Measure | Comments |
|---|---|
| Implement all measures to conserve electricity in commercial buildings | A large fraction of municipal electricity use is in commercial buildings. |
| Switch off alternating street lights | This may be limited by the design of circuits. |
| Shift municipal pumping for water and sewage to off-peak | Many municipal operations are not even aware of peak electricity consumption and opportunities to shift to off-peak. Tokyo avoided operating its water filtration plants between 16:00 and 19:00. |
| Switch traffic signals to flashing during low-traffic periods. | Traffic signals draw 60-130 watts and contain often more than 12 lights; by making them flash, power consumption can be cut by more than half. |
| Reduce outside lighting. | Lighting levels in municipal facilities, such as stadiums and parking areas can be reduced and the operating hours shortened. Security and safety may be a problem. |

## Technical Fixes

Technical modifications to reduce electricity use can be an attractive strategy to reduce electricity demand. These are generally familiar technologies that are cost-effective or pursued through traditional programmes to save electricity slowly. The largest difference is that the rate of implementation is greatly accelerated during a crisis. There are three general technological approaches:

- Retrofitting or adjusting existing equipment to make them more efficient (or less wasteful).
- Replacing inefficient equipment with more efficient models.
- Switching to alternative fuels or energy sources.

In practice, one, two or all these methods might be applied to a single situation, but it is easier to describe them separately. A complete list of technical measures is beyond the scope of this book; instead, selected technical fixes are described below in order to convey the diversity of measures available. Each measure, however, has an implied chain of materials, tools, labour and expertise supporting it; if those are not immediately available, then the measure is unsuitable[12].

## Retrofits to Existing Equipment

One technical fix involves retrofitting or adjusting existing equipment to make it more efficient (or less wasteful). Lighting replacements have been the most frequently used retrofit. Replacing incandescent light bulbs with compact fluorescents was used in Brazil, California and New Zealand. Brazil distributed more than five million CFLs to poor people. California's cities replaced almost one million traffic signals with LED lamps. Other examples include adding insulation and tuning-up air conditioners. A partial list of retrofits is given in Table 4-5.

## Energy-saving Traffic Signals

California embarked on many crash electricity conservation programmes. Much of the activity focused on residential and commercial customers, so it is unusual to find a measure exclusively targeting municipal governments. It also illustrates how a programme can transform the market and generate even greater participation.

California has about 40 000 intersections with 1.8 million traffic lamps (U.S. Department of Energy, 2004). Each lamp draws 60-130 watts, so traffic signals contributed as much as 200 MW to peak demand.

Light emitting diode – LED – lights are a new alternative to traditional lights. Illumination from LEDs is exceptionally well matched to the needs of traffic signals. They also draw less than a quarter of the power of a traditional bulb depending on their colour. Maintenance costs are lower and they have a longer lifetime. Their low power consumption allows battery back-up to provide as much as two hours of service during power interruptions (which is a very useful feature when a power shortage is expected).

[12] *The fact that the shortfall is temporary opens up the possibility of new kinds of measures that would not ordinarily be acceptable for permanent operation because of additional maintenance, supervision or inconvenience.*

Table 4-5

*Retrofit Measures to Conserve Electricity*

| Measure | Comments |
|---|---|
| Replace incandescent lights with compact fluorescent (CFL) bulbs | Cuts power consumption by about two-thirds but it remains difficult to assure acceptable fitting, illumination levels and colour rendition. The supply chain needs to be transformed so that the consumer can easily obtain replacement when first CFL burns out. |
| Insulate building envelopes | Limited by building design, available labour supply, construction schedules, etc. More economic when co-ordinated with other improvements. |
| Install building management systems and improved controls and sensors | Norway made this a key part of its conservation programme. |
| Insulate water heater storage tanks | Reduces storage losses. Anti-convection valves will provide further savings but need a plumber. |
| Convert old roofs into "cool roofs" by applying reflective coating | Saves less if roof is already well-insulated and may save nothing during peak if AC is undersized. |
| Replace motors with more efficient units | Retrofits to motor systems can cut use 75% but require careful consideration of the application. |

As a result of California's electricity crisis, the state launched a crash programme to install LEDs in all traffic signals. The programme included grants, information and purchasing assistance. The state estimates that by early 2004, about half the lamps in California had been replaced by the LED type. The resulting energy saving – approximately 60 megawatts – was enough to power nearly 60 000 homes.

The programme also helped transform the market, leading to even lower costs. The Department of Transportation lists over ten pre-qualified suppliers of LED traffic lights that meet California specifications. Because of the greater demand, more manufacturers emerged. Prices decreased as the market became more competitive. Now that communities have gathered experience with the technology, they are purchasing them on their own initiative.

Energy savings are particularly easy to confirm because most traffic signals have their own attached kilowatt-meter. A recent study examined 55 LED conversion projects, most of which were in cities where multiple traffic signals were converted. The average success rate in meeting their cost savings expectations was 94%.

A second technical fix involves replacing older equipment with more efficient models. California aggressively encouraged consumers to replace older air conditioners, refrigerators, clothes washers and dishwashers with new units qualifying for the Energy Star endorsement of high efficiency.

Huge savings in individual homes are possible when all major appliances are replaced. This was demonstrated in a French metering campaign carried out in 20 households (Enertech, 2002). Each electrical end-use was metered for a year. Then all appliances were replaced by class A or B appliances of the same capacity/service or better, before being metered for another year. Electricity use dropped 40% in the second year. In Florida, researchers (Masiello et al., 2004) replaced existing air conditioners in several homes with new, high-efficiency units. The savings averaged about 50% with reductions to peak demand of 35-50%.

A similar study in Florida (Parker and Schrum, 1997) demonstrated that the electricity use for lighting could be cut by about half through replacement with new, efficient lighting fixtures. The same (or higher) level of illumination was provided.

Of course, the logistical and financial barriers to a complete replacement of all appliances or lights in a large group of homes, offices or factories are enormous, and it is unrealistic to expect that they could be undertaken during a brief electricity crisis. (One bottleneck during California's crisis was obtaining an adequate supply of high-efficiency appliances.) However, these studies demonstrate the technological savings potential with no change in lifestyle or behaviour. It should be considered one kind of limit.

## Fuel Switching

A third technical fix involves fuel switching. Electricity is often used to heat air or water, especially in the residential sector and in sparsely populated areas. There are numerous opportunities to burn wood, oil or natural gas directly to obtain the desired heat. Homeowners in Norway and New Zealand, for example, reverted to existing wood stoves and boilers for space and water heating. Fuel switching is an important electricity-savings measure because it removes the homes' largest electricity-consuming end-uses. The greatest benefits from fuel switching will generally occur during shortages caused by cold weather but some measures can also save summer peak power. For example, the Brazilians replaced in-line electric shower heaters with gas-fired units, thus saving about 3 kW electrical demand per unit.

Most of the other fuel-switching technologies cannot be easily or quickly brought into operation. Still, they can have large impacts during longer campaigns. If natural gas already reaches the customers, then gas-fired appliances –clothes dryers, stoves, water heaters, spa-heaters – can replace their counterparts relying on electric resistance heat. When fuel-switching is feasible, the electricity savings are likely to be greater than almost any other measure. For example, a residential electric water heater in North America consumes 3 000-5 000 kWh per year and replacing it with a gas unit totally eliminates this consumption (though creates a new gas consumption).

*Table 4-6*

*Fuel Switching Measures*

| Measure | Comments |
| --- | --- |
| Increased reliance on (or switching entirely to) wood fired boilers | Especially useful in winter-peaking countries such as Norway, New Zealand and Austria. |
| Replacing in-line electric water heaters with natural gas | This is an appliance unique to Brazil. |
| Replacing electric resistance water heaters with natural gas or oil-fired units | A lively fuel-switching market already exists (in both directions) for these appliances. |
| Replacing electric clothes dryers and stoves with natural gas-fired equipment | This can be easily accomplished only in homes where gas service already exists. |
| Solar water heating in place of electric resistance water heating | Large savings are possible but rapid deployment is difficult. |
| Photovoltaic electricity replacing mains electricity | Insignificant contribution today although may be politically necessary to gain support for other measures. |
| Use line-drying of clothes to substitute for electric clothes dryer | Requires space and cultural acceptance (or re-acceptance). |

Solar energy can replace electric energy in a few applications. The simplest is to use a clothes-line instead of a clothes dryer. When more time is available, a solar water heater can be installed. For mostly political reasons during the crisis, governments have created programmes to promote the installation of photovoltaic collectors (PVs). The electricity generated by a PV will indeed displace some grid electricity but the overall contribution of PV will generally be insignificant. A typical rooftop PV unit provides only a few hundred kWh per year.

## Daylight Saving Time

Even the clock can be harnessed to help during a truly economy-threatening electricity crisis (Prerau, 2005; California Energy Commission, 2000). Brazil shifted office and school hours so as to minimise electricity consumption. Several studies have shown that implementing Daylight Saving Time (DST) saves energy. The demand for electricity is directly connected to the daily cycle of living patterns. A significant fraction of residential electricity use is consumed while (and because) the occupants are home, especially lighting, heating and cooling, so its use depends on schedules controlled by clock time. By moving the clock ahead one hour, both the amount and timing of the electricity consumption change.

Britain exploited the energy saving aspects of Daylight Saving during World War II. Clocks were changed two hours ahead of GMT during the summer (which became known as Double Summer Time). The clocks also remained one hour ahead of GMT through the winter. In the 1970s the U.S. Department of Transportation estimated that Daylight Saving Time would cut the entire country's electricity usage by about 1%. In Japan, a shift to Daylight Saving Time was considered as a measure towards fulfilling its Kyoto Protocol emissions reductions. A more recent study in Japan estimated that Daylight Saving Time would cut that country's electricity use. Last year, Japan even experimented with Daylight Saving Time in the city of Sapporo (The Japan Times, 2004). However, a California study (California Energy Commission, 2001) estimated that implementation of double DST in the summer and single DST in the winter would result in marginal electricity savings. The peak impacts were less certain. Winter DST would probably reduce winter peak electricity use by 3.4% but Double Summer DST would save about 0.5%.

Nevertheless, representatives from California requested federal permission to modify Daylight Saving Time (Sherman, 2001). The proposed legislation, H.R. 704, the *Emergency Time Adjustment Authorization Act* would have allowed California and Pacific Time Zone states to use Daylight Saving Time as a means to conserve energy. This bill was merged with a larger package of energy legislation which was ultimately rejected by Congress.

## Folklore "Conservation" Measures that don't Save (Much) Energy

A special group of conservation measures falls into the "folklore" category; they are consistently recommended by utilities and government agencies yet save little or no electricity. Instead, the amount of electricity savings is not worth the acrimony and inconvenience. Some examples from North America are listed below.

**Refrigeration maintenance and operation.** Utilities in North America have long advocated several measures to conserve electricity use in refrigerators: clean the coils regularly, defrost (if it is not frost-free) and open the door less often. Some even advocate replacing worn gaskets. From a technical standpoint, these measures will surely conserve some electricity but, curiously, their energy savings appear to be very small and, in any event, have never been carefully documented (Meier *et al.*, 1993).

**Rely on clock thermostats to control heating and cooling systems.** Again, this is reasonable advice but it often backfires and leads to increased energy use. Studies in climates ranging from those dominated by air conditioning to those dominated by heating found that use of clock thermostats actually resulted in higher energy consumption. Researchers attributed this to the "set and forget" attitude that replaced a constant vigilance. (Nevertheless, properly set and maintained regulators in industrial situations should be encouraged.)

**Switch off elevators and escalators or strongly discourage their use.** These measures save electricity but cause resentment and user backlash if not properly introduced and explained. Careful management can often yield nearly the same savings with much fewer complaints.

**Saving the wrong fuel.** California consumers unintentionally devoted considerable effort to save natural gas rather than electricity. Part of the problem arose because two large utilities send a combined gas and electric monthly bill to consumers and it was difficult to isolate gas and electricity use.

One role of the authorities is to ensure that recommended conservation measures do actually save electricity. This can be accomplished through laboratory tests or household surveys.

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# MOBILISING CONSUMERS TO SAVE ELECTRICITY

## Introduction

Chapter 4 demonstrated that a wide variety of technical and behavioural measures are available to save electricity. However, somebody must implement them (and do it quickly). Ultimately, implementation is the consumer's responsibility. These consumers include homeowners, grocery store owners, breweries, factories, municipal governments and restaurants. This chapter deals with informing and motivating consumers to take actions that will quickly reduce electricity consumption. The chain of events needed to achieve actions is enumerated in Box 5-1.

**Box 5-1: The Chain of Events Necessary to Stimulate Consumer Actions**

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

1. Consumer learns that a shortfall exists.
2. Regardless of cause, the consumer recognises that measures to reduce electricity use must be taken.
3. Consumer recognises that his/her contribution will help mitigate the shortfall.
4. Consumer decides to reduce electricity use.
5. Consumer selects feasible measure from universe of alternatives.
6. Consumer selects measure(s) to implement.
7. Consumer arranges for implementation of measure (buys, hires contractor, studies operating manual for thermostat, etc.).
8. Consumer implements measure.
9. Electricity use declines (assuming measure actually works as intended).
10. The measure is repeated (if sustained consumer action is required).

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 only about 10% of all consumers will actually achieve electricity savings. An electricity conservation programme will not deliver savings if any of the steps described above have a low success rate.

## The Key Role of Mass Media

Mass media will be the chief tool for reaching consumers during an electricity crisis. No other tool can be as quickly mobilised and reach as many consumers as television, radio, newspapers and (increasingly) the Worldwide Web. California, for example, launched its information campaign and broadcast sophisticated appeals less than two weeks after funding was made available. The message conveyed by the media (and who will create it) is the subject of the following discussions.

Mobilising the consumers is fundamentally a marketing campaign, requiring many of the techniques used to introduce and sell detergent, cars or beer. Nearly every region with a long-term electricity shortfall covered here engaged a media consultant and an advertising agency to design and manage its campaign. California's strategy was perhaps the most carefully constructed and co-ordinated. Much of the description below is based on California's strategy, so some of these steps may be less relevant for shorter-term crises.

## Three Media Campaigns in Brazil, New Zealand and California

Successful conservation programmes have taken from mild to extraordinary steps to link the solution to the shortfall to direct customer behaviour. The range in incentives to achieve a specific electricity savings target is best illustrated in three residential programmes in New Zealand, California and Brazil. The principal difference was that New Zealand's programme was voluntary with limited rewards, California's programme was voluntary with explicit financial rewards, and Brazil's programme was mandatory.

At the beginning of New Zealand's 2001 shortfall, the government established the target because it calculated that blackouts could be avoided if everybody reduced their consumption 10% for ten weeks. Thus "10 for 10" became the goal. The government distributed advice on how to obtain those savings but gave no incentives towards more efficient equipment or reduced bills[13]. Overall electricity consumption declined after the programme began, including a roughly 8% average reduction by non-government customers. At

[13] *When the crisis was over, several retailers provided financial rewards to customers. For example, Meridian Energy distributed NZ$ 1 million to the top 10 000 electricity savers. Other firms made donations to charities in proportion to total customer savings. However, none of these rewards were announced in advance.*

the beginning of New Zealand's 2003 shortfall, the industry introduced the "Target 10" programme, with the goal of cutting use 10% for an unspecified period. It used similar procedures to inform the public. The goal was achieved only six weeks after the programme was announced.

In California, the "20/20" programme sought to reduce electricity use 20% from the previous year. (This goal could be easily determined because utility meters are read – and billed – every month and the utility keeps the last 13 months of utility bills on-line.) The state of California (through the utilities) gave successful customers a rebate based on the percentage reduction from the bill 12 months previously. Even greater rebates were available for those who saved more than 30% and more than 40%. Customers received a rebate each month in which they used less electricity compared to that month the year before.

This programme was developed hastily and the reasons for selecting 20% are unknown. Some organisations complained that the programme rewarded inefficient consumers and that rebates should have been based on a low absolute consumption. Nevertheless, this programme was relatively simple to explain and administer. The magnitude of electricity savings (and cost-effectiveness) from the 20/20 programme hinges on the number of "free riders", that is, the number of customers that cut electricity use 20% for non-programmatic, random, reasons.

## Explaining the Electricity Shortfall to Consumers

Consumers may not realise that a shortfall exists so education is the first task. When the shortfall is caused by a drought, cold wave, or fire at a key facility, for example, consumers can readily understand the cause and effect. More than likely, television news programmes or newspapers already displayed pictures of empty reservoirs or a damaged facility. A cold wave or heat wave is also easily understood because the consumers are also experiencing it. Still, the level of awareness may be insufficient for an adequate demand response and a concerted information campaign will still be needed. As the calculation in Box 5-1 explains, nearly 100% awareness is an essential starting point for broad-scale conservation.

Consumers may also not understand the type of electricity shortfall. The most important distinction is between energy and capacity shortfalls. Residents of California and Tokyo needed to learn the concept of peak power demand before they could effectively reduce it. This added yet another educational hurdle. Figure 5-1 is a Japanese advertisement, educating consumers about both the time when one should conserve and the measures that one could take.

**Figure 5-1**

*Japanese Government Advertisement Urging Consumers to Conserve Energy*


In other situations, the consumers may be sceptical that a shortfall actually exists. This was certainly the case in California where many consumers believed that the shortfall was artificially contrived by electricity suppliers – they were mostly right – and therefore felt no reason to conserve. "The energy situation was such that the media campaign had to enlist the help of the public without blaming or offending it." (FYP, 2001a). In New Zealand, there was some resistance to voluntary demand savings since some consumers blamed the crisis on market reforms. Tokyo faced a similar challenge due to the closure of nuclear power plants. Thus the authorities first needed to convince consumers that a shortage existed. In addition, California and Brazil lacked an entity with credibility because the utilities, the generators and some of regulatory agencies – had been mostly discredited in the run-up to the crisis. California and Brazil created new entities responsible for the conservation effort as a way of circumventing the credibility obstacle.

The consumers must next be convinced that conservation is a necessary element of the solution. Other elements may include installing new generation capacity, importing power from other regions, or fixing market problems, but these alone cannot immediately solve the shortfall.

California mounted a multi-media campaign, flooding televisions, newspapers, radio, outdoor advertisements and other outlets. On television, for example, over 50 advertisements per week were broadcast. By the end of the campaign's fourth week, an astounding 95% of the state's adult population had seen advertisements 25 times (Bender *et al.*, 2002). Special ads were also designed to appeal to unique cultural or ethnic groups (see Box 5-2). New Zealand employed many extremely short reminders on television – some lasted only five seconds – to reach the public.

Another level of the information campaign (both to inform people of the crisis and conservation measures) can target people through unconventional approaches. Box 5-3 lists some of the methods used in California to generate and sustain awareness. These approaches can have tremendous impact. For example, four million paper liners to food trays at McDonalds carried a conservation message (FYP, 2001b).

**Box 5-2: Targeting the Media Campaign**

In order to achieve the high levels of awareness, advertising must reach beyond the mainstream into smaller demographically and culturally distinct groups with a message appropriate to their norms and sensibilities:

- Maori (in New Zealand)
- Blacks
- Hispanics
- Asians (in California)
- Children
- College students
- Retired people

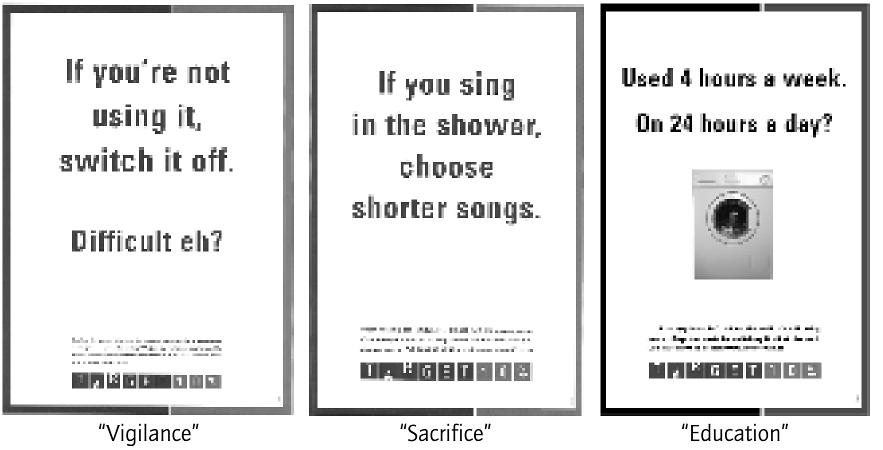
A vital element of the campaign is raising conservation to the level of a civic obligation, patriotism and, if possible, making it fashionable. The information campaigns in Tokyo, California, New Zealand and Brazil enlisted celebrities in their television and print advertisements to help achieve that goal. Elegant restaurants in Brazil re-adopted the romantic concept of dinner by candlelight, thereby making a highly visible statement and making progress towards meeting their mandatory 20% reduction. Cities in Brazil competed in the extent of electricity savings they achieved. By turning this sociological corner, a conservation campaign can take on a life of its own.

Humour played a vital role in media campaigns to introduce the public to the crisis and then to conserve electricity. Many conservation measures were explained or reinforced through jokes, puns and other humorous situations (depending on the media). Some examples from New Zealand are shown below. Norway, New Zealand, California and Brazil relied heavily on humour to engage the consumer. A humorous presentation avoids assigning blame, educates people, and increases recall rates. The Tokyo campaign relied more on serious exhortations by movie stars instead.

Three advertisements in New Zealand's Target 10% campaign illustrate three messages that the media campaigns need to convey (Figure 5-2.). The first message, "vigilance", reminds people to switch off equipment when not using it. Constant reminders (and requests for vigilance) to consumers are necessary to sustain energy savings based on behavioural change. The second message, "sacrifice", reminds people to take shorter showers. It reminds people that sacrifice may be needed to save energy. Finally, a third message (actually a goal) is "education". The goal of this advertisement is, first, to introduce consumers to the concept of standby power use of the washing machine. This consumption, while small, occurs continuously even when switched off. The advertisement explains this surprising concept and then instructs consumers on how to eliminate standby power use.

**Figure 5-2**

*Three Advertisements in New Zealand's Target 10% Campaign*




"Vigilance" "Sacrifice" "Education"

*Source: Target 10%.*

Another aspect is to insure high visibility of consumers that have taken measures. California's Flex Your Power campaign reached thousands of grocery stores, restaurants and other commercial outlets and convinced them to undertake conservation measures, such as switching off lights and raising temperatures. Flex Your Power gave them signs to post in windows and at entry points to explain the measures. This allowed firms to show that "I'm doing my part" and to deflect potential complaints about diminished services. The signs (not to mention the dimmed lights) provided yet another means of reminding everybody of the need to conserve. Brazil undertook similar measures.

## Linking Consumer Actions to Solving the Shortfall

Even if consumers know that an electricity crisis exists, they still need to be motivated to take action. The first step is to convince them that individual actions can make a difference. Part of this can be accomplished through skilful public information – the strategy used in California's advertisements "... tried to combat the faulty perception of powerlessness to do anything about the energy crisis" (FYP, 2001b). For this reason, it is important to link specific consumer actions to relieving the crisis. Some programmes seeking to make that link are described in more detail below.

**Box 5-3: Unconventional Means of Delivering the Conservation Message**

- Book marks
- Signs in store windows
- Conservation "pledges"
- "Bill stuffers" and grocery bag inserts
- Point of sale information
- Office posters
- Partnerships with allied organisations
- Conservation curriculum kits for schools
- Paper tray liners in fast-food restaurants

## When Consumers Take Actions

After convincing consumers to act, the government and utilities must have programmes in place to channel them into productive, energy-conserving investments and behaviour. For shortfalls that arrive unexpectedly, there will not be time to plan much beyond ensuring that the recommended measures do indeed save electricity (and at the right times). These programmes will rely almost exclusively on changes of behaviour to achieve electricity savings.

There are many cases where excellent opportunities for electricity savings were squandered because the requirements of the infrastructure to support it had not been fully considered or prepared. The Norwegians created a popular programme to encourage installation of heat pumps but failed to ensure that there were enough qualified installers, equipment and inspectors to meet requests for installation. The California State Legislature made large amounts of funding available to state agencies to reduce the agencies' own electricity use. Unfortunately the financial and auditing arms of the government established so many obstacles that few agencies dared risk drawing upon the funds[14].

More planning is possible – and necessary – when the authorities have advance notice of the shortfall. In these cases the scope of measures is greatly expanded. If the conservation action requires a purchase, such as compact fluorescent bulbs or energy-efficient appliances, then the market must be prepared for a huge increase in demand for the products and services. (This is particularly true when a rebate or tax incentive is planned.) More than likely, the programme will need to create an entire supply chain, including the materials, labour, paperwork and quality control. Programmes that "save electricity slowly" may already be working with these supply chains and greatly expanding an existing programme is easier than starting from nothing.

In general, customised information and programmes are more likely to encourage actions and energy savings. For example, a programme tailored to grocery stores will focus on saving lighting and refrigeration electricity. A manager of a grocery store will find this more credible than a broader guide that includes office equipment and other end-uses that represent a small fraction of a typical grocery store's electricity use. Examples of some of these programmes are presented in boxes.

[14] *There are two lessons from these examples: 1) some programmes will fail and 2) saving electricity in a hurry must consist of a portfolio of programmes (because some will fail).*

# Mass Media Campaigns have an Impact but it is Hard to Measure

There is surprisingly little evaluation of the actual energy savings impact of the mass media campaigns. At a gross level, the information campaigns in California, Brazil, Norway, New Zealand and Japan were successful because electricity consumption dropped (all without the assistance of blackouts). But other forces – principally higher electricity prices – were also working to reduce consumption, so how much impact can be attributed to the mass media campaigns? To partly answer this question, one has to rely on indirect evidence of impact.

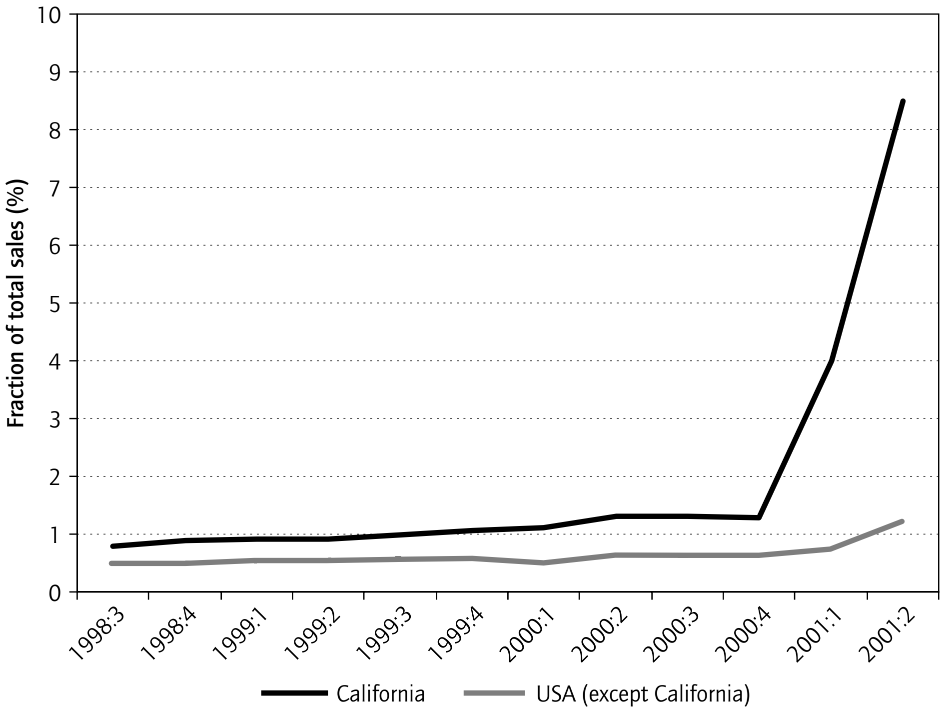
Evaluations of individual aspects of the mass media campaigns do not exist (or have not been made public). For example, were TV advertisements more effective than print? Was humour a more effective tool for getting consumers to act than the threat of a blackout? We do not know.

Media tracking studies found that about half of the population of California could accurately "play back" the advertisements by the end of the crisis, including the recommended conservation measures (Bender et al., 2002). But (as advertisers know from long experience) a high recall rate does not guarantee action. According to a Japanese survey, eight in ten respondents said they took measures to conserve energy. About 75% of all those who took measures claimed to have dimmed their lights. About 60% raised the thermostat settings on air conditioner units and about half cut their air conditioner use (Japan Times, 2003).

For electricity crises that last longer or have a longer lead-up time, sales of energy-efficient products are slightly better indicators of the real impact. The compact fluorescent light bulb (CFL) has been an icon of many crash conservation programmes, so sales of these bulbs should reflect their premier role. Sales of CFLs certainly increased in California when compared to the rest of the country. The proportion of bulb sales that were CFLs suddenly increased in California as the Flex Your Power Program started – from 1% to 8% – while national sales were relatively constant at 1% (Pang, 2003). The proportion of sales dropped somewhat, to about 4%, when the crisis ended, but remains higher than the United States as a whole. This behaviour reflects a more permanent transformation of the market. During this time, however, a host of rebate programmes were under way to reinforce the media campaign. It is therefore impossible to apportion responsibility for the actions by the consumers between the two programmes.

*Figure 5-3*

*CFL Share of Medium Screw-based Lamps*




*Source: Pang, 2003.*

Similar sorts of sales behaviour occurred for other energy-efficient equipment. The Energy Star programme – designed to save electricity slowly – proved to be an easy way for consumers to identify efficient products and for authorities to track the up-take of more efficient products. The fraction of sales of new appliances complying with Energy Star nearly doubled in California during 2001.

Again, sales of energy efficient products are two steps away from actual savings because they need to be both installed and correctly used. In the case of lights, consumers may find that the CFLs do not fit or the illumination is unsatisfactory, so they are actually removed. In the case of white goods, sales may be a closer proxy for energy savings, though one can still find perverse situations where anticipated energy savings fail to occur. For example, consumers may decide to keep their old refrigerators in their basements or garages, causing electricity use to increase.

California's Flex Your Power Campaign built partnerships between all the major participants: the manufacturers, retailers and government agencies. The state produced brochures and specialised marketing products including "window clings", training packets and "tip" cards for sales staff. Flex Your Power required retailers to train their sales staff to sell Energy Star (and other efficient products) and display and distribute the related material to customers. In return, the states funded full-page advertisements promoting those products throughout the region (Sanders et al., 2002).

## Real-time Information about System Status

Electricity cannot be stored, so electricity supply problems can appear quickly. Most utilities are unable to adjust prices fast enough to signal a higher cost of supply, and during many shortfalls they will not be able to change the prices at all (see Chapter 6). Most utilities resort to qualitative appeals for conservation through television, radio and newspapers when a problem arises. These qualitative actions are essential and are discussed elsewhere. 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. Some examples are given below.

During their droughts, Brazil, New Zealand and Norway broadcast or published the key reservoir levels every day. The status was typically translated into remaining days of electricity supplies. Arizona television stations gave daily updates about the progress of the replacement transformer across the desert. Consumers could easily appreciate the sense of the crisis, plus the extent to which their collective efforts at conservation (or fresh rains) pushed back the day when supplies would run out. These reports often became the starting point for many informal discussions among consumers and unquestionably raised awareness.

Almost from its inception, California's Independent System Operator (CAISO) displayed the total demand for electricity on its Web site and updated it every 15 minutes[15]. Anyone could visit their Web site and view this information (though it took an expert to interpret it). At first, the Web site simply listed the current demand and expected peak demand. Later, the CAISO switched to a graphical format and included the forecast demand for

[15] *www.caiso.com.*

the entire day. Other electricity exchanges, such as Nordpool[16] in Scandinavia and GRTN in Italy[17], have the same feature.

However, consumers still could not determine if a shortfall was imminent because the CAISO did not indicate how much capacity was available to serve the projected demand (that is, if the supply and demand lines were going to converge). Consumers needed to “see” when the demand was getting perilously close to the available capacity. In fact, estimating this is complex and depends on definitions. It also depends on predictions of imports, ease of bringing the spinning reserve on line, starting other plants, and so on.

The Lawrence Berkeley National Laboratory (LBNL) devised a way to roughly estimate available capacity in a consistent manner and combined this information with the CAISO demand data. LBNL displayed the data on a special Web site: currentenergy.lbl.gov[18] (see Figure 5-4.) The LBNL methodology assumed that the power available at any given moment equalled the installed capacity within the ISO area, plus net imports, minus plants that were off-line for repairs. The approach was admittedly crude. For example, it updated off-line plants only once a day and it ignored local disparities that might be caused by transmission limitations. However, for the first time it was possible for the public to view the electricity crisis unfolding in real-time.

The “currentenergy” site was very popular, attracting more than one hundred thousand visitors a day during the peak of California’s electricity crisis. No rigorous study of the site’s visitors was undertaken, but anecdotal information suggests that a broad spectrum of consumers visited the sites for equally diverse reasons. Visitors included regulators, utility staff, operators of large factories, and many consumers who simply wanted to know when they should do their laundry. The U.S. Department of Energy (DOE) monitored the Web site during the crisis, as did the governor’s office. Later, the CAISO adopted the same approach (with some improvements) and began displaying both demand and supply[19]. Since then, the “currentenergy” Web site has grown to include more than five ISOs. It is

16 *www.nordpool.no.*

17 *www.grtn.it.*

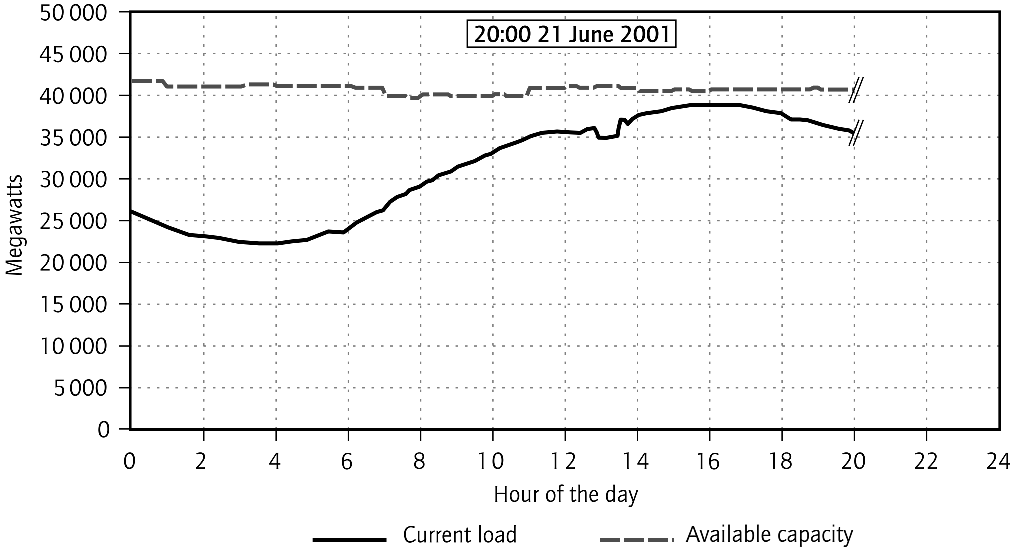
18 *Originally http://energycrisis.lbl.gov.*

19 *The CAISO initially claimed that it could not display – or even release – capacity information because it would reveal confidential information submitted by suppliers. LBNL was initially forced to draw on alternative, less accurate sources. After the LBNL site demonstrated the feasibility – and popularity – of the combined demand/supply chart, the CAISO reversed its position and also began displaying the capacity data.*

considered a useful tool to quickly monitor the status of the major U.S. ISOs and even has a security role.

Figure 5-4

*California Electricity System Status*




*Source: Adapted from currentenergy.lbl.gov.*

Tokyo Electric Power Company (TEPCO) created a Web chart[20] similar to that used in California as TEPCO's shortfall approached the most vulnerable months, i.e. July and August (see Figure 5-5). TEPCO's data were updated hourly (as against every 15 minutes for the "currentenergy" site. The TEPCO chart is even simpler than the California chart and more clearly conveys the status of the electricity grid. TEPCO's policy appears to be to display the information only during July and August. There is no public information about the number of visitors to the Web site.

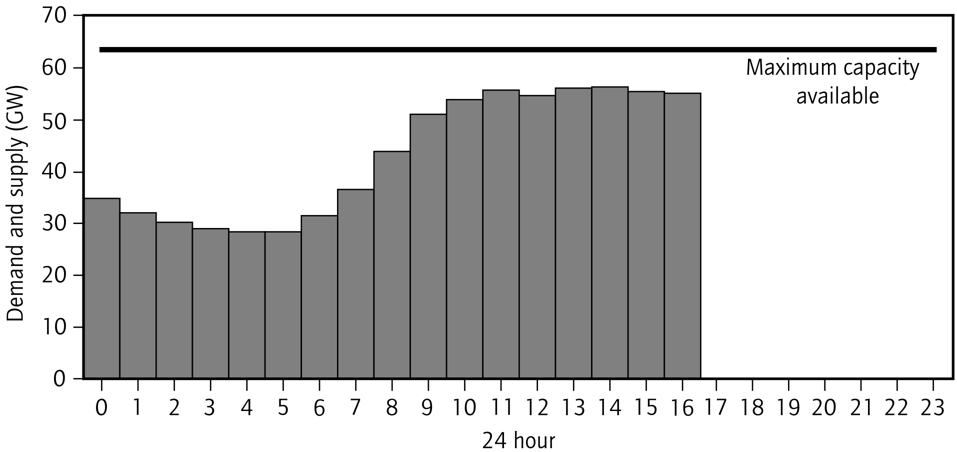
It is impossible to assess the contribution of these Web sites, and the information they provide, to the overall electricity conservation effort. Key decision-makers – regulators, consumers and suppliers – were monitoring the "currentenergy" Web site during the crisis, so it is likely that the

[20] *www.tepco.co.jp.*

information had an impact. The cost of establishing and maintaining such a site is modest. It can also help introduce consumers to tariffs with prices varying according to time of use.

*Figure 5-5*

*Tokyo Electric Power Web Site*




*Source: Adapted from TEPCO, 2003.*

## After the Shortage Ends: the Transition to Normality…and the Next Shortage

The rains have replenished the reservoirs, the heat wave is over or the transformer has been repaired. This is good news and politicians want to announce it to the public. However, the director of California's Flex Your Power Campaign recommended that one should "never declare victory", arguing that one should not discourage the new electricity-saving behaviour. Anyway, the crises that end have an unpleasant habit of returning sooner than expected. This is certainly the case in New Zealand and in California. Instead, a better strategy would be to transform the short-term campaign into a long-term electricity saving strategy (e.g. saving electricity slowly).

An important element of saving electricity in a hurry takes place once the crisis has ended: evaluation of the programmes. There will be strong pressure to disconnect the hot lines, switch off the Web sites, close down rebate programmes and stop paying for anything related to a crisis that has passed. Nevertheless, a small investment in determining which programmes saved electricity and how much they cost can make the next conservation programme more effective and economical.

At the start of Norway's electricity crisis, the Prime Minister announced an electricity conservation programme based on rebates for heat pumps, electronic controls for buildings, and pellet stoves. The agency responsible for administering the programme, ENOVA, was given only a few weeks to organise all aspects of the programmes between the day they were announced and the day they were supposed to begin. With such a short time available, it is no surprise that ENOVA could not prepare evaluation plans. This situation is typical for all the regions. Nevertheless, some sort of evaluation of effectiveness is justified, if only to know what worked and should be used again if another crisis arises. Many programmes created during the crisis get converted into permanent programmes and deserve scrutiny for their cost-effectiveness. Campaigns that quickly reduce electricity consumption are expensive so it is worthwhile to determine if the costs were justified.

## Many Levels of Impact Evaluation

If the region's overall electricity consumption was less than anticipated, then the package of programmes can be judged a success. When programmes (or their impacts) are closely linked, this gross evaluation may be appropriate. Wherever possible, though, it is better to assess the performance of individual programmes, especially when some are cheap and others are expensive.

California attempted the nearest thing to a comprehensive evaluation for its 2001 crisis. Not only is California concerned about effective use of past resources, the state hopes to use the results to improve future campaigns (which it expects will be needed). California also has a tradition of evaluating its energy efficiency programmes and even established a group – California Measurement Advisory Committee (CALMAC) – to continually monitor their efficacy. CALMAC compiled the evaluations and sought to answer the following questions (Wikler *et al.*, 2003):

- How much energy did the 2001 programmes actually save?
- Which programmes saved the most energy per dollar invested?
- What is the expected persistence of the savings?

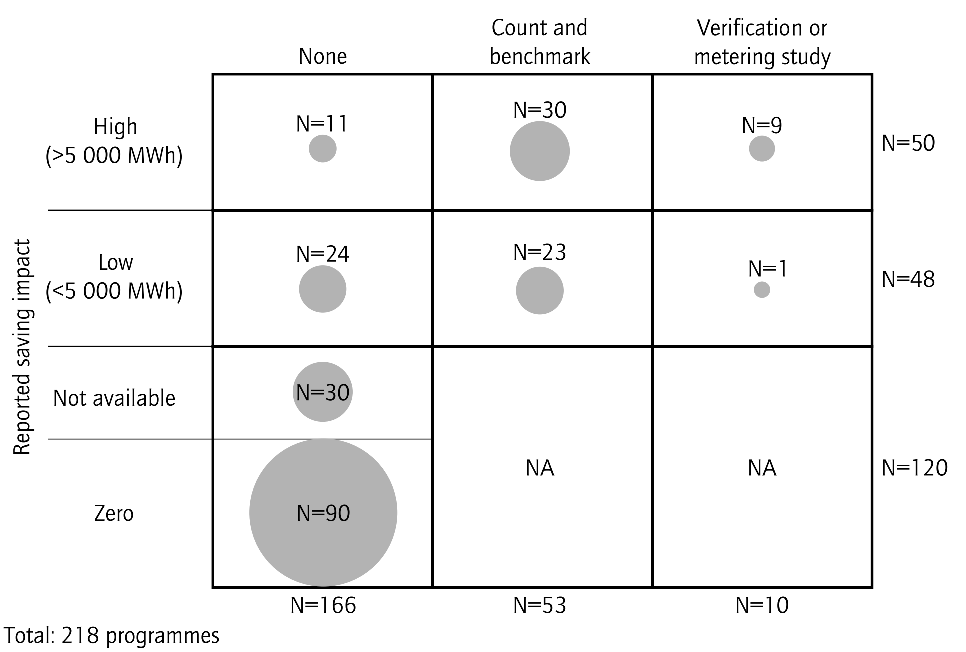
CALMAC also sought to find lessons for future programmes in terms of success stories and failures.

CALMAC identified over 218 separate programmes administered by more than 35 different entities (cities, utilities, counties, NGOs, etc.). Programmes had different objectives. For example, some targeted peak power, others sought to reduce electricity consumption, and still others tried to deal with high bill complaints. CALMAC found wildly varied criteria for the measurement and evaluation of savings. This diversity was further reflected in the availability of data and documentation.

Some programmes were evaluated in only the most cursory way while others were examined in detail. Figure 5-6 summarises the data and evaluation quality for the 218 programmes.

**Figure 5-6**

*Available Data to Support Savings Impact*




*Source: Adapted from Wikler* et al., *2003.*

Some of the problems in evaluation documentation included:

- Unclear treatment of programme year versus annual savings.
- Inconsistent assumptions of net to gross savings.

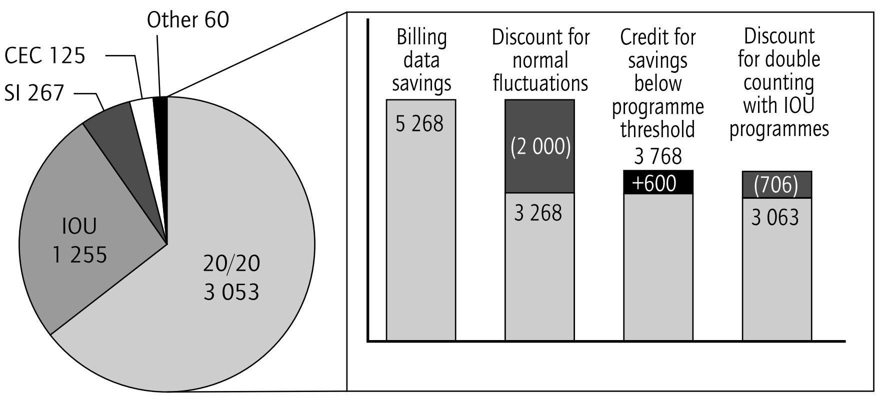
- The study tracked only demand or only electricity savings.
- Not clear if kW savings were on peak.
- No clear methodology for estimating savings.
- Ambiguous reporting of programme costs.
- Savings possibly already included in 20/20 savings.

After making suitable adjustments for the different approaches and assumptions in the evaluations, CALMAC concluded that the 218 programmes cost $893 million. This investment netted savings of about 3.4 GW at a cost of $0.03/kWh saved. This estimate included lifetime savings from those measures expected to persist. For comparison purposes, the average price for contracted energy purchased by the state of California during the first half of 2001 was over $0.20 per kWh, ten times higher than the cost of saved electricity. By these measures, the programmes were cost-effective at both the average price of electricity and the cost of acquisition of additional electricity. These costs do not include the costs to the consumer of possible inconvenience, discomfort, and additional time devoted to the conservation actions (which must also be balanced against the potential costs caused by a blackout).

CALMAC found that the 20/20 programme was responsible for the majority of the energy savings (see Figure 5-7). The chart shows the kinds of adjustments made to the results of the 20/20 savings in order to derive the final savings.

**Figure 5-7**

*California Energy Savings in 2001 for 218 Programmes*




Total savings: 4 760 GWh

*Source: Adapted from Wikler* et al., *2003.*

California is unusual in the breadth of its evaluations. Most regions undertook little evaluation beyond a technical memorandum or simple tabulations of brochures printed, television advertisements, etc. It is not surprising that evaluations of the crash programmes to save electricity are scarce because designing an evaluation plan is the last thing on a manager's mind when rushing to get electricity savings programmes under way. When the programme has started, it is difficult to fix data gaps or inconsistencies afterwards.

## Conclusions on Mobilising

A campaign to save electricity in a hurry must rely heavily on the mass media to introduce the problem to the public and then convince them to take action. The shortages in Sweden, New Zealand, California and elsewhere have demonstrated that these tasks can be accomplished in as little as a few days. Even though few governments have this expertise in-house, advertising firms are familiar with launching co-ordinated campaigns on short notice. In many ways, requesting consumers to conserve electricity is no different than convincing consumers to buy a new detergent.

Television, radio and newspapers have been the primary means of bringing the message to consumers. Like any public relations campaign, the message should be tailored to the medium, but New Zealand and California showed the value of creating simple, consistent messages that avoided blame. Longer crises will need new messages to encourage new actions while sustaining the measures already taken.

The mass media is conventionally thought of as the broadcast and print media and, more recently, the Worldwide Web. However the technology of delivering information to targeted groups is rapidly evolving. Arizona utilities relied on e-mail to quickly reach key groups of consumers. Text messaging, smart meters, and other new technologies will no doubt be useful in future shortages, even though the messages they deliver will be the same.

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# HIGHER ELECTRICITY PRICES AS A TOOL TO REDUCE DEMAND QUICKLY

Raising the retail price of electricity during a shortfall is the first and most obvious strategy to bring demand and supply into equilibrium. In liberalised electricity markets, the price mechanism will be the primary means of obtaining conservation. Regulators in Norway and New Zealand – two countries with liberalised electricity markets – speak of a "price crisis" rather than a shortage. (IEA, 2003a) Intermediate measures exist in partly liberalised markets. For example, Demand Response programmes have been created to introduce or increase price-responsiveness among electricity consumers (IEA, 2003b).

However, it is more difficult to quickly raise electricity prices in most of today's regulated electricity supply systems. A combination of technical and political obstacles prevented the price-reliant approach used in New Zealand and Norway. This chapter summarises the extent to which higher prices were used to quickly reduce demand and explores the limitations of the price mechanism during temporary shortfalls.

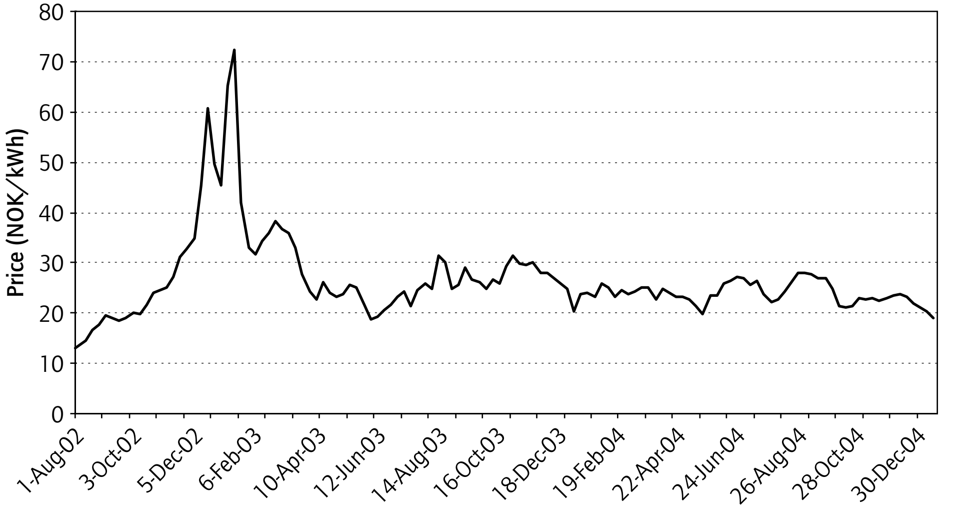
## Summary of Electricity Price Changes During Shortfalls

One would expect electricity prices to rise during a shortfall. In many cases they did. Wholesale prices – the price offered to utilities and large customers – rose particularly sharply. The trajectory of wholesale prices in many ways defines the crisis. The situation in Norway is typical of a brief shortfall caused mostly by a drought combined with unusually cold weather (see Figure 6-1). The wholesale prices were almost four times higher than those in the previous year.

California's electricity crisis was caused by several factors, including drought, uncertainties prompted by market liberalisation and outright market manipulation. As a result of these diverse causes, the wholesale price rises were more erratic and prolonged (see Figure 6-2). Mandatory price caps further distorted the situation. Average wholesale prices during the height of the crisis climbed to over ten times earlier prices.

*Figure 6-1*

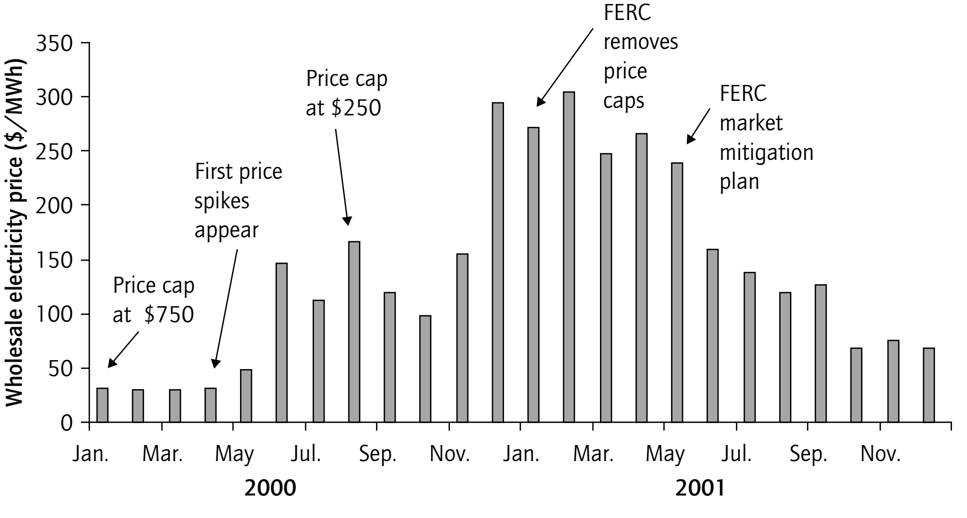
## *Electricity Spot Prices in Norway*




*Source: Statistics Norway, 2005.*

*Figure 6-2*

## *California Wholesale Electricity Prices*




*Source: California Public Utilities Commission.*

The San Diego area in California experienced market liberalisation in 2000 before the rest of the state. Retail prices were allowed to fluctuate according to the cost of supplying the electricity. In the summer of 2000 – about one year after liberalisation – residential electricity prices rose from about 10 cents/kWh to 23 cents/kWh. Thus, San Diego residents saw their electricity rates climb in three months from near the national average to among the nation's highest. There was little advance warning to consumers, so most became aware of the price increases when they received their bills[21]. Reiss and White (2003) examined the response of over 70 000 San Diego households to the higher prices. They found that electricity consumption dropped 12% in about two months. The savings were not uniformly distributed: about one-third of the households cut their consumption by more than 20% but another third showed no change or actually increased consumption. Further reductions appeared to be under way but were then discouraged when a price cap at 13 cents/kWh was established in September. Consumption then rebounded to about 3% less than historical levels.

The San Diego experience demonstrates the extent to which consumers (or at least residential consumers) can respond quickly to higher electricity prices. However, it also demonstrates the political limits of their response because the high prices in San Diego forced politicians to impose a price cap.

Most California consumers did not experience the full extent of the variation that occurred in San Diego. Retail prices of electricity rose by as much as 200% for a few customer classes during the electricity shortfalls but, in many more cases, the price increases were small or non-existent (see Table 6-1). Figure 6-3 shows the approximate electricity rates for the three major sectors in Pacific Gas & Electric Company's service area during California's electricity crisis (Goldman, 2002).

The size of price rises in Brazil varied greatly with the category of consumers. Small consumers – generally poor households – saw no increase in prices and actually received rebates if they cut consumption. Large consumers faced a doubling of prices, plus strict limits on consumption.

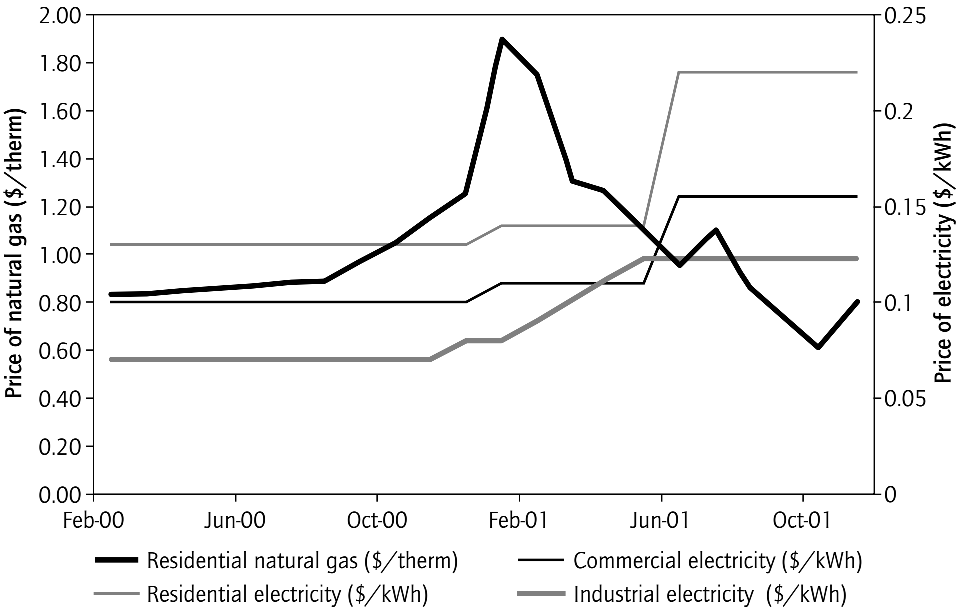
Fixed elements in electricity bills, such as taxes and distribution charges, dampened the percentage change in many countries. More important, however, was the role of pricing regulations. These rules – sometimes enacted as a transition to a liberalised market – insulated consumers from

[21] *Even then the reason for the higher bill was obscured by many other costs shown in the bills, including the charges for consumption of natural gas.*

the full impact of higher electricity prices. New Zealand's retail prices increased only slightly. In Tokyo, Arizona and Ontario, rates did not change at all for residential customers nor for most commercial customers during the period of shortage.

*Figure 6-3*

*Gas and Electricity Prices in Pacific Gas & Electric Company's Service Area*




*Source: Adapted from Goldman* et al., *2002.*

The reasons prices did not rise – or rose less than actual costs – were unique to each situation, but they include:

- **The price rises needed to make the market clear were politically unacceptable.** There were serious equity and other social impacts of drastically higher electricity prices. In California, the controversy surrounding higher electricity prices first forced the imposition of price caps and eventually toppled the government. The governments in Norway and New Zealand were put under strong pressure to solve the crisis. Some regions (notably California and Ontario) were in the midst of a complex and politically fragile market liberalisation where frozen – or even lowered – retail prices were a fundamental element of the compromise.

Table 6-1

*Retail Electricity Price Changes During Shortfalls*

| Location | Retail Price Changes during Shortfall |
|---|---|
| California | Residential prices increased 9% between 2000 and 2001, commercial prices increased 38%, and industrial prices increased 37%. As a result of the 20-20 programme begun in June 2001, customers received a rebate if they used less than in the previous year. |
| Norway | In the first quarter of 2003, residential electricity prices rose 63%, commercial prices rose 61%, and non-energy intensive industry rose about 37%. However, residential bills rose less than this because taxes and grid costs represent more than half of the electricity cost. |
| Tokyo | No change. |
| Brazil | Tariffs for electricity consumed in excess of the quota 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 taking more then 500 kWh. Additionally, a bonus of 1 Brazilian real was offered for each kWh saved in excess of the quota for consumers with a demand of less then 200 kWh/month. The high load consumers paid the spot market price for the excess demand (this price was capped at about $250 per MWh). |
| France | No change. |
| Arizona | No change. |
| Sweden | No change in prices except to largest industrial customers, where spot price rose about 400%. |
| Ontario | No change. |
| New Zealand | Electricity prices rose about 8% during the first half of 2003. |

- **Electricity prices were regulated and could only be changed through a lengthy administrative process.** There was simply no procedure available for making big changes quickly. This was the situation for most consumers in Tokyo, California, Ontario, Brazil and France.
- **Billing and metering systems were not designed to deal with frequent changes in electricity prices.** Shortfalls lasted from one day (Sweden) to

two weeks (Ontario) to a few months (Norway). Utilities in Europe typically read the meter only once a year and provide estimated bills every two months. These practices are unlikely to give adequate feedback to consumers. Most existing meters and billing systems are designed to measure total electricity consumption (rather than time of use) and new meters require years to install[22].

- **Customers with fixed-price contracts had little incentive to conserve.** Many customers chose fixed-price contracts in order to minimise uncertainty in their electricity costs. Some utilities offer their customers the option of levelling their utility bills through the year to prevent very high winter charges. In both cases, the customers are insulated from short-term fluctuations in electricity prices.
- **Market failures insulated the energy user from information about the electricity price.** In many situations the energy use decision-maker – that is the person who adjusts the thermostat or runs the laundry – does not pay the utility bill. In such cases, higher electricity prices may not influence behaviour.
- **There was no correct price.** In the liberalised electricity markets of Norway and New Zealand, the market continued to function and establish a clearing price. But imperfect markets are not necessarily able to accurately find the clearing price because the dimensions of the crisis often fluctuate wildly. Sometimes there is not even a market. In Ontario, the government suspended operations of the wholesale market for two weeks. Early into the California crisis, the wholesale electricity market was shut down. Manipulation of the electricity market can also result in electricity prices that are too high, forcing the consumers to over-respond or respond in the wrong way.

In summary, most consumers never saw the true cost of providing the electricity during the shortfall. Furthermore, it is unlikely that consumers will ever see the higher prices until the shortfall has already begun or, in the case of brief problems, is already over.

[22] *Time-of-use meters are more common in liberalised markets. In the Nordic countries, for example, over 50% of total consumption goes through meters that can be read hourly (Nordel, 2004).*

# Is Demand Response Sufficient During a Major Shortfall?

Utility Demand Response Programmes – encompassing both variable prices and interruptible service – are an important tool to limit demand and avoid expensive generation (IEA, 2003b). The amount of demand elasticity created by Demand Response (DR) programmes depends on the conditions faced by the utility. Ideal DR programmes – they do not exist yet – cover around 10% of total demand, although it is not clear if this is peak or average demand. Other factors will also influence the ideal amount, including the speed at which the DR programme can deliver reductions, the utility's load shape, the composition of the demand, and the reliability of electricity supplies. For small shortfalls, use of DR may contribute. Most utilities already have curtailment plans that begin with DR measures. For larger shortfalls, DR and interruptible contracts alone will probably be unable to help the market clear. Additional measures need to be taken (and that is the subject of this book).

A recent study (Barbose *et al.*, 2004) evaluated the response of customers to real-time pricing programmes in the United States. It concluded that, even among customers enrolled in real-time pricing programmes, an important fraction of customers failed to respond at all:

*"... Among programmes with more than 10 participants, most programme managers reported that between 20 and 60% of participants have exhibited some discernable response to hourly prices. To explain the fact that the remaining customers evidently do not respond to hourly prices at all, programme managers cited their belief that many customers enrolled in RTP without any intention of monitoring or responding to prices on a day-to-day basis. Programme managers also pointed to various operational and institutional factors that they believe make price response difficult for many customers: a lack of flexibility in customers' operations, a lack of technical expertise, employee turnover, and a general tendency for customers simply to forget about electricity prices if they remain low and stable for prolonged periods."*

The situation in other countries (or during a crisis) will of course be different, but the survey explains why the price tool alone cannot be relied upon to make the market clear during a temporary shortfall.

## Prices Based on Long Term Contracts

Electricity prices have other dimensions, including time, amount, and special conditions of sale. In California, Norway, New Zealand and Brazil, certain electricity-intensive industries had established long-term, fixed-price electricity contracts. Most of them involved aluminium smelting or other electrolytic processes. Each contract was unique because they were negotiated individually (and often confidentially). Some contracts, for example, are "take or pay", that is, the customer was obliged to purchase a fixed amount of electricity in each time period. As wholesale prices for electricity rose during the shortfall, the potential value of these assured supplies also rose. A few firms found it possible (and immensely profitable) to reduce production and re-sell the surplus electricity. Aluminium manufacturers in the Pacific Northwest United States (adjoining California) closed many facilities and re-sold about 5 GW, but there were many smaller examples in Norway and New Zealand. Information on these activities is scanty but it appears that contracts often prohibited re-sale. During a crisis, it may be necessary to suspend re-sale prohibitions and, if appropriate, make a market for this power.

## Conclusions

The price signal is a key factor in influencing how much electricity consumers will demand. Raising the price of electricity is a desirable element of any strategy to deal with a temporary shortfall. Indeed, getting the price right early on – before a true crisis arises – may eliminate the crisis altogether. However, there are both technical and political barriers to quickly raising the price. It will be impossible to obtain the necessary regulatory approvals or implement the tariff adjustments quickly enough to adequately respond to the shortfall. Even then, the price increases needed to cut demand sufficiently may be politically unacceptable and the market will be sidestepped.

In the end, raising electricity prices will be one of many tools employed during an electricity shortfall. In fully liberalised markets it will be the only tool but much less so in regulated markets. In any event, the price signal will work only if transmitted before the electricity is actually consumed. Based on the experiences of many regions, with many different forms of electricity markets, price increases will probably remain a tool to be used with considerable restraint.

**The French "Tempo" Time of Use Pricing Tariff: the Useful Tool that could not be Applied**

France's "tempo" residential tariff schedule allows the utility to impose a "red" rate roughly ten times higher than normal for at most 22 days per year and an intermediate "white" rate 43 days per year. The tariff was created to discourage winter peaks, but it is an excellent tool in the event of a temporary shortfall occurring anytime. All the metering and billing is already in place and tested. Several hundred thousand French residential customers subscribe to this tariff, so the potential savings are considerable. Electricité de France never activated the "red" or the "white" tariffs during the 2003 heat wave. The tariff contract specified that the red tariff could be activated only between November and March. Furthermore, EDF had already used up all its "red" days during the winter. EDF is now considering extending the programme to year-round electricity consumption.

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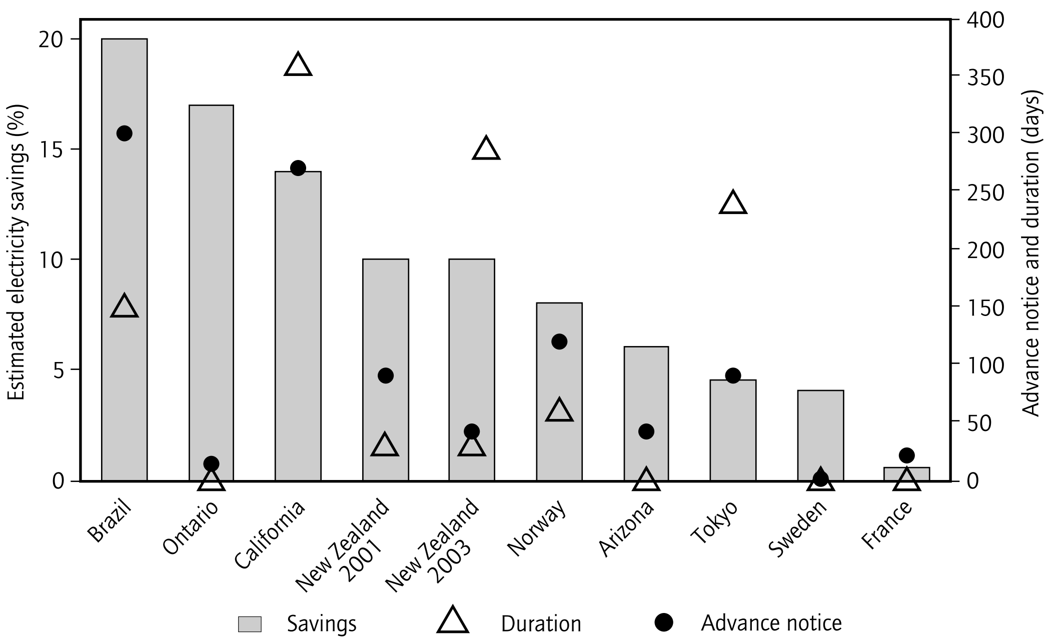
# CONCLUSIONS

## Looking Back

This book identified a unique form of electricity crisis – the temporary shortfall – and showed how different regions have dealt with it by quickly reducing demand. Temporary shortfalls in electricity are relatively rare events but are certainly more common than accidents at nuclear power plants or other events for which we make elaborate preparations. The vignettes in Chapter 2 and summarised in Figure 7-1 demonstrate that temporary shortages of electricity supplies occur even in the wealthiest countries with the most sophisticated electricity networks. The diversity of causes suggests that all electricity supply systems are vulnerable, and often in ways that are not predictable. Who, for example, would have foreseen a summer electricity shortage in Northern Europe? There is every reason to expect that shortfalls similar to those described in the vignettes will occur again – though each will have its own unique and unpredictable twists.

***Figure 7-1***

***Summary of Estimated Electricity Savings, Advance Notice of Shortfall, and Duration***




*Source: IEA analysis.*

The vignettes also showed how regions found creative strategies to save electricity in a hurry instead of simply curtailing power. These strategies differ substantially from traditional policies to raise energy efficiency in three major ways:

**In a crisis it is acceptable to request consumers to make themselves more uncomfortable** – hotter in the summer, colder in the winter – and be inconvenienced. If consumers are persuaded that a crisis exists, they will respond. This kind of sacrifice would be difficult to promote as a long-term strategy and is contrary to the concept of higher efficiency yielding the same services with less energy.

**Raising electricity prices to depress demand, while a sensible goal, may not be feasible.** The crisis may have ended by the time the practical obstacles to delivering the price signal have been overcome.

**A campaign based on intensive use of the mass media is an essential tool for rapid reductions.** The same type of campaign will probably have little impact outside a crisis situation.

The experiences in these shortages also underscore strong connections between saving electricity in a hurry and saving electricity slowly through higher efficiency. Both programmes need similar information to operate effectively: where is electricity used and where can it be saved? Temporary shortages are often indicators of a larger, underlying problem in the electricity system. Long-term improvements in energy efficiency will help solve the problem.

## Loose Ends

There is not enough experience to answer all questions about saving electricity in a hurry. For example, how often can consumers be asked to conserve? New Zealand called for drastic conservation twice in three years. This would appear to push the limits of consumer participation. But the second campaign in 2003 appeared to be even more successful than the first in 2001. Perhaps the 2003 campaign was more effective or perhaps the consumers remembered the tricks – we don't know.

The persistence of the energy savings is also unclear. A durable reduction in energy use is important because the longer the savings persist, the more time a region has to fix underlying problems (although there is no assurance that they will use this time wisely). Brazil's electricity consumption did not return to its pre-crisis levels for several years and the "pause" gave it time to fix its electricity restructuring programme. In California, about half the electricity savings persisted one year after the crisis. Even if California did not solve its supply problems, the pause gave time for the traditional efficiency campaigns to make a greater impact.

What happens if a crisis is declared but is a false alarm? Saving electricity in a hurry is easiest when there is a long lead time to start a campaign. If the damaged transformer is repaired ahead of schedule or the cold wave never arrives, an expensive campaign may have been created for no reason. Tokyo's shortage was not as severe as forecast because the summer proved to be one of the coolest in history. So far there are no examples of massive conservation campaigns abruptly cancelled, though New Zealand terminated its programmes earlier than anticipated because heavy rains replenished its reservoirs.

New technologies still need to be fully proven. For example, advanced metering technologies (and the tariffs to exploit them) appear to be valuable tools in communicating the shortage to consumers. But the evidence of actual performance is scanty and inconclusive. Advances in mass communications offer new ways to reach targeted groups. The next power shortage could rely much more on the Web, e-mail, and text messages but only if the addresses of those groups can be quickly compiled (again demonstrating the need for advance preparation).

## Summing Up

Saving electricity in a hurry is not an elegant, localised operation like building a new power plant; it is a messy, chaotic activity with groups scrambling all over (and sometimes bumping into each other). It is complicated because it involves – and possibly inconveniences – so many people. Strong, credible, leadership by responsible authorities – usually, but not always the government – plays a crucial role in launching and sustaining an effective campaign. Furthermore, saving electricity in a hurry can be expensive in unfamiliar directions, such as for advertising, rebates and other subsidies. This may still be an attractive alternative to much more severe economic dislocation and disruption caused by curtailments in electricity supplies.

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IEA Publications, 9, rue de la Fédération, 75739 Paris Cedex 15
Printed in France by Jouve
(61 2005 24 1 P1) ISBN 92-64-1094-55 2005