Demand-Side Management in China's Restructured Power Industry

How Regulation and Policy Can Deliver Demand-Side Management Benefits to a Growing Economy and a Changing Power System

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December 2005

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Energy Sector Management Assistance Program
(ESMAP)

First printing December 2005

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Foreword

China expects its gross domestic product in 2020 to be four times that of 2000. Limits on energy resources and China's environmental needs require that electricity use grow at a much lower rate than the economy. Demand-side management (DSM) is a critical component of China's sustainable development. It is a set of tools and practices taken by utilities to influence the amount and/or timing of customers' energy demand in order to utilize scarce electric supply resources most efficiently. DSM is a proven method of meeting economic goals in an environmentally sustainable way, and it is also a fast and effective way to address power shortages.

The World Bank has supported the Chinese government's efforts to develop a reform strategy and implementation plan that will improve the overall efficiency of the power sector. As part of the process, the State Electricity Regulatory Commission (SERC) requested, through the World Bank, Energy Sector Management Assistance Program (ESMAP) assistance to assess China's potential for DSM and energy efficiency and develop regulatory policies to encourage investment in load-management and energy-efficiency programs. The timing of the study was opportune: it took place in the wake of the widespread power shortages and a looming energy crisis across the country.

This report reviews China's experience with DSM, explores the barriers to and the potential for new demand-side investment, and examines successful DSM strategies in other countries. It suggests the near-and long-term regulatory and government policies needed to support substantial new investment in comprehensive, cost-effective programs for end-use efficiency and load management.

We hope this report proves useful to members of the international community who are interested in reducing energy consumption through DSM.

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Acknowledgments

This report presents the results of the study "Demand-Side Management in China's Restructured Power Industry," which was undertaken by the Energy and Mining Development Sector Unit, East Asia and Pacific Region of the World Bank, with support from ESMAP, a joint program of the United Nations Development Programme (UNDP) and the World Bank.

A steering committee consisting of Jia Yinghua, Zhang Xubo, Li Zhe, Zhang Yangming, Yan Xiuwen, Luo Wenlong, Duan Sufang, and Xu Renwu, all from the State Electricity Regulatory Commission, China, provided guidance and valuable comments in preparing this report.

The team that worked on the study included Jianping Zhao (task leader) of the Energy and Mining Sector Development Unit, East Asia and Pacific Region of the World Bank; Frederick Weston, Richard Cowart, David Moskovitz, and Catherine Murray of the U.S. Regulatory Assistance Project; and Hu Zhaoguang, Li Jingru, and Han Xinyang of the State Power Economic Research Center, China. The team benefited from the contribution and comments of several other Bank staff members, in particular Noureddine Berrah from the Energy and Mining Sector Development Unit. We also thank Hans Nilsson, Chairman of the DSM Program at the International Energy Agency (IEA), and Xu Hang, Director General of East China Branch, SERC for reviewing the report.

We gratefully acknowledge the review and comments of Luiz Maurer from the World Bank's Energy and Water Department and Apura Sanghi from the Infrastructure Department, East Asia and Pacific Region of the World Bank. Editorial support was provided by The Grammarians, Inc. The publication and distribution of the report was supervised by Marjorie K. Araya from ESMAP. Special thanks to Ms. Nidhi Sachdeva for formatting this report. The report team is also grateful for the support and guidance of the management of the East Asia and Pacific Region's Energy and Mining Sector Development Unit, the China country program, and the Bank's Energy and Water Department.

Abbreviations and Acronyms

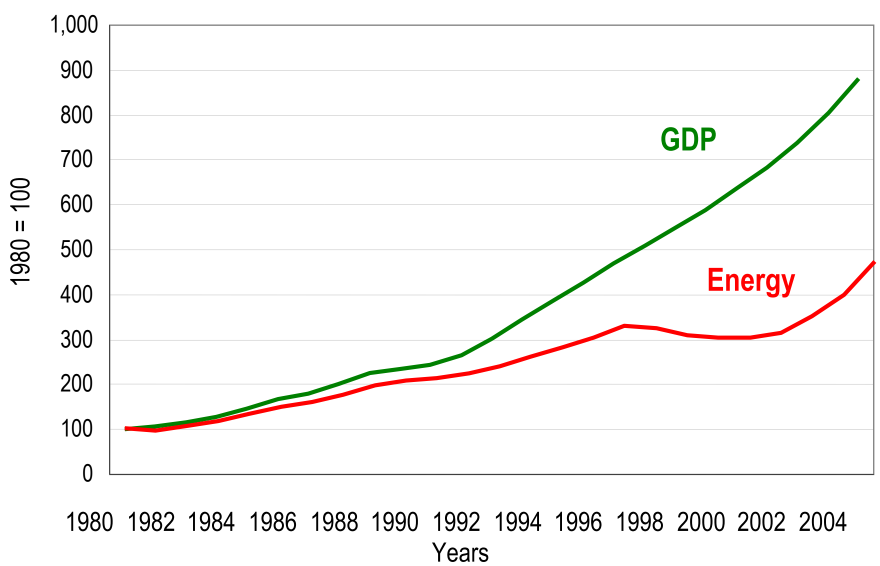
AC	alternating current
ASE	Alliance to Save Energy
BWEN	Brazil Water Efficiency Network
CEC	California Energy Commission
CNIS	China National Institute of Standardization
CPUC	California Public Utilities Commission
DC	direct current
DSM	demand-side management
EEC	Energy Efficiency Commitment
EER	energy efficiency ratio
EESoP	Energy Efficiency Standards of Performance Program
ESCO	energy service company
ESMAP	Energy Sector Management Assistance Programme
GW	gigawatt
HVAC	heating ventilating and air conditioning
IEA	International Energy Agency
IOU	Investor Owned Utilities
IRP	Integrated Resource Planning
IPMVP	International Performance Measurement and Verification Protocol
kV	kilovolt
kWh	kilowatt-hour
Mtce	million tce
MW	megawatts
NDRC	National Development and Reform Commission
PBR	performance-based regulation
PGC	Public Goods Charge
PPP	purchasing power parity
SBC	system benefit charge
SEER	seasonal energy efficiency ratio
SEPA	State Environmental Protection Agency
SERC	State Electricity Regulatory Commission
tce	ton coal equivalent
TOU	time of use
TPF	third-party financing
TWh	terawatt-hours
UNDP	United Nations Development Program

Executive Summary

China's Energy Use and Power Markets

1. China, with more than 1.3 billion people, is the world's most populous developing country. China has experienced remarkable economic development since the beginning of economic reforms in 1978, and has had remarkable success in transforming the economy from a planned system to a market economy. From 1980 to 2000, China's official average annual economic growth rate was 9.7 percent, about four times higher than the rate in developed countries; at the same time, primary energy consumption grew 4.6 percent annually. As a result, China's GDP grew 6 fold. But, as shown in Figure 1, energy consumption grew by only about 3 fold. This trend may be partly attributable to the changes in China's industrial mix; but it is also clear from improving energy intensities for individual industries that China's energy efficiency investments and policies led to improvement in energy efficiency from 1980 to 2000.

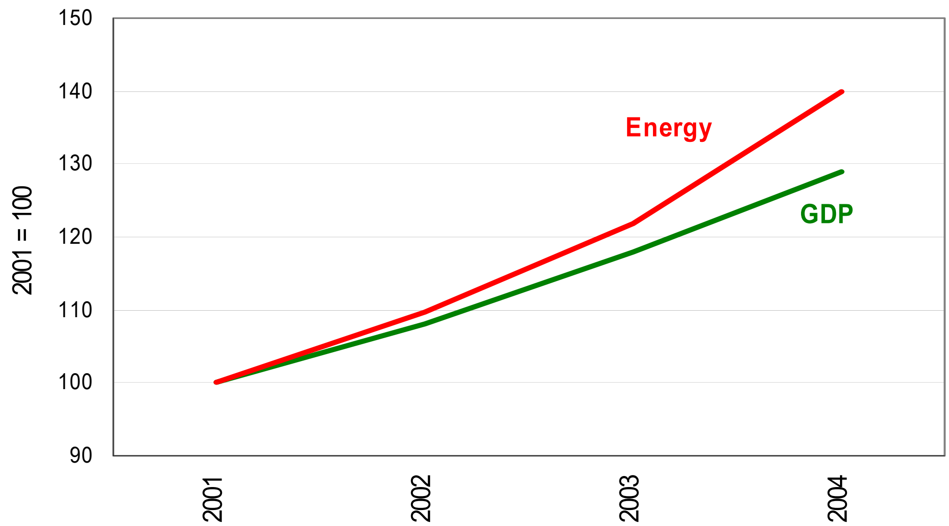
Figure 1: Energy Consumption and GDP Growth in China, 1980–2000



Source: Levine, Mark D. and Lin, Jiang. 2004

2. But past success only makes recent trends more alarming. As shown in Figure 2 however, the past trends have been reversed and since 2001, energy demand has been growing much faster than economic growth. This trend means that China's energy and environment goal for 2020 will not be met without immediate and very strong action.

Figure 2: Energy Demand and GDP Growth in China, 2001–2004



Source: Levine, Mark D. and Lin, Jiang. 2004

3. China's economic goals call for 2020 GDP to be four times that of 2000 while energy use just doubles and pollution is reduced. Given the trend of the last four years, it is clear that the energy and environment related goals will only be met if China commits to new and more effective energy efficiency policies. DSM is a proven way to meet economic goals in an environmentally sustainable way.

4. DSM is a set of tools and practices taken by utilities to influence the amount and/or timing of customers' energy demand in order to use electricity most efficiently. DSM decreases the cost of meeting customers' energy needs through increased investment in end-use energy efficiency and load management. Demand-side resources can reduce or postpone investment in generation, transmission, and distribution capacity, and decrease fuel consumption, and improve environmental quality. DSM also reduces emissions of acid rain related pollutants and damaging greenhouse gases. DSM also has been demonstrated to be a fast, inexpensive, and effective way to address power shortages without hurting productivity. China's very large opportunity to increase energy efficiency is one of its most promising untapped optionsa.

5. China is in the middle of a step-by-step reform of its power sector. These reforms aim at creating a more competitive, market driven, and efficient power sector. However, power shortages caused by very rapidly growing power demand have caused the reform process to slow. There are still many problems in China's electricity sector. Ongoing and planned power sector reforms will help to address some of these problems. The main DSM-related problems include the following:

- **Environment.** Heavy reliance on coal-fired generation causes severe environmental problems and these will become worse in the future. After years of environmental progress, emissions are on the increase.

- **DSM barriers.** There are many barriers to customer investment in DSM and, under the existing tariff-setting method there are also strong disincentives for utility investment in end-use energy efficiency. The lack of utility incentives to invest in energy efficiency has caused growth in electricity demand to be much greater than necessary to fuel China's economic growth. Pricing at both the generation and consumer levels does not fully reflect costs and as a result is inefficient. These inefficiencies are of particular importance because of their effects on DSM and their impact on the power shortage.
- **Power shortage.** China's most immediate problem is the power shortage. In 2003, 22 provinces, autonomous regions, and municipalities had to cut off electricity at peak times. The power shortage is not limited to summer peak periods. During the winter of 2003 and for six months of 2004, power grids across the country were intermittently shut off to reduce power consumption. In addition, rapid growth in air-conditioning and cooling loads is causing the system load factors to fall.
- **Low reliability of the electricity network.** China's electricity networks are vulnerable and unreliable because of rapid load growth, occasional ineffective peak load management, and other load-related problems.

China's DSM Experience

6. China has a long history with load management and energy efficiency programs. Recent DSM programs have focused on four goals:

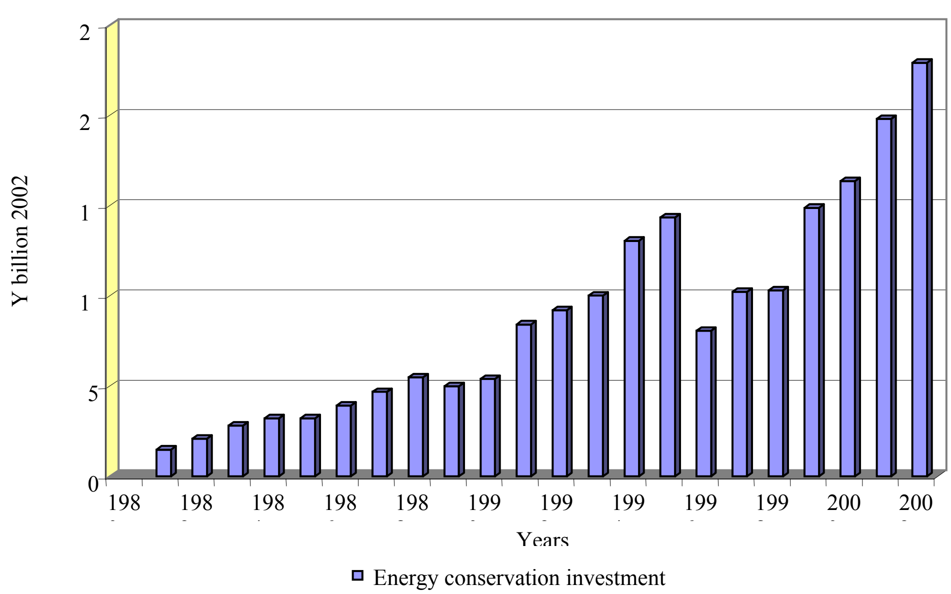
- **Load management.** Significant load management efforts have been implemented in the past few years. These efforts have included substantial shifts to time-of-use (TOU) power pricing with large differences between peak and off-peak prices; interruptible tariffs that compensate consumers for voluntary demand reductions during peak periods; and off-peak storage techniques like ice-storage air conditioners and heat-storage electric boilers. In addition, many large customers have lowered their contribution to peaks by shifting production schedules, and are participating in other government-mandated load management efforts.
- **Energy efficiency.** Economic and environmental benefits have been achieved by the adoption of a number of policies and measures to encourage the use of efficient equipment such as energy-saving lamps, adjustable-speed motors and water pumps, and high-efficiency transformers.
- **Energy conservation.** The shortages of generating capacity and fuel have caused government to adopt energy conservation measures and practices such as changing thermostat settings and reducing hours of operation.

- **Fuel substitution.** Local governments have formulated policies to replace coal-burning facilities with more efficient and less-polluting technologies to reduce local air pollution problems.

7. Because of the power shortage, most of China's focus for the year 2003 and 2004 was on load management. Government action reduced peak load by over 20 gigawatts (GW) in 2003 and nearly 30GW in 2004. About 30 percent of the peak load reduction was due to DSM. While this DSM achievement is significant, it is far less than the DSM reductions achieved in California or the Pacific Northwest during their power crisis. Other load reductions were achieved by rationing imposed through government orders or government requests to modify work schedules, maintenance schedules, and production schedules. The cost of these rationing measures to China's economy is not known but it is undoubtedly substantial.

8. China built an impressive record in energy efficiency. As shown in figure 3, China committed large amounts of national resources to saving energy. Investment then dropped off before increasing again in 2002 as the power shortage began to occur.

Figure 3: China's Investment in Energy Conservation 1981-2002

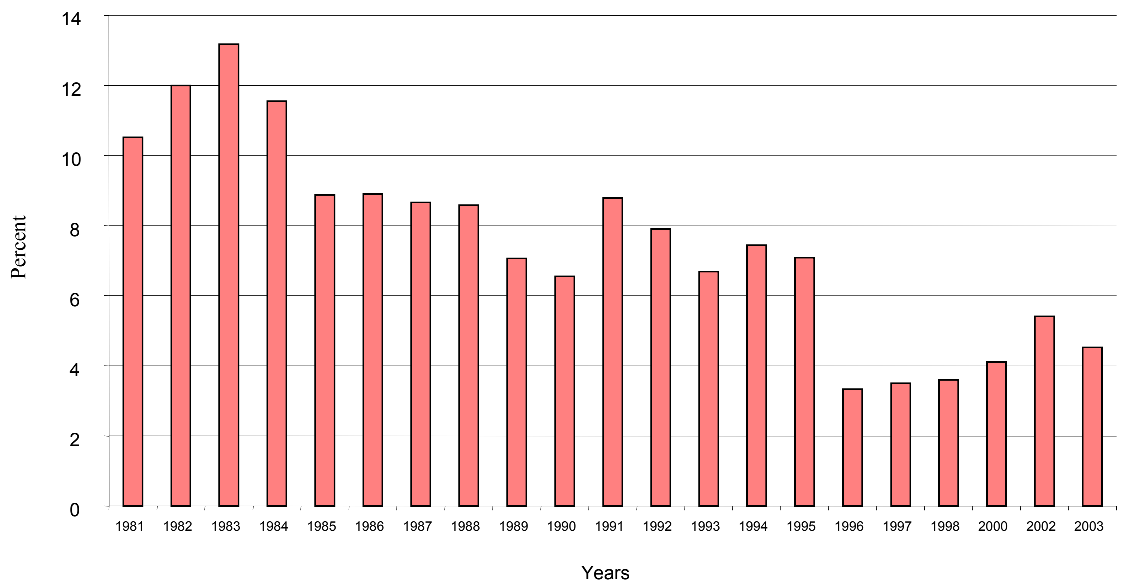


Source: Levine, Mark D. and Lin, Jiang. 2004

9. Significant energy savings were achieved through a large-scale program of energy conservation investments beginning in 1981. These investments were aimed mainly at improving the efficiency of industrial boilers and energy-intensive industries such as steel, cement, and chemicals.

10. When viewed as a percentage of total energy investment, however, the trend in energy efficiency investment has been downward (see figure 4). The last two years charted, 2002 and 2003, show a slight increase, but energy efficiency investment remains low compared to earlier years. This trend has contributed to the current power shortage.

Figure 4: Total Energy Efficiency Investment as Percent of Total Energy Investment



Source: Levine, Mark D. and Lin, Jiang. 2004

11. China has started a few recent energy efficiency programs, such as Green Lights in Hebei and Shanghai and the installation of variable-speed drives in industrial applications in Jiangsu. These programs have been very successful.

12. More recently, China has gained additional energy efficiency experience with the energy service company (ESCO) model. As of June 2004, three ESCOs had entered into 315 energy-performance contracts with aggregate investments of over $95 million. Their businesses are successful and growing rapidly. These ESCO projects have demonstrated that China, like other countries, has large amounts of cost-effective potential for energy efficiency. However, in China as in other countries, ESCOs will be unable to surmount the significant barriers to energy efficiency in the absence of clear public policies and financial support for efficiency investments.

DSM Potential in China

13. China's energy efficiency potential is very large. China could meet its growing demand for energy services, yet avoid the construction of hundreds of power plants, by investing in lower-cost efforts to improve energy efficiency and load management.

14. Energy efficiency in China is still well below that of most developed countries. Analysis of energy inputs into individual products reveals that in 2000, the energy intensities of 13 products in 7 industries were 6–36 percent higher in China than comparable energy intensities in advanced countries.

15. This report reviews most of the recent estimates of China's DSM potential. An overview study of China's DSM potentialb concludes that energy efficiency could reduce China's total electricity needs by about 220 terawatt-hours (TWh) by 2020. The peak load over 95 percent of the yearly load curve (approximately 40–50 GW) can be reduced by load management measures. Additional policies that promote or provide incentives for DSM could reduce the need for generation capacity by more than 100 GW by 2020.

16. A June 2003 study by Chinese experts estimates that improved energy efficiency standards for common domestic appliances and major energy-using industrial equipment in China can save almost 60 GW of power by 2020. This would eliminate the need to build and fuel 200 average power plants (300 megawatts [MW] each), and would reduce residential electricity use and costs substantially over the next 17 years.c

17. A simulation studyd shows that improving load factor in China by one percent in 2003 could have saved more than 7 million ton coal equivalent (tce) annually by improving the efficient operation of generating stations, assuming that total energy consumption did not also rise. Thus, load management efforts can also provide efficiency gains.[1] As China's economy grows and commercial and residential sector electricity use rises, load factors will tend to decrease. For these reasons, load management should continue to play an important role as a feature of DSM in China.

18. This report reviews 13 end-use sectors and finds that the total potential for DSM savings in 2010 is well over 200 TWH. While some of the specific estimates are being reviewed, it is clear that the energy efficiency potential in China is very large. These findings are consistent with the findings in other developing and advanced countries. If these opportunities for efficiency were tapped, China would experience a lower cost of business, improved competitiveness, improved reliability, and reduced environmental impacts from the electric system.

Barriers to DSM in China

19. The vast potential of DSM remains underutilized in China because there are very powerful barriers to customer and utility investment in energy efficiency. In addition to well-known barriers such as lack of capital, lack of information, and electricity prices that do not reflect the full direct and indirect costs of power, China has its own unique barriers, among them the following:

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1 That study also found that lowering line losses by 1 percent could save nearly 7.5 million tce annually in thermal generation requirements. Lower line losses can be achieved in a variety of ways, including more efficient transmission, distribution, and transformation technologies, some load management options, and energy efficiency measures.

- China lacks the legal basis to adopt effective DSM policies.
- China lacks an adequate and stable DSM-funding mechanism. International experience shows that public and/or utility funding for DSM is critical to DSM success.
- Much of China's industrial base is in transition and is attempting to cope with enormous economic change and restructuring. This creates added uncertainty, making it harder to commit needed funds to energy efficiency projects.
- China's approach to generation pricing is unreasonable, and this leads to unreasonable retail pricing. It also increases the grid companies' disincentives for energy efficiency, load management, and improved pricing for retail consumers.
- Tariff-setting methods discourage grid utilities from investing in DSM. The electric company's revenues are determined by power sales, so any reduction in sales will result in reduced profits for the company. In general, energy efficiency programs would reduce power consumption, or at least reduce the growth of energy demand, which would reduce utility profits.
- Retail pricing in China does not give consumers adequate signals to invest in DSM.
- Some kinds of energy-efficient products made in China, such as compact florescent light bulbs, are of low quality.
- China has a shortage of specialized professionals trained in DSM matters.

Impacts of Power Sector Reform on DSM

20. Reform of the electric industry in other countries and states has had substantial impacts on investment in demand-side resources, both positive and negative. But only in those places where explicit policy care was given to DSM did the reforms have beneficial consequences for the electric system and its customers.

21. A recent study by the IEA's Demand-Side Management Program examined how power sector reform affects DSM. The study found that typical power sector reforms do little if anything to reduce the barriers to DSM. Many reforms, such as China's separation of generation from the grid, actually increase the barriers to DSM, unless perverse incentives are addressed. The IEA study also found that the

> *"…overarching policy barrier that affects all electricity industry structures …is the lack of regulatory or legislative attention and interest in energy-efficiency issues."*[e]

22. Power sector reform by itself will not address energy efficiency or other DSM options unless the government adopts specific policies that make them part of the restructuring process. Restructuring in other nations and states has had the following effects on DSM:

- Policymaker, regulatory, and utility focus on complex issues of power sector reform has often led to significant reductions in existing DSM programs.
- Separation of the grid from generation makes it more difficult for any one entity to see the full value of DSM. However, a single-buyer power supply company without the ability to pass all generation costs on to consumers retains the incentive to capture all of the generation, transmission, and distribution value of DSM.
- Separation of generation from transmission and distribution creates smaller companies with lower earnings and profit levels. This magnifies each utility's disincentive to invest in DSM.
- Markets deliver what they are designed to deliver and will only deliver energy efficiency if they are designed to do so. Markets can be designed to allow DSM to compete against power supply, but this is not often done.
- Many restructured markets have experienced much higher levels of price volatility than they had before restructuring. Where restructured markets have exposed customers to this price volatility, customers have responded in a variety of ways, including with investment in load management options.
- In many countries and U.S. states, industrial customers have been given preferential subsidized prices. Restructuring in some places has resulted in the loss of these subsidized prices, and industrial price increases have increased customer investment in DSM.

International DSM Experience

23. Many countries and states have decades of experience with DSM in the power sector. Some of these jurisdictions have restructured their power sector, some have not, and some are in the process of doing so. The fate of DSM programs in the face of power sector reform has varied widely across the globe.

24. In some jurisdictions, DSM programs are now coordinated by government or other agencies, rather than utilities, and funded with taxes or general revenues, rather than by consumers. However, in most countries DSM is funded through electricity bills and the electric utilities are actively involved in program delivery. Like the studies in China, international studies consistently show that the potential DSM benefits for the economy, employment, environment, supply security, and reliability are massive.

- South Africa's largest electric utility, Eskom, expects to avoid 7,300 MW of new capacity through the use of energy efficiency and load management, even while adding 5,000,000 new customers by 2007.
- If energy efficiency programs in the EU were expanded to reach the entire EU, electricity and gas consumption would be reduced by 10 percent with a net economic gain of around 10 billion euro per year.

- Total electricity consumption in the Southwest, the fastest-growing region in the United States, could be cut 33 percent by 2020 with the accelerated use of presently available energy efficiency technologies at an average cost of $0.02 per kilowatt-hour (kWh).
- Of special importance to China is the international experience showing how DSM can address power shortages. Experience demonstrates the following:
- Short-term measures for responding to demand, including price reforms (for example, real-time pricing, TOU pricing, and interruptible pricing) and rationing, are useful for meeting immediate needs to maintain system reliability. By contrast, long-term investments in demand-side resources can permanently improve the demand-supply balance.
- In contrast to conventional generation resources, demand-side management can lower stresses on the electric grid at the point of consumption, improving the reliability of local distribution grids and transmission delivery systems.
- In contrast to the high economic costs of rationing and the long-term economic costs of adding supply, low-cost efficiency investments can lower the overall cost of electricity service to the economy and lower the environmental cost of the power sector.

Policy Recommendations

25. It will be very difficult to implement DSM more broadly in China without the adoption of new policies. The critical task in China is to identify the policies that are needed to allow DSM to have a role in the reformed power system. This is especially important now because China's power sector is in the process of reform. In some respects, China's power sector is like a centrally planned industry where command-and-control approaches to increasing investment in DSM work best. In other respects, the power sector is becoming a market-driven industry where more market-oriented DSM policies will be needed. This report identifies and recommends that the government of China consider a number of near- and long-term policy options to encourage DSM. Some of these policies rely on regulations, standards, and other measures that could be considered command-and-control mechanisms. Other policies rely on illuminating true costs and incentives so that the market will lead to the lowest-cost solution.

26. Power sector reform is well underway in China. The State Electricity Regulatory Commission (SERC) has been established. The generation business has been unbundled from the transmission and distribution business. However, if the reform process fails to accommodate the potential of demand-side resources in its structure and rules for power sector reform, China will overlook an important mechanism in the pursuit of efficient and sustainable economic development. The good news is that senior leaders in China are interested in DSM and as a result, new regulations on strengthening DSM have been issued by the National Development and Reform Commission (NDRC) and SERC.

27. China is facing a serious power shortage, which is making power sector reform even more difficult. The lesson learned by public officials and utility managers in other countries that have faced shortage conditions is that solving the shortage with a supply-side-only approach may be possible, but relying heavily on DSM can solve the problem faster, at a lower cost, and with less pollution.

28. As described in this report, there are still some barriers to implementing DSM in China. China's power sector reform and reform plans must remove these barriers to DSM. The following policy recommendations would support reform efforts while reducing barriers to DSM.

Near term

29. The most important near term steps are as follows:

- **Make DSM a priority policy.** International experience clearly demonstrates that DSM, including both energy efficiency and load management, will only happen with clear, strong, and consistent government and regulatory leadership.
- **Make DSM a power supply company's service obligation.** One of the best ways to implement DSM is to adopt a policy that the distribution utility service has an obligation to delivery cost-effective energy efficiency services. This policy can be implemented through NDRC and SERC regulations and through the standard conditions included in each distribution company's license. The policy should require distribution companies to identify, design, and deliver DSM programs for customers in all customer classes, subject to review and oversight by NDRC and SERC. If this policy is not adopted, a separate efficiency agency should be created with a DSM mission and adequate resources to deliver significant DSM success.
- **To successfully implement DSM programs, there must be stable and adequate DSM funding.** DSM funding may be through tariffs, local construction fees, or other sources. China may need to create special funds to support DSM within the power sector, perhaps as a percentage of the overall power rates as is common in the United States and elsewhere.
- **Remove financial disincentives to utility investment in DSM.** It is important to adopt tariff methods that align financial incentives for power supply company with DSM obligations.[2] This alignment of obligations and incentives

[2] The grid companies are government-owned monopolies. Ordinarily the lack of private ownership would suggest that cost-recovery, performance-based regulation, and financial incentives would be less important than direct government direction. In China's socialist market economy, however, the distinction between government-owned and investor-owned utilities is not as great as it may be elsewhere. The grid companies are expected to be profitable, and management's performance is judged on profitability and quality of service. Power supply company representatives have repeatedly identified the lack of DSM cost-recovery, DSM-related revenue losses, and revenue losses from implementation of TOU prices as key barriers to DSM in China.

has two parts: (a) recovery of DSM-related costs and (b) the adoption of tariff methods that do not reward increased sales.

- o Under existing practices in China, the power supply company is allowed to include the cost of power purchases in the prices it charges consumers. There is no similar mechanism for the power supply company to recover the cost of investment in DSM, even where the DSM investment replaces a more costly power supply option. The costs of cost-effective DSM investments should be treated like any other utility cost that is recovered in the charges paid by retail customers.
- o Allowing the electric utility to recover its DSM costs is not enough to assure that the company will deliver DSM programs to the greatest extent possible. Under China's tariff-setting methods the electric company's revenues are determined by its level of sales. Almost any reduction in sales will result in reduced profits for the company. Even if the cost of DSM is zero, the lower revenue means that the DSM option reduces the grid utility's profit. This is a very powerful disincentive for grid utility investment in DSM.
- o Correcting this problem requires the adoption of tariff-setting methods that remove this financial disincentive to DSM. An approach, used successfully in Australia, South Africa, the United Kingdom, and parts of the United States, is a form of performance-based regulation (PBR) that sets a cap on the revenues that a utility can retain. PBR that sets revenues on a per customer basis is an approach that may be best suited to China.

- **Adopt further pricing reforms.** Experience in China and elsewhere has demonstrated that consumers will modify their consumption in response to price signals. China's rapid implementation of TOU and interruptible prices are the most recent examples. Chapter 6 describes a set of pricing reforms that combines rewards, penalties, and DSM funding aimed at addressing the power shortage. Reforms include the following:
  - o *Raising prices that are below supply cost.* Prices for some energy-intensive industries are now set at levels that are well below cost. Such consumers are very responsive to price signals. Artificially low electricity prices for these consumers reduce their incentive to invest in DSM and energy efficiency. The resulting inefficient consumption of electricity contributes to China's power shortage. It also appears that residential prices may be too low. Currently, residential prices are roughly the same as prices for large industrial consumers. This is inconsistent with international trends and costs.
  - o *Adopt a high-reliability price option.* Optional high-reliability prices should be made available to large industrial and other customers that are

willing to pay higher prices to avoid service curtailments. The price premium, or surcharge, should be used to pay other consumers to voluntarily curtail use and to fund financial incentives for consumers to purchase and install more energy-efficient appliances, motors, and other devices. If an electricity curtailment can be avoided by the power supply company's purchases of emergency sources of power, the funds can be used to cover the power supply company's incremental cost for that emergency power.

  - *Adopt critical peak prices for large industrial customers.* Existing TOU on-peak prices cover too many hours and days during which there is not a high risk of power curtailments. A critical peak pricing plan would adopt somewhat lower "peak rates" for many hours, and sharply higher "critical peak" prices for just the highest peak hours. This pricing approach could apply to large consumers that do not elect interruptible service or the high reliability option described above. Funds collected under this option could also be used as described above.

  - *Price reductions for consumers that interrupt or reduce electricity use.* China has already adopted interruptible pricing programs. These should be improved to reflect customer choice and expanded to include more customers, including groups of smaller customers to collectively reduce demand on request, and to allow payments for providing this service to the grid.

- **Improve DSM analysis.** Most of the information now available on the cost and environmental savings of DSM relies on simple estimates. Greater use of detailed and more sophisticated analytical tools can improve cost/benefit analysis and reduce uncertainty about DSM investment.

- **Adopt DSM programs to address power shortages.** NDRC and SERC should support the grid utilities to implement as soon as possible the set of DSM programs described in Chapter 6 of this report. These programs are designed to address near-term power shortages.

Long Term

30. In the long term, the DSM-related policies and practices that appear best suited to China are as follows:

- **Integration of DSM in national power planning and investment.** Regulated utilities should be required to engage in least-cost planning, in which the potential and cost of DSM is continually assessed and compared to the cost of meeting customer demand in other ways. NDRC and SERC should make this a clear obligation for power grid utilities through regulations or license conditions. SERC should also coordinate this requirement with NDRC and others.

- **Build DSM into market structure.** One of the main lessons from the California electricity crisis was the importance of designing competitive spot markets to allow full participation by demand-side options. The importance of demand-side participation in these markets has now been widely accepted internationally. Demand bidding, demand-side participation in ancillary service markets, and voluntary demand reductions administered through the system operator are all proven methods of peak load management.
- **Standards and rewards for DSM performance.** In the longer term China should consider targeted incentives to reward superior DSM performance. Such incentives are also considered a form of "performance-based regulation," but are distinct from types of PBRs described in the report that apply to a utility's overall revenues.
- **Recognizing the cost of congestion.** In the near term, transmission pricing may not reflect congestion costs. In the longer term, a functioning wholesale market with locational marginal pricing will provide economic incentives to locate demand-side resources in the best locations. In the interim, however, there are proxies for location that can be used in pricing.
- **Environmental quality.** Generation markets and environmental rules should be designed to eliminate the competitive advantage highly polluting generating plants could have over clean plants.
- **Governmental coordination.** Various government departments will be responsible for developing and implementing the full complement of policies needed to promote DSM, including energy standards by the China National Institute of Standardization (CNIS); pricing and planning by NDRC; monitoring, evaluation, and enforcement by SERC; and environmental regulation by the State Environmental Protection Agency (SEPA). All the relevant government agencies should be coordinated by a DSM steering committee The committee would comprise key officials from the different departments who would meet regularly to share information, discuss initiatives, and develop policies and action plans to implement them.

1

China's Energy Use and Power Market

Energy Resources in China

1.1 As shown in table 1.1, China possesses varied and abundant energy resources. However, the average reserves available per capita are lower than worldwide averages, and China's energy resource mix is not ideally distributed to meet both the nation's energy demands and the need for environmental protection. Coal resources account for a great proportion of the nation's energy production and consumption, resulting in severe pollution problems. China needs to decrease coal consumption and increase the use of resources with lower emissions and technologies in order to lower emissions.

1.2 In addition, China's energy resources are located mainly in the less-developed and less-populated regions. For example, coal reserves are distributed more in the north and west; hydropower opportunities are located mainly in the south and west; and natural gas in the west. Development of these would require coordinated development of transmission and transportation systems.

Table 1.1: Recoverable Reserves and Production of Primary Energy in China (Not Including Nuclear Fuel)

Varieties	Recoverable reserves	Standard coal equivalent	Production in 2003
Coal	114.5 billion tons	81.7 billion tce	1.67 billion tons
Oil	3.274 billion tons	4.64 billion tce	0.17 billion tons
Natural gas	1,366.9 billion m^3	1.83 billion tce	35.2 billion m^3
Hydropower	1,920 TWh/year	70 billion tce	283 TWh/year
Total		158.17 billion tce	1.6 billion tce

Source: Study Team

1.3 Table 1.1 shows that coal accounts for 51.65 percent of reserves of primary energy, hydropower accounts for 44.26 percent, and oil and natural gas account for only 4.09 percent. This table does not include the potential of wind, solar, and biomass energy resources, which could, over time, become much more significant. The table also does not show the very large potential "reservoir" of energy efficiency. This topic is discussed in more depth later in this report.

Production and Consumption of Energy

1.4 China's primary energy consumption grew at an average of 4.6 percent annually from 1980 to 2003, thus more than doubling in 20 years (table 1.2). In the past, China's production of energy was adequate to meet the nation's energy demands. However, since 1993, China has become a net energy importer. In 2004, oil production was 175 million tons, an increase of 2.9 percent over the prior year, and oil imports were 120 million tons, an increase of 34 percent. The gap between supply and demand will increase in the future. China will need to import more to fill the gap, even with improvements in energy efficiency and increases in resource extraction and development.

Table 1.2: Primary Energy Consumption and Energy Mix

		1980	1985	1990	1995	2000	2003
Total primary commercial energy consumption (millions of tce)		602	767	987	1,311	1,302	1,678
Mix (%)	Coal	72.15	75.81	76.20	74.4	66	67.1
	Oil	20.7	17.1	16.6	17.5	24.5	22.7
	Natural gas	3.1	2.2	2.1	1.8	2.5	2.8
	Hydropower and nuclear	4.0	4.9	5.1	6.1	6.9	7.4

Source: Study Team

Forecast of Energy Demand

1.5 The driving force behind all forecasts of energy demand is China's economic goal to quadruple its 2000 GDP by 2020.

1.6 The China Coal Industry Development Research and Consulting Center has forecast that China's coal demand will be 1.82 billion tons in 2010 and 2–2.2 billion tons in 2020, and that production of coal will fall short of demand. It is forecasted that the annual growth rate of oil consumption will be around 3.5 percent until 2010, and around 3 percent during the period 2010–20. In the next 16 years, domestic oil production is forecast to increase slightly, from about 0.17 billion tons per year in 2010 to 0.18 billion tons in 2020.

1.7 However, other experts predict greater disparities. Experts in the Chinese oil industry forecast that the gap between demand and supply of oil to grow from about 0.12 billion tons in 2010, to 0.21 billion tons in 2020. A third projection, from international experts, estimates that the gap will be much larger, 0.15 billion tons in 2010 and 0.4 billion tons in 2020.

1.8 Electricity consumption will rise along with national economic development. As shown in table 1.3 and figure 1.1 (both of which are based on a forecast by the State Grid Corporation), total electricity demand in China is expected to rise to 2,300 TWh by 2005, while installed capacity will be 457 GW. By 2020, demand is projected to rise to 4,400 TWh with peak loads of 840 GW. With a 13 percent reserve margin, capacity would rise to 950 GW. Some researchers have suggested adding an extra 10 percent to installed capacity to lower spot energy prices in the competitive market[f]. If this approach is implemented, installed capacity would have to be 1,030 GW.

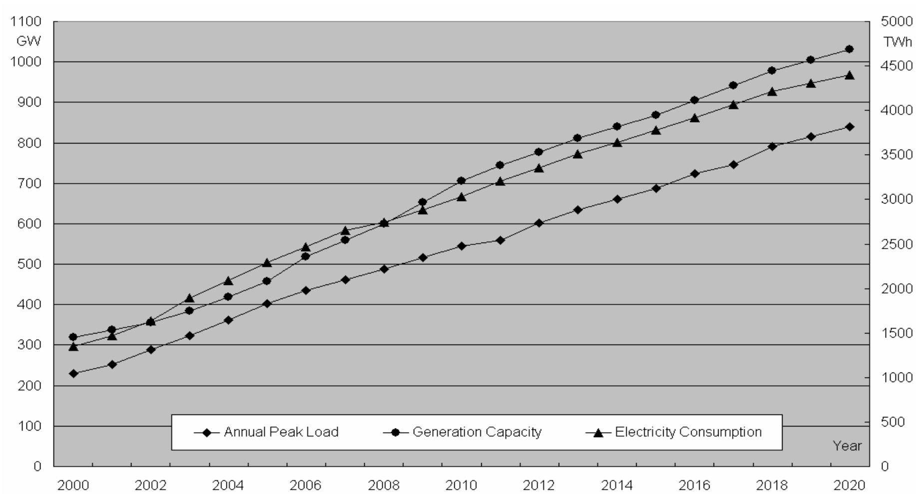
1.9 These forecasts were made only 2–3 years ago, and they were already outdated. They all have underestimated the scale of the energy demand growth. In 2004, coal production exceeded 1.9 billion tons and the gap between supply and demand of oil was more than 120 million tons. The total installed generation capacity reached 440 GW. The actual energy demand growth in the coming decade may be faster than anybody is willing to predict.

Table 1.3: Growth of Electricity Consumption, Annual Peak Load, and Generation Capacity from 2000 to 2020

		2000	2003	2005	2010	2015	2020	Growth rate annually
Electricity consumption	TWh	1,347	1,891	2,291	3,031	3,782	4,400	6.10
Annual peak load	GW	230	323	402	544	687	840	6.68
Generation capacity	GW	319	385	457	706	868	1,030	6.03

Source: State Grid Corporation

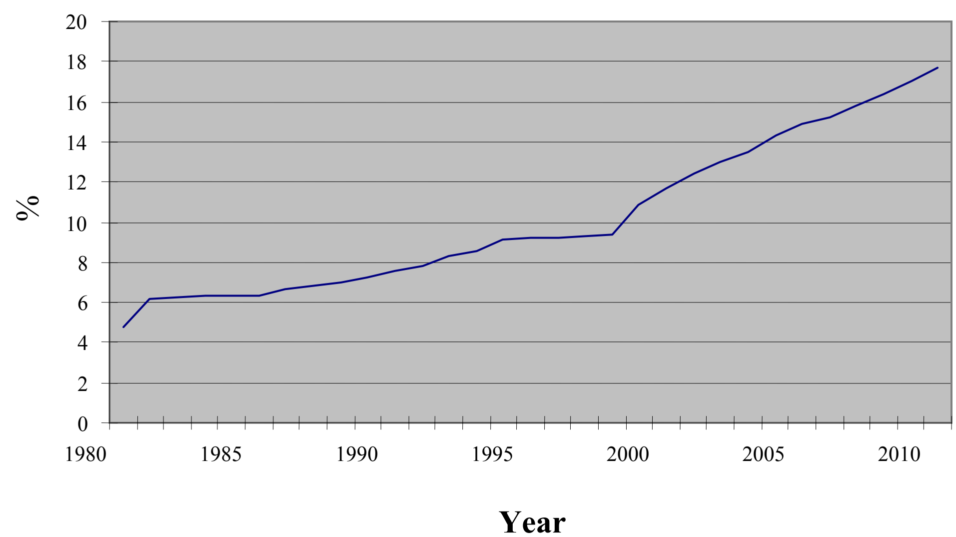
Figure 1.1: Electricity Consumption, Annual Peak Load, and Generation Capacity (TWh, GW)



Source: State Grid Corporation.

1.10 Figure 1.2 shows that, along with this growth, electricity as a proportion of final energy use will increase from 11 percent in 2000 to 17 percent in 2010. Average per capita electricity consumption will also increase, consistent with the development of a more advanced economy.

Figure 1.2: Electricity as Proportion of Final Energy Consumption



Source: Study Team

1.11 In 2004, the installed capacity in China was about 0.34 kW per capita, and power generation was 1,682 kWh per capita, just about 50 percent of the world average. This is only 17 percent of the electrification rate in Japan and 7.4 percent of the rate in the United States. The proportion of electricity consumption to final energy use was 11.2 percent, far less than the average in Organisation for Economic Co-operation and Development (OECD) countries, which was nearly 20 percent.

1.12 While growing consumption and generating capacity indicate significant and positive potential for increased electrification as China's economy develops, such increases are not by themselves indicators of economic success. For example, the high rate of electricity use in the United States reflects a great deal of energy waste, and in fact the high power bill is a detriment to economic progress, just as high oil imports are a detriment to the economy and the balance of trade.

Present Status of China's Electricity Sector

1.13 Since reforms and opening up started in China, particularly after the government implemented the policy permitting electricity investments to be financed by independent and foreign investors, China's electricity industries have developed dramatically. From 1977 to 1999, installed capacity increased 8.32 percent annually, and electricity generation increased 8.07 percent annually. Installed capacity exceeded 100 GW in 1987 and 200 GW in 1995. It reached 440 GW at the end of 2004, while power generation reached 2,187 TWh. In both capacity and energy, China's power system is now the second largest in the world.

1.14 During the past two years, China's national economic policy has led to rapid economic growth. This growth in the equipment industries, the automobile industry, and real estate has driven equally rapid growth in energy-intensive industries such as metallurgy and nonferrous industries. In 2001, total electricity consumption increased by 9.03 percent; it increased 11.6 percent in 2002, 15.4 percent in 2003, and 14.8 percent in 2004.

1.15 In the summer of 2002, power shortages began to affect the country. Mandatory restriction of electricity consumption commenced in Zhejiang, Sichuan, Shandong, and Henan, revealing that supply and demand were no longer balanced. In 2003 and 2004, the electricity shortage was more severe, due primarily to the unusually high and persistent summer temperature in some regions and the unusual water shortages in Fujian and Hunan. The number of provinces restricting electricity consumption rose from 11 in 2002, to 22 in 2003, and to 24 in 2004.

Box 1.1: Power Sector Fuel Mix

In 1995, the installed capacity of thermal power was 162.94 GW, increasing to 237.54 GW in 1999. Thermal power provided 75.0 percent of the capacity mix in 1995, increasing to 76.0 percent in 1999. Hydropower capacity was 52.18 GW, increasing to 72.79 GW in 1999, and its share of the capacity mix decreased slightly from 24.0 percent to 23.3 percent. Nuclear capacity stayed steady at 2.1 GW from 1995 to 1999, and its share of the capacity mix decreased from 1.0 percent to 0.7 percent.

Between 1995 and 2000 there were only small changes in the generation mix. In 1995 the total generation of thermal power was 807.3 TWh (80.2 percent), hydropower was 186.8 TWh (18.5 percent), and nuclear power was 12.8 billion TWh (1.3 percent). In 2000 the total generation of thermal power was 1,107.9 TWh (81.0 percent), hydropower was 243.1 TWh (17.8 percent), and nuclear power was 16.7 TWh (1.2 percent). Generation from new energy sources (such as wind power, geothermal power, and tidal power) was 0.05 percent. In general, the proportion provided by thermal power generation increased by one percent, and the proportion contributed by hydropower decreased by one percent. Installed capacity increased by 4.7 percent in 2001, by 6.8 percent in 2002, and by 7.8 percent in 2003.

While the mix has remained fairly constant over recent years, there has been a trend toward increasing unit sizes of thermal power facilities. In 1995, the total installed capacity of coal-fired units larger than 300 MW was 39.68 GW, making up 28.2 percent of the total generating capacity. In 2003, units larger than 300 MW totaled 121.18 GW, and made up 41.8 percent of total capacity.

Historical Review and Present Situation of China's Power Sector Reform and its Relationship to DSM[g]

1.16 China's reform of the power sector can be divided into two stages:

1.17 In the first stage (1978–97), funds were raised to construct power plants. The reform of the power sector included simpler administration, decentralization, profit-and-loss responsibility, commercialization and corporatization of provincial companies, and improved service with power generation. During this stage, the government set up the Huaneng Group Corporation, the provincial power companies, and the regional power group corporations.

1.18 Power shortages caused the government to establish the Three-E offices in 1989 to oversee electricity planning, electricity saving, and the safe use of electricity. Three-E offices were usually set up in power grid enterprises. They had close relations with consumers and helped them find ways to increase energy efficiency. The Three-E offices provided a link between the government, power grid enterprises, and consumers.

1.19 The second stage of reform started in 1998. It aimed at breaking up the pre-existing monopoly, promoting competition, and establishing a power market. This reform is well under way. The managerial system, managerial methods, enterprise organizational structure, and the main part of the power market are being revised and improved. Progress has been made as follows:

- Separation of the functions of government from those of the enterprises has been successful.
- Separation of power plants from power grids is now complete. To break up the monopoly and introduce competition, the former State Power Corporation was split into 11 power group companies by the end of 2002. There are five power generation companies, two power grid companies, and four tertiary companies in the national level. The structural reform of administrative and provincial companies is well under way.
- Power regulatory institutions were established. SERC was founded in December 2002 and began to study and work out regulations, rules, and measures on market access, competition, and transactions. SERC officially opened on March 20, 2003.
- A document regarding the reform of power prices, the "Measure of Power Price Reform," was approved by the State Council in July 2003 and put into effect. This was necessary to promote the reform of generation prices, power transmission prices, and market prices.

1.20 In 1997, after the Ministry of Power was reorganized, national and local power bureaus and Three-E offices were closed, as reform separated the functions of the government from those of enterprises. Their power management and power-saving responsibilities were shifted to the departments in charge of power marketing. The approval of DSM shifted to government departments and is now handled by provincial development and reform commissions or economic and trade commissions. However, the actual DSM implementation is handled by power companies and coordinated by power companies and consumers under the organization of the government. The experience of the past decade suggests that power distribution companies are now the most qualified entities to implement DSM methods.

1.21 As power system reform continues, measures designed to break up the power monopoly and introduce competition—including separating power plants from grids, price competition, separating power transmission from distribution, and retail sales competition—have created new challenges for DSM. The disintegration of the monopoly system of the sector has greatly shaken the overall planning of resources and DSM's industrial base.

1.22 The reform separating power plants from grids has divided the power corporation into two parts, the two power grid corporations and five power generation corporations. At present, government departments are still responsible for DSM, while the power supply companies are in charge of its implementation. Power generation companies are not involved in DSM. Power generating companies only show interest in moving peak load and are worried that improved end-use efficiency would lower their power output, and thus their revenue.

1.23 Before 2000, funds for DSM mainly came from (a) power supply discount charges and power capacity expansion fees, and (b) fines for the excessive use of power. For example, the Beijing Three-E Office invested Y 20 million annually to shift peak loads in 1997–98, Y 60 million to improve power-saving efficiency, and Y 60 million in technical transformation. The office provided support for the renovation of high-cost electric appliances such as motors and transformers, and the installation of power compensation systems for high- and low-voltage electric equipment in line with actual conditions.

1.24 Both of these sources of funding disappeared by 2002. In the late 1990s, the power supply gradually turned from shortage to surplus. To expand the power market, most power supply companies canceled rules that fined those who used excessive electricity. As a result, funds from this source declined. There was no fine for the excessive use of electricity in 2002.

1.25 Beginning in 2000, the Chinese government began to adjust power supply surcharges. In June 2000, the State Planning Commission and the State Economic and Trade Commission jointly issued a notice to reduce the power supply surcharges and the standard charge for power expansion capacity to reduce the burdens on power consumers. The collection of power supply surcharges would stop by the end of 2000, when the state-approved urban power grid construction and transformation projects were completed. The power supply subsidies were abolished in 2002.

1.26 With the cancellation of public power surcharges, the major source of funds for DSM carried out by all provinces and cities were exhausted. A number of areas which were severely short of electricity began to think of other ways to raise funds.

Primary DSM-Related Problems in the Electricity Sector

1.27 Though there has been great progress in electricity reform in China, there are still some problems in China's electricity sector. The major problems that relate to DSM are described below. Ongoing and planned power sector reforms will help to address some of these problems, but without government adoption of policies to encourage DSM, power sector reform will only increase the barriers to DSM.

Power Shortages

1.28 China’s most immediate problem is the current power shortage. In 2003, 22 provinces, autonomous regions, and municipalities had to cut off electricity at peak times. The power shortage is not limited to summer peak periods. During the winter of 2003–04 and the first six months of 2004, power grids across the country were intermittently shut off to conserve power. In 2004, China had a shortfall of about 30 million kW. In most areas of the country, the power shortage in 2004 was worse than in 2003[h].

1.29 As described in Chapter 1, China has responded to the shortage with a very aggressive set of pricing and load management policies. However, China has not yet adopted many additional DSM opportunities that have been demonstrated to successfully address power shortages.

The Lack of Investment Incentives or Mechanisms for DSM

1.30 There are many barriers to customer investment in DSM, the most serious of which are described in Chapter 3. Under existing tariff-setting methods there are also strong disincentives for utility investment in end-use energy efficiency. Energy efficiency reduces utility revenue and profits and the tariff-setting process does not allow utilities to recover the cost they might invest in energy efficiency.

1.31 Mechanisms to fund DSM existed in China in the past, but they have been mostly eliminated. The lack of a clear and stable DSM funding mechanism and the lack of utility incentives to invest in energy efficiency have caused growth in electricity demand to be much faster than necessary to fuel China’s economic growth.

Environmental Problems

1.32 Heavy reliance on coal-fired generation causes severe environmental problems and these will become worse in the future. The electricity sector had been making progress in reducing emissions, but this trend has recently been reversed. According to the SEPA, total sulfur dioxide emissions were reduced to 19.27 million tons a year in 2002, down from 19.95 million tons in 2000. However, in 2003 emissions climbed to 22.20 million tons, or 15.2 percent higher than 2002. SEPA reported that the increased emissions were the result of efforts to address the current power shortages[i]. Power plants generate over half of China's sulfur dioxide emissions.

1.33 China has a pollution fee for sulfur dioxide emissions, but the fee is not enough to control emissions. The pollution fee used to be about Y 200 ($25) per ton and was raised to Y 600 ($72.49) per ton in 2005. The cost of sulfur dioxide control, however, is about Y 1,000 ($120.82) per ton.

1.34 In part, these environmental problems are the result of China’s lack of cleaner and more advanced technologies, such as clean-coal generation, wind generation, nuclear power, large super-critical generation units, and high voltage direct current (DC) transmission. In 2002, coal consumption for power supply was 385 grams per kWh; this is higher than the rate in advanced countries by approximately 40 grams per kWh. Average circuit loss was higher than advanced systems by 2–3 percent. Thermal efficiency in power plants was 34.3 percent, 3–5 percent less than in advanced systems. These data demonstrate that China can make significant progress in increasing the efficiency of generation and distribution, in addition to needed improvements in the efficiency of end-use technologies.

Low Reliability of the Electricity Network

1.35 Since 1998, with the reconstruction of power grids in both rural and urban regions of China, power system reliability has improved. In 1998, there were 277 cities in which the average supply reliability was 99.81 percent. For 10 kilovolt (kV) consumers, the average outage time was 16.6 hours per customer. In 2003, reliability reached 99.87 percent in 312 cities, and 10 kV customers were without power for 11.7 hours on average. In 2003, the 99.9 percent level of reliability was met in only 159 cities. This is lower than the general level of reliability in advanced countries of at least 99.99 percent.

1.36 Rapid load growth and occasional ineffective peak load management have led to problems including the need for reactive compensation and voltage adjustments. Moreover, many main networks are still at 220 kV. The electricity networks in many areas are too old to support rapid development and increasing electricity consumption.

Rapid Demand Growth and Decreasing Load Factors

1.37 Rapid growth in loads from air conditioning and cooling is causing the system load factors to fall and the difference between daily peaks and valleys to increase. For example, the average daily load factor in Beijing Grid was 86.8 percent in 1992; by 1996, this figure dropped to 82.3 percent.

1.38 In a static condition (no demand growth and a fixed set of existing power plants), lower load factors may lead to less-efficient power plant operation and price increases for certain types of customers. In a dynamic condition (growing demand and new power plant additions), rapid growth in electricity demand and declining load factors will require the construction of more intermediate and peaking power plants and fewer base load plants. DSM and the use of more efficient air conditioners and cooling technologies can help improve this situation.

Power Prices

1.39 Pricing at the generation level is inefficient and pricing at the consumer level could be improved to encourage greater consumer investment in DSM. These inefficiencies are of particular importance because of the effect on DSM investment and on utility incentives to encourage or discourage DSM.

Pricing at the Generation Level

1.40 Under current generation pricing practices each generating plant receives a single energy-based price for its output. The price covers capital and energy-related costs and is reviewed and changed periodically. In December 2003 NDRC agreed that some electricity prices should be increased and restructured. The main modification was an increase of about $0.85 per MWh for all coal generation. Other small upward revisions to power prices were made in 2004. In addition, in December 2004 the NDRC adopted a new generation pricing scheme that automatically increases prices if coal prices increase significantly.[3]

1.41 The current generation pricing practices are not consistent with international practices and lead to several types of inefficiencies. First, dispatch of generation is inefficient. Dispatch is now based on each generator's total price, not just the plant's running cost. Plants with low running costs but high capital costs may be dispatched after plants with high running cost but a lower total cost.

1.42 The second inefficiency relates more closely to DSM. With current generation pricing practices, capacity costs are spread broadly across all hours. As a result, there is little, if any, time-of-day difference in generation costs incurred by the power supply company. Meanwhile, TOU prices are imposed at the consumer level based on pricing principles that assign generation capacity costs to peak periods. This mismatch between pricing practices at the generation and consumer levels produces a serious mismatch between the power supply company's TOU revenue and its underlying power purchase costs.

1.43 For example, in Shanghai, many consumers pay TOU prices with on-peak prices of about Y 1 per kWh and off-peak prices about Y 0.20 per kWh. The power supply company's purchase costs, however, range from Y 0.30 to Y 0.50 per kWh. This means on-peak sales at Y 1.0 are very profitable and off-peak sales at Y 0.20 per kWh are made at a substantial loss. Customers responding to TOU prices by shifting load to off-peak periods cause significant losses to the power supply company.

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[3] NDRC issued the *Notice on the Establishment of a Linkage Scheme for Coal and Power Prices* (F.G.J.G. [2004] 2909). If the change in power coal prices is 5 percent or more, generation prices will be changed immediately. Otherwise, generation price changes will be made every six months. Under the new formula, generation will have to absorb 30 percent of any coal price increases.

1.44 Third, generation prices do not fully reflect environmental costs. Many studies have identified the significant environmental cost of air pollution.[j] This leads to generation prices that are too low in general and unfair competition between high-polluting plants and low-polluting plants.[k]

Pricing at the Consumer Level

1.45 An important purpose of efficient consumer prices is to encourage consumers to adjust the ways they use electric power to reflect the real cost of power. Better pricing will result in consumers deciding to invest in more efficient homes and appliances and to adjust the way they use appliances at different times of the year or times of the day. TOU, interruptible, real-time, and inverted block prices have all been shown to influence consumer use and investment decisions.

1.46 A transparent and rational power price system is an important element in the optimization of power resources. A basic principle is that prices should reflect the full marginal cost, including environmental costs, of providing service to different customer classes.

1.47 Appendix A shows the distribution of electricity prices around China. Averaging across all provinces and customer classes, electricity prices appear to be in the range of the average marginal cost exclusive of environmental costs.[4] However, there are many flaws in the current pricing system. Average prices in China vary widely from province to province and from customer class to customer class. It is clear that in many cases there are significant differences between power prices and marginal costs. This is especially the case for the largest customers. In other cases, capacity and energy prices do not reflect the capacity and energy costs. The current TOU prices do not reflect the actual TOU costs. Differences in reliability among power suppliers are also not reflected in the prices.

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[4] Detailed marginal cost studies have not been found but recent estimates of marginal costs in Jiangsu and Shanghai suggest marginal costs are in the range of Y 0.40 to Y 0.45 per kwh exclusive of externalized environmental costs. For example, see "DSM Strategic Plan for Jiangsu Province: Economic, Electric and Environmental Returns from an End-Use Efficiency Investment Portfolio in the Jiangsu Power Sector," Prepared by Optimal Energy, Inc. and the State Grid Corporation DSM Instruction Center, February 11, 2005.

2

China's DSM Experience

An Overview

2.1 By modifying the level and timing of electric consumption by end-use customers, DSM offers important tools to balance the operation of electric power systems. DSM can enhance the total social benefit of the power system, improve the safety and stability of electric grid operation, and ultimately lower the cost of electric service. China has substantial DSM experience and achievements, which have generated obvious social and economic results.[l] DSM programs to date have focused on the following three goals:

2.2 **Load management.** Load management is one of China's main DSM programs. Load management's objective is to adjust the load curve by (a) clipping the peak load, (b) increasing the valley load, or (c) moving peak loads to off-peak hours. Load management has been pursued though pricing reform (mostly TOU and interruptible pricing), information, and the application of new technologies. It has reduced peak capacity demands and flattened the overall load curve in many locations. A major tool in load management has been TOU pricing: power prices have been increased in the peak period and reduced in the off-peak period. This guides consumers to adjust their production schedules and to employ off-peak storage techniques such as ice-storage air conditioners and heat-storage electric boilers. Large industries have been encouraged to modify their maintenance schedules and their daily and weekly work schedules. All of these steps have flattened the load curve.

2.3 **Energy efficiency.** Economic and environmental benefits have been achieved by adopting a number of policies and measures to encourage the use of efficient equipment such as energy-saving lamps, adjustable-speed motors and water pumps, and high-efficiency transformers, among others.[m]

2.4 **Fuel substitution.** Local governments have formulated policies to replace coal-burning facilities with more efficient and less-polluting technologies such as heat-storage electric boilers, gas boilers, and electric furnaces in urban areas and at tourist attractions. Although these policies were pursued to improve local environmental conditions, significant efficiency improvements were achieved.

2.5 This discussion of China's DSM experience is divided into a load management section and an energy efficiency section. This is because China has much more experience with load management and because the barriers to load management and energy efficiency are very different, as are the needed policy responses.[5]

Load Management Experience

2.6 China has a long history of experience with load management. Recent experience with load management to address the power shortage has been especially successful, and has reduced the number, severity, and duration of wider power outages while improving system load factors. Load management strategies have focused on rapid implementation of TOU pricing, adoption of interruptible tariffs, and deployment of energy storage[6] (cooling and heating). Efforts have been aimed at reducing peak load and shifting use from on-peak periods to off-peak periods. In essence, the new concept of load management involves a kind of "cooperative partner" relationship between the electric power consumers and the electric power corporations.

2.7 As shown in Table 1.1, government action reduced peak load by over 10 GW in selected provinces in 2003. But, as discussed below, only about 30 percent of the peak load reduction, or 3 GW, was due to DSM. While this is a significant achievement, as described in more detail later, California and the Pacific Northwest in the United States achieved far greater savings in response to a less serious power shortage.

Table 2.1: 2003 Peak Load Reductions

Province	Peak load reduction (MW)
Jiangsu	2,800
Zhejiang	1,400
Shanghai	1,700
Guangdong	2,250
Hubei	1,000
Hunan	700
Hebei	250
Total	10,100

Source: Study Team

5 While this discussion distinguishes between load management and efficiency in some respects, it is important to note that some energy efficiency resources also have very positive load management characteristics. For example, the savings produced by energy-efficient air conditioners have a 7 percent annual load factor and most of the savings are on-peak.

6 China's TOU pricing policy requires that increased on-peak prices be offset by lower off-peak prices. The average electric price is not increased as a result of the power supply shortage. Despite the merits of TOU, this is one of its problems; prices do not vary according to the specific market conditions. TOU is only an initial step in demand response.

2.8 The remaining 7 GW of reduced demand was essentially rationing imposed by government orders, requests, or advice to enterprises to modify work schedules, maintenance schedules, and production schedules.

2.9 Over the past 10 years, China's DSM efforts have produced significant economic and environmental benefits. The savings are summarized in table 2.2.

Table 2.2: China's DSM Results (1990–2000)

Electricity savings (TWh)	130.4
Peak load shifting (GW)	3.8
Peak load reduction (GW)	36.5
Coal saving (millions of tons)	58.6
SO2 emission reduction (million of tons)	1.33

Source: Study Team

Note: The average investment of coal plant units is $605 per kW.

2.10 DSM experiences at the provincial and municipal level are described more fully below.

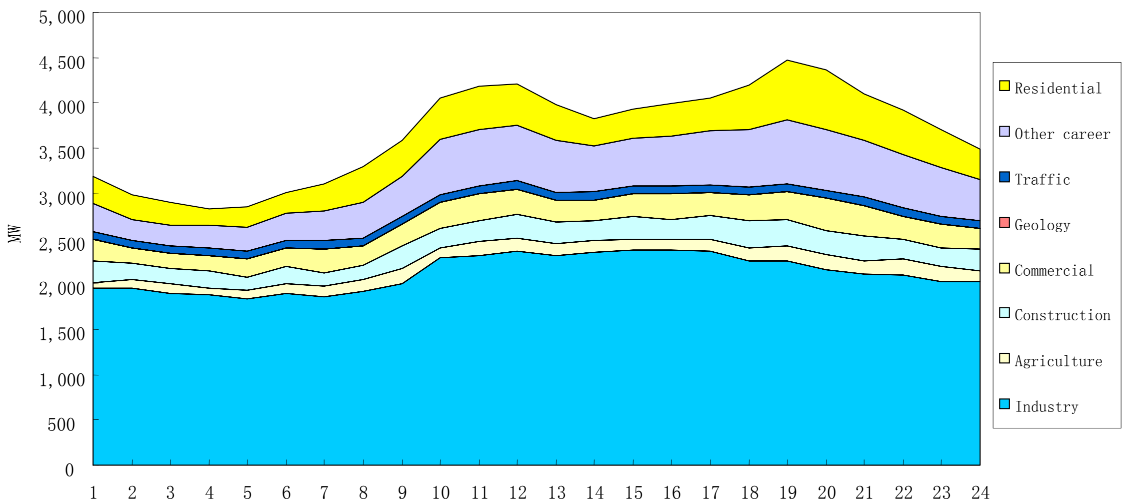
Beijing

2.11 In the past 10 years, the electric load of Beijing city has grown steadily and rapidly. The peak load increased from 3.01 GW in 1992 to 4.47 GW in 1996, a growth rate of 10.4 percent annually. Peak load has grown faster than electricity sales so the annual load factor decreased from 86.81 percent in 1992 to 82.31 percent in 1996. Much of Beijing's DSM efforts have been aimed at the declining load factor.

2.12 Before developing peak load management measures, Beijing carried out a survey to determine the customers' consumption patterns. The results are shown in figure 2.1. The survey revealed that in 1996, industrial consumption accounted for over 55.43 percent of the total power in Beijing (winter typical load curve). Industrial customers accounted for 51 percent of the system's morning peak load and around 50 percent of the evening peak load. Residential and commercial customers accounted for about 16 percent of total load and their load factor was about 60 percent. After 1996, Beijing was able to obtain substantial additional load shifting from these three customer classes.

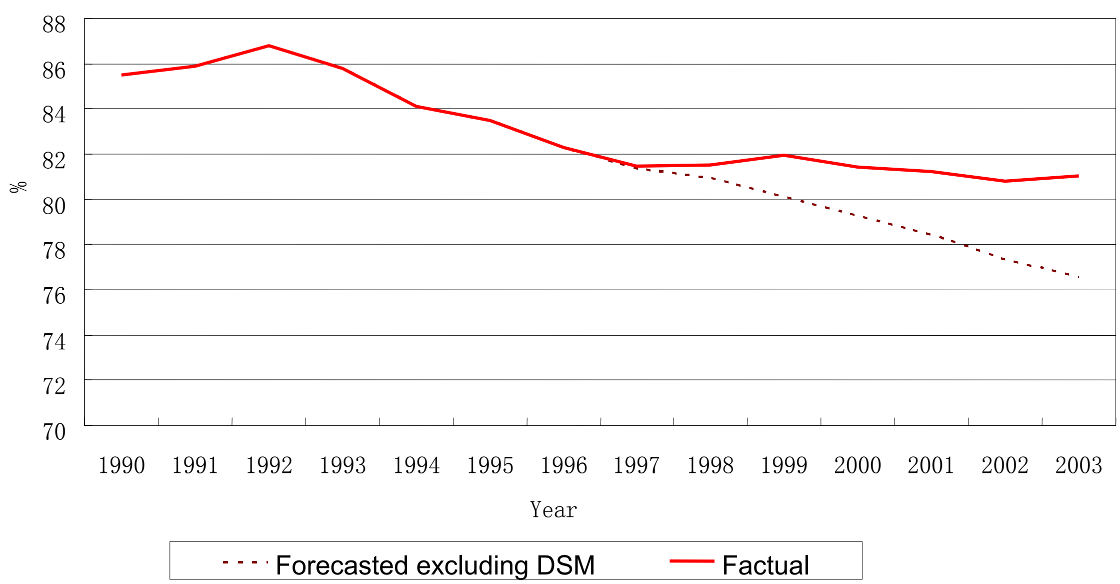
2.13 Figure 2.2 shows the effect of load management on Beijing's load factor. The actual load factor has been maintained at about 81 percent from 1997 to 2003. The figure also shows what the load factor would have been without the load management activities. If DSM were not taken into account, the load factor would have decreased to 76.59 percent in 2003.

Figure 2.1: The Structure of the Load Curve of Beijing in 1996



Source: Study Team

Figure 2.2: Beijing Actual and Forecasted (Excluding DSM) Load Factor



Source: Beijing Engineering Academy "Study of DSM Mechanism in Beijing."

2.14 In order to capture the peak-shifting potential, the following measures were used from 1997 to 2003:

- widening the price difference between on- and off-peak periods
- helping enterprises arrange their production plans rationally (for example, maintaining and testing machines should be arranged in peak-load time)
- setting interruptible load protocols with industry customers, first on a pilot basis, then on a more widespread basis
- implementing special policies for energy-storing equipment such as ice-storage air conditioners and heat-storage electric boilers.

2.15 After implementing the above measures, more than 50 MW of peak load was shifted to off-peak periods in 1997, and another 50 MW in 1998. Valley-period sales increased by more than 150 GWh in the two years.

2.16 The investment in the peak-load shifting was $1.46 million in 1997 and $0.69 million in 1998. The benefits were about $3 million in saved generation capacity costs per year.

2.17 Other DSM accomplishments in Beijing include[n]:

- **TOU.** By the end of 2003, 77,431 consumers representing 61.69 percent of total consumption were on TOU prices. Compared to 2002, the proportion of valley consumption increased 0.75, and the proportion of peak consumption dropped 0.81. About 700 MW was shifted by TOU prices. In April 2004, the Beijing Development and Reform Commission decided to widen the difference between the peak and valley tariff. During the summer, the off-peak price will fall 11 percent, and the on-peak price will increase between 5.5 percent and 20 percent.
- **Energy storage.** Beijing has now added 443 ice-storage air conditioning units and heat-storage boilers. These devices have reduced peak load by more than 300 MW.
- **Promoting electric heating.** Beijing encourages the use of electric-storage space heating to reduce the direct consumption of coal in the city. By the end of 2003, 23,175 residential customers had installed storage heat units in more than 9 million square meters of living space. These units consumed 221 GWh, of which 149 GWh or 67.36 percent was off-peak.
- **Using interruptible tariffs.** Beijing Distribution Company has interruptible load protocols with major enterprises such as Capital Steel Corporation, Special Steel Corporation, and Yanshan Chemical Industry Corporation. About 100 MW of peak load may be shifted per year.
- **Load control at Electric Load Management Center.** The Wireless Electric Load Management Center in the Beijing Grid has been playing an important role in balancing power supply and demand. The facility has the potential of

connecting over 5,000 locations. In 2003, 1,600 locations with 2,800 MW of load were connected, and about 500 MW, or about 6 percent, of Beijing's total load could be directly controlled.

2.18 The Beijing DSM projects were successful primarily because they focused on peak load management, which is generally easier to implement than other DSM programs. In many cases, load management can be accomplished with properly designed and progressive tariffs, such as TOU and interruptible tariffs. Yet load management programs are largely short-term responses that do not exhaust the cost-effective demand-side potential. Beijing may now turn its practical experience with load management towards developing DSM programs that result in long-term reductions in demand through efficient end-use technologies.

Jiangsu

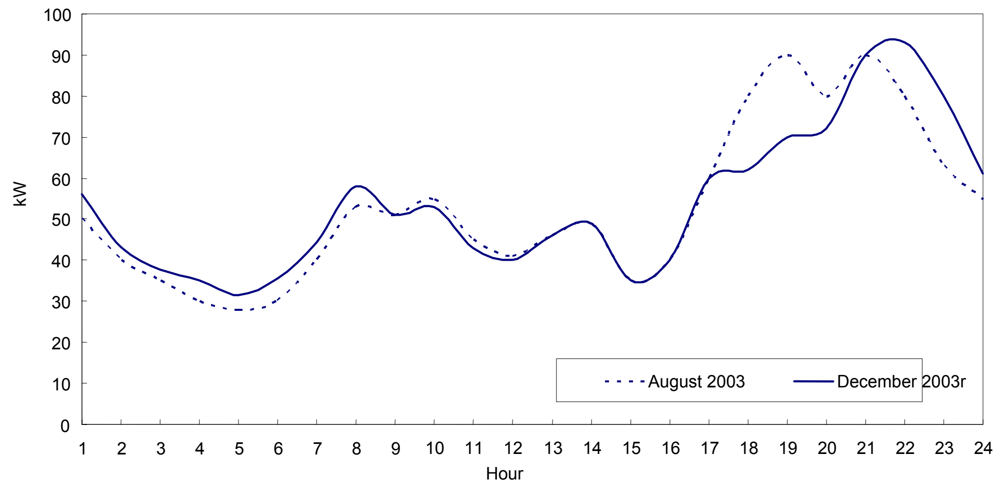
2.19 Jiangsu Province has gained a great deal of DSM experience in the past two years. As a result, DSM is now playing an important role in addressing the power shortage. In 2003, the gap between demand and supply in Jiangsu was 3,890 MW. To address this shortage, the government and power corporation implemented the following DSM measures:

- industrial facility maintenance scheduled to reduce peak period use
- business shut-downs and vacations rotated (956 MW)
- interruptible tariffs (780 MW)
- voluntary shifted load (592 MW)
- TOU prices (see figure 2.3)
- load control system—Electric Load Management Center (475 MW).

2.20 Beginning in August 2003, TOU prices were offered to residential consumers on a voluntary basis. The price for the residents who do not use TOU is $62.88 per MWh. TOU prices are $66.51 per MWh on-peak (8:00–21:00 Beijing time), with a valley price of $36.28 per MWh (21:00–8:00 Beijing time).

2.21 The utility incurs the cost of a new TOU meter, about $30. By the end of 2003, about 750,000 families selected TOU. The proportion of peak consumption and valley consumption has been changed to 55:45 from 64:36. Figure 2.3 shows how the load curve of these customers has changed. The time of peak load was deferred about 2.5–3 hours, and about 20 percent of peak load was shifted (about 100 MW) to off-peak periods.

Figure 2.3: Load Curve Changed By Using TOU —Summer 2003



Source: Study Team

2.22 Together these measures reduced peak load by 2,800 MW. Demand, however, still exceeded supply by about 1,090 MW, so the load control center imposed curtailments on some customers.

2.23 Additional experience in Jiangsu includes the following:[o]

- From October 1999, industrial TOU prices were applied to six large industries representing 83.12 percent of the total industrial consumption in 2002. The on/off-peak price difference was 3:1. (The difference was widened to 5:1 in July 2003). The peak load reduction from this action was about 600 MW. The load factor in Jiangsu increased 0.18, 1.57, 1.12, 1.00, and 1.47 percent from 1999 to 2003 respectively (The load factors were 79.19, 79.37, 80.94, 82.06, 83.06, and 84.53 from 1998 to 2003 respectively).
- About 30 percent of the total peak load in Jiangsu in these years is due to air conditioners. Jiangsu Power Company has invested about $7.2 million to spread the use of ice-storing air conditioning. The ice-storing cooling reduced peak load by about 70 MW per day in 2003. For example, Nanjing Yuhua Distribution Company has installed ice-storing air conditioning and heat-storing boilers. The result is that 750 kW can be shifted from peak to off-peak periods. This has saved the company $37,850 in power costs.
- Interruptible tariffs have been made available to some industrial consumers, mainly the steel corporations. Customers are compensated $0.12 per kWh for interruptions. In 2002, 5 steel corporations took part in the program. Consumers were interrupted 15 times in 10 days for a total of 28 hours. The power corporation paid them $950,000 for these interruptions, and peak load was reduced by about 400 MW. In 2003, 12 steel corporations took part in this project, and peak load was reduced by about 800 MW. This program could be

considered a buy-back program where the utility buys back the energy at a given or negotiated price. Wholesale markets are not yet operational but the price paid here may be a proxy for the market price.

- In 2002, Jiangsu implemented about 65 DSM projects, including ice-storage air conditioners, heat-storage boilers, green lighting, and variable-frequency speed controls at high-consumption industries. The enterprises invested $75 million, with government providing about $5 million as an incentive. The projects reduced peak demand by 100 MW and reduced energy use by 280 GWh. Industrial power costs were cut by $25 million per year.
- Communication with about 237 industrial customers (in steel, chemical fertilizer, and electrolysis industries) resulted in rescheduling industrial maintenance schedules. Peak load was reduced by 66 MW. In addition, some customers agreed to reschedule their day off from Sunday to Saturday or from weekend to weekday.
- By the end of 2003, each city had built an Electric Load Management Center. These centers monitor and can control the use of about 20,000 industrial machines with a total monitored load of about 11,230 MW and 4,590 MW of demand under control. For example, the Electric Load Management Center of Nanjing Distribution Bureau was built in 1997 at a cost of $8.6 million. The annual operating cost of the center is $240,000 per year. The Center allows Nanjing to monitor 2,430 MW, or 71 percent of the district's total load. The Center has direct control over 600 MW, or 18 percent of the maximum load. In 2003, the Center shifted enough demand to avoid serious outages.
- Energy-intensive consumers pay a capacity charge and an energy charge. The capacity charge is either based on actual demand or the transformer capacity. If the customer chooses to be charged on the basis of actual demand they will have an incentive to control peak use. For example, Nanjing Steel Corporation used a computer control system to limit their maximum demand to 50–70 MW (the transformer capacity is 90 millivolt-amps). Their power cost was reduced by about $500,000 per year.[p]

2.24 In total, Jiangsu's DSM efforts reduced peak demand by about 2,000 MW in 2002 and 3,000 MW in 2003. These efforts saved about $1.21–$1.81 billion of investment in new coal plants. Annual energy savings are about 2,300 GWh, equal to about 1 million tons of coal and 23,000 tons of sulfur dioxide.

Hebei

2.25 Hebei province (including the southern and northern parts) has had a great deal of DSM experience in recent years. Hebei is currently experiencing a gap of about 3,000 MW between power supply and demand.

2.26 Air conditioning load has increased rapidly and now accounts for 2,300 MW or 25.2 percent of annual peak demand. Electricity consumption from air conditioning has contributed to Hebei grid's declining load factor. Off-peak load is now 45 percent lower than on-peak load. DSM experience in Hebei includes the following:[q]

- By the end of 2003, the Electric Load Management Center was monitoring load at 4,154 locations. About 4,160 MW of load is currently being monitored and about 1,300 MW is under control.
- Interruptible tariffs have been made available to some industrial consumers. Like the program in Jiangsu described above, customers are compensated $0.12 per kWh for interruptions. In 2003, 36 factories took part in this program, and peak load was reduced by about 200 MW.
- There are about 39,540 consumers, representing about 50.2 percent of all the sales, on TOU prices, reducing peak load by about 1,100 MW. In addition, about 80–100 MW were shifted by the use of ice-storage air conditioning and heat-storage boilers, and about 50 MW was saved by the use of green lighting. By the end of 2003, about 141 sets of ice-storage air conditioning and heat-storage boilers, total capacity 84.7 MW, had been installed. About 80–100 MW can be shifted by these units.[r]
- Beginning in 2003, a critical peak price that is 10 percent higher than peak prices was instituted, and the off-peak price for consumers using ice-storage air conditioners was reduced by 10 percent.

2.27 In the past five years, DSM efforts in Hebei have reduced consumption by 4 TWh, saving about 2 million tons of coal, 40,000 tons of sulfur dioxide, and 4 million tons of carbon dioxide.

Some Other Provinces

2.28 The experiences of Beijing, Jiangsu, and Hebei are not unique. Below the experience in Shanghai, Zhejiang, Hubei, and Guangdong is briefly summarized.[s]

Shanghai

2.29 In 2003, in Shanghai the difference between on-peak and off-peak prices was increased from 3.5:1 to 4:1. In July, August, and September of 2003, many customers were given a load use limit. Electricity consumed within the limit was at the normal price. For use above the limit, the electricity price was much higher. This practice reduced load by about 80 MW.

2.30 Further price reforms were instituted in December 2003. Under these reforms the price differential between each voltage level was widened; the price differential between peak and valley price was widened to 4.5:1; subsidized prices for energy-intensive industries were reduced; and the capacity price in the two-part tariff system was raised to $3.26 per kW-month (based on the maximum demand) from $2.18 per kW-month (based on the transformer capacity).

2.31 Shanghai's Electric Load Management Center could monitor and control about 250 MW in 2003 and was able to monitor and control 350 MW in 2004. From 13:00 to 15:00 Beijing time, the maximum load of large customers must be lower than 90 percent of the daily maximum demand; otherwise, the electric price will be doubled.

Zhejiang

2.32 Most factories in Zhejiang Province are midsize or small. In 2003, about 3,800 factories participated in load management programs and demand was reduced about 1,600 MW.

2.33 In 2003, TOU prices were implemented for 34,582 consumers representing about 60 percent of all sales. The critical-peak/off-peak price difference and on-peak/off-peak price difference are 3:1 and 2.2:1 for large industrial users, and the ratios are 2.6:1 and 1.8:1 for other normal industrial users. Through these measures, the load factor in Zhejiang has been kept at about 95 percent in recent years.

Hubei

2.34 Hubei province has been encouraging ice and heat storage technology. About 546 units have been installed. Peak load has been reduced by about 80 MW, and about 225 GWh have been shifted from on-peak to off-peak periods annually.

Guangdong

2.35 From September 2001, Duangzhou city and Dongguan city began to use TOU prices for industrial enterprises. The TOU prices were divided into three time periods, a six hour peak period, ten hour shoulder (or normal) period, and an eight hour off-peak period. The ratio of prices is 1.35:1:0.6. In April 2003, each city in Guangdong began to use TOU prices, which were divided into three eight-hour time periods. The ratio of prices was widened to 1.5:1:0.5. This program reduced peak load by about 500 MW.

2.36 By the end of 2003, 68,000 consumers with capacity in excess of 315 kilovolt-amps had installed multiple-function meters. This represents 95 TWh of energy use in 2003 and 58 percent of all of the sales. Guangdong province plans to build a load management center to monitor and control the load of these customers.

Experience with Energy Efficiency

2.37 China has a great deal of experience with energy efficiency, although most of this experience is not directly within the utility sector. For example, from 1981 to 1990, China spent 4.5–6.5 percent of the total energy investment budget on energy conservation each year. Significant energy savings have been achieved through these investments, which began in 1981 and were aimed mainly at industrial boilers and energy-intensive industries such as steel, cement, and chemicals.

2.38 China also has gained some excellent experience with energy efficiency from working with private energy efficiency services. China, with assistance from the World Bank, has been involved in developing the energy service company (ESCO) model of delivering energy efficiency services. As of June 2004, the three ESCOs have entered into 315 energy performance contracts with aggregate investments of over 95 million USD. Their businesses are successful and growing rapidly.

2.39 These ESCO projects have demonstrated that, like other countries, China has large amounts of cost-effective energy efficiency potential, but also that China has similar barriers to energy efficiency.[t] Other countries have found many remaining barriers to ESCO-led efficiency programs, and that power utility and government support has been necessary for broad ESCO success.

2.40 Some industrial customers have also been leaders in energy efficiency. A recent example of very cost-effective energy efficiency at the Nanjing Chemical Plant is summarized below.

2.41 China's utility-related energy efficiency experience is much more limited than its experience with load management. In the early 1990s, China conducted a number of studies aimed at energy efficiency but the recommendations were not implemented.[u] For example, a 1992 study found that the DSM programs alone could reduce electricity use in Hainan by 21 percent in 2000, with savings of $200–$400 million.[v]

2.42 In recent years, several energy efficiency programs have been implemented, such as Green Lights in Hebei and Jiangsu and variable-speed drives in industrial applications in Jiangsu. But their deployment has generally been limited in scope.

Box 2.1: Nanjing Chemical Plant

Basic Information (before DSM):

Annual Output: 377,674 tons

Annual Electricity Consumption: 191,837,160 kWh

Electricity Expenses/Total Production Cost: 10.39 percent

DSM Implementation:

Start Year: 2002

Measures:

A. Retrofit Electrolytic tanks

B. Retrofit On-site Water Plant Pump Houses

Total DSM Investment: $544,000

Benefits from DSM Programs:

Annual Electricity Saving: 9,904,800 kWh

Annual Economic Benefits from Electricity Saving: $565,000

Production Capacity Increase: 33 percent

Source: Energy Foundation, China Sustainable Energy Program.

3

The Potential for Demand-Side Management

3.1 The two major strategies of DSM, load management and end-use energy efficiency, can be used to shift load and reduce demand. They make it possible for China to reduce costs and environmental impacts while meeting demand and improving competitiveness. The question is, how much of an impact can DSM have on China's electricity use? As discussed below, various studies and thoughtful forecasts have resulted in estimates of the vast potential of DSM to meet China's energy needs more efficiently and cost-effectively.

Load Management Potential

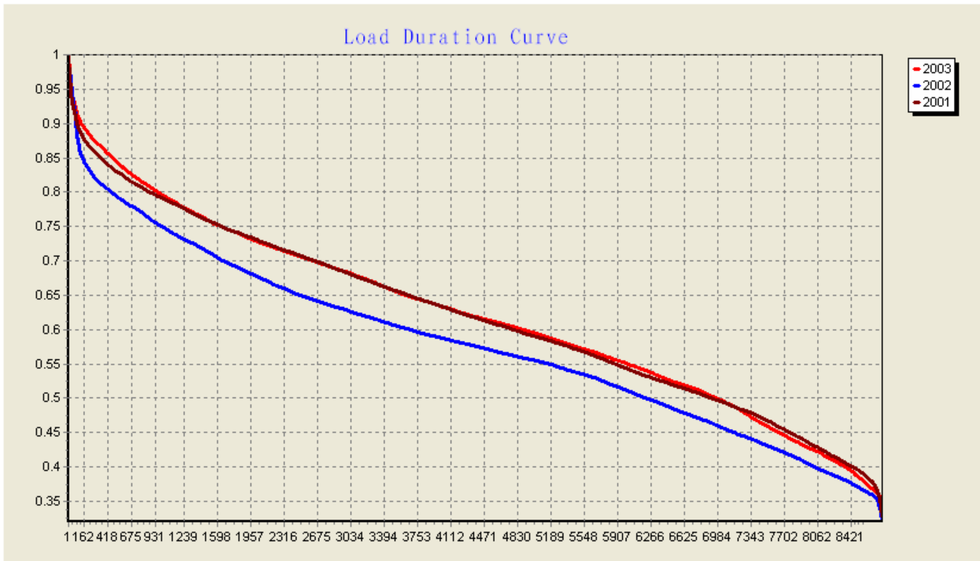
3.2 China's experience with load management provides a solid foundation for load management to continue to help address the power shortage, and to manage system resources efficiently over time. During the power shortage the real benefits of load management have been clear; it helped to avoid some involuntary outages and the heavy costs incurred during power supply disruptions.

3.3 The benefits of load management during shortages will be measured by the economic and environmental savings of particular strategies. Savings will include generation-related capacity costs, transmission and distribution system savings, and some operating cost savings. The exact level of savings will vary from system to system.

3.4 The cost of load management strategies also varies. For example, storage technologies, such as ice-storage air conditioners and heat-storage electric boilers, have been developed in East and South China and cost about $150 to shift 1kW of load. Cement industries have enlarged the miller capacity to shift load from on-peak to off-peak periods. This strategy requires about $250 to shift 1kW of load. This compares favorably to the cost of about $350/kW for peaking capacity.

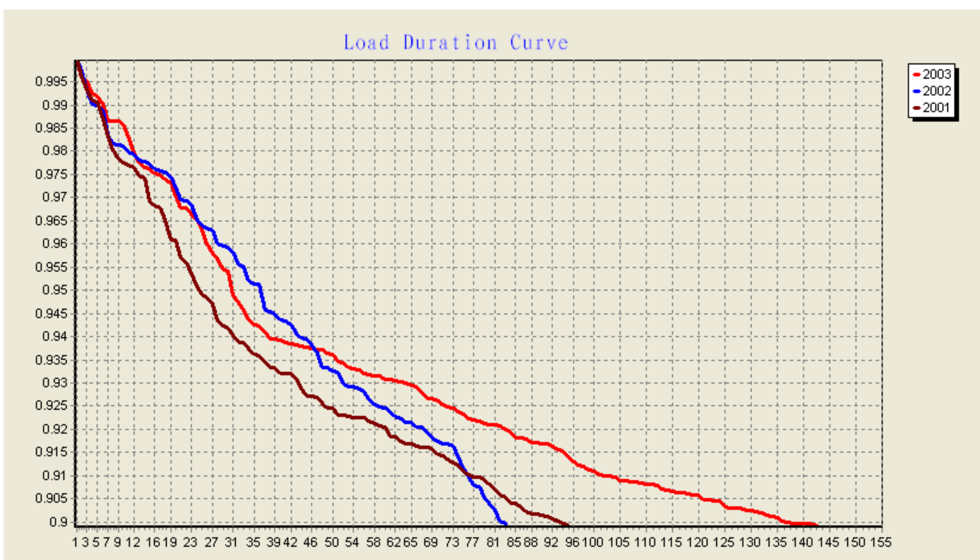
3.5 Load management practices are especially well-suited to reducing the highest peak loads that last for relatively few hours. As shown in the following figures, during 2001–03 there were less than 35 hours each year that load was more than 95 percent of Beijing's annual peak load, and less than 140 hours that the load was more than 90 percent annual peak load. The Shanghai grid shows similar peaks that were critically high for relatively few hours.

Figure 3.1: Load Duration Curve of Beijing Grid in 2001, 2002, and 2003



Source:.Study Team

Figure 3.2: Peak Period Load Duration Curve of Beijing Grid in 2001, 2002, 2003



Source: Study Team

3.6 Under present forecasts, China's electricity demand in 2020 is expected to be about 4,400 TWh, excluding any effects of DSM, and the peak load will be about 840 GW. Of this demand, about 40 GW would be the peak demand that is over 95 percent of the annual peak. The benefits of clipping or shifting these 40 GW would be very large. Load management will be a crucial strategy for reducing this peak demand.

3.7 As China's economy grows and commercial and residential sector electricity use rises, load factors will tend to decrease. A simulation study[w] shows that improving the load factor in China by 1 percent in 2003 could have saved more than 7 million tce annually by improving efficiency of generating stations, assuming that total energy consumption did not also rise.[7] These figures suggest that load management should continue to play an important role as a feature of DSM in China.

Savings Potential of End-Use Electrical Equipment in China

Energy Efficiency and Energy Intensity in China

3.8 Remarkable progress has been achieved in energy conservation in China, in part because energy use has made steady gains in efficiency over the past 20 years. However, considerable improvement is needed in order to bring China in step with the international levels of advanced energy intensity.

3.9 A direct comparison of energy intensity per dollar of GDP between countries is complex. On a simple basis, China uses 1,067 tce per million dollars of its GDP. This is 3.8 times the world average level, 6.0 times the energy intensity of Europe, and 11.2 times the energy intensity of Japan (See Appendix B.) Adjusting the economic data for purchasing power parity (PPP) brings the countries much closer together.[8] For example, on a PPP basis China's energy intensity is roughly equal to the world average and is only 1.4 times Japan's energy intensity.[x]

3.10 A more useful comparison is energy consumption per unit of production for particular industries or products. China's energy intensity in 11 major industrial sectors is much higher than international standards. Those sectors—coal, petroleum refining, power, steel, nonferrous metal, building material, chemistry, light industry, textiles, and railways and transportation—use 82 percent of the energy consumed in industry and transportation, with total use of 892 million tce (Mtce) in 1997. Analysis of energy inputs reveals that the average value of energy consumption for 13 products in these industries was higher than international advanced levels by 6–36 percent in 2000, or 230 Mtce more for those products alone. Total energy consumption for all products in these sectors was 300 Mtce more than international advanced levels.

3.11 Low investment in energy-efficient technology and practices is only one of many reasons for China's higher energy intensity. For example, China's steel output was the same as Japan's in 1997; however, China's energy consumption for steel was 40 Mtce more than in Japan. This is due to China's smaller equipment scale and the low recovery

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7 That study also found that lowering line losses by 1 percent could save nearly 7.5 million tce annually in thermal generation requirements. Lower line losses can be achieved in a variety of ways, including more efficient transmission, distribution, and transformation technologies; some load management options; and energy efficiency measures.

8 PPPs are the rates of currency conversion that eliminate the differences in price levels between countries.

rate of waste heat resources in the steel industry, among other reasons. (See Appendix B for more detailed data on national and product energy intensity.)

3.12 In the Tenth Five Year Plan, it is estimated that the total potential energy saving for all fuels is 400 Mtce. By 2015, total energy conservation potential will grow to about 900 Mtce. This general conclusion is also true with respect to the energy conservation potential of end-use electrical equipment throughout China.

3.13 The major equipment-related end-uses for electricity consumption are pumps, blowers, air compressors, industrial electric furnaces, rolling mills and take-up machines in mines, electrolysis and electroplating equipment (for aluminum, alkali, and other products), rollers, trolley buses, electric engines, electric welding machines, lighting, and home appliances. In general, the efficiency of electric equipment is low, and the potential for energy conservation is high. The energy-saving potential for important categories of end-uses is discussed below.

Electric Motors

3.14 Electric motors account for 60 percent of all electricity consumed in China. Improving the efficiency of medium and small electric motors is an important priority, because their total power capacity accounts for 75 percent of all electric motors.

3.15 Before the 1980s, China used a large number of electric motors in the "J" series, with an efficiency of just over 86 percent. At the beginning of 1980, the "Y" Series electric motor was introduced in China. Compared to the "J" series motor, starting torque was improved by 30 percent and the size and weight were both reduced by 10 percent. Efficiency, however, was essentially unchanged, improving by only 0.412 percent.

3.16 At the end of the 1980s, the "Yx" series of electric motors was developed, which improved efficiency of 92 percent. At present, "Y" series motors account for 70 percent of three-phase electric asynchronous motors, while "Y2" series motors account for 10 percent. The average motor in China is 3–5 percent less efficient than the average international level of motor efficiency. An American energy conservation research institute (American Council for an Energy Efficient Economy; ACEEE) estimates that the potential for energy conservation is 33 TWh per year if motor efficiency can reach U.S. levels.

Distribution Transformers

3.17 Electric power passes through several steps of transformation from the electric network to the end user. Several transformer classes are used in China, including 500, 300, 220, 110, 35, 10, and 0.4 kV units. The electric power consumed by all transformers is very large, and the potential for energy conservation through better transformers is also impressive. ACEEE estimates that more efficient transformers could save 25 TWh annually in China.

Pumps, Blowers, and Air Compressors

3.18 As of 1990, pumps consumed 20.87 percent of total electric power in China, blowers consumed 10.43 percent, and air compressors consumed 9.39 percent.[y] The design, manufacture, and operation of pumps, blowers, and air compressors remain underdeveloped compared with the quality available in advanced countries. One problem is the low quality of precision machining during manufacture. Other factors contributing to the low efficiency of pumping systems include:

- mismatched parts of systems
- underloading of motors
- missing or inadequate equipment for testing, control, and timing
- inefficient piping and pumping system designs
- poor management and systems maintenance

3.19 Approximately 20–40 percent of the electric power used by these systems could be saved if the design and operation of pumps, blowers, and air compressors met existing Chinese government standards. Switching to variable-speed drives would improve energy efficiency by more than 25 percent. Increasing the efficiency of existing units by one third would save about 30 TWh of electricity annually.

Electric Furnaces

3.20 Electric furnaces consume about 5–7 percent of the total electric power in China. There are two main types of furnaces: smelting furnaces and heat-treatment electric furnaces. Many smelting furnaces in China use outdated, inefficient technology. If these furnaces were improved, for example, by changing to DC electric power, 10–20 percent of their electric demand could be saved. The electrical demand of heat treatment electric furnaces could be reduced by 30 percent if they were changed from a main-frequency furnace to an intermediate-frequency furnace. For some applications, infrared heating technology could be used for low-temperature heat treatment and dry furnace process, saving 25 percent of electric power requirements. The estimated potential for energy conservation from improving all low-efficiency electric furnaces would be about 9 TWh each year.

Rolling Mills, Elevating Conveyors in Mines and Cylinder Mills

3.21 There are over 500 steel firms in China and nearly 1,000 rolling mills. There are numerous elevating conveyors in mines throughout the nation. If the alternating current (AC) unit powering these systems were improved through the use of thyratron inverters, efficiency would be improved by 20–25 percent. If frequency controls were added to these motors, their electric power requirements could be reduced by 30 percent. By improving these technologies, about 8 TWh could be saved in these end-uses annually.

Electric and Internal Engine Locomotives

3.22 If the DC drive systems of electric and internal engine locomotives were improved by the addition of frequency-control systems, the power factor of those engines would improve by 20–40 percent, and system efficiency would be improved by 6–7 percent. This would reduce the electricity requirements of the vehicles by about 25 percent. Nationwide, the efficiency potential of these changes is about 2 TWh annually.

Trolleybus and Mine Engines

3.23 Changing the speed-regulating control for trolley buses and mine engines from a rheostat to a direct-current chopped-wave control would improve efficiency by 30 percent. The annual energy savings potential from these systems is 2.5 TWh.

Electrolysis and Electroplating

3.24 Electrolysis is used in the production of nonferrous metals such as aluminum, copper, zinc, and nickel and by the chlorine-alkali industry. Most of the processes use heavy-duty rectifiers. If high-efficiency heavy-duty rectifiers were adopted, the annual electricity conservation potential would be over 1.5 TWh. In addition, DC electricity sources are used for electroplating in China. This process results in low-quality products, takes longer, uses more materials, and consumes more electricity than more efficient alternatives. If these systems were replaced by systems using pulse electricity, quality and production would improve and electric power savings would be 2.5 billion kWh annually. Together, these two improvements would save about 4 TWh of electricity each year.

Electric Welding Machines

3.25 There are about 3 million electric welding machines in China, consuming about 0.8–0.9 percent of all electric power in the nation. The most common machine is the AC electric welding machine. The use of more efficient welding technologies would reduce electricity use by 30 percent. Retrofitting 1 million electric welding machines would save 1.8 TWh of electric power annually.

Transmission and Distribution System Line Losses

3.26 The loss rate in China's transmission and distribution system is large. In 1980, it was 8.93 percent. By 1996, it was reduced to 8.51 percent. In Japan, the loss rate in the transmission and distribution system is about 5.5 percent.[z] If China's system losses could be reduced by 1 percent, 20 TWh would be saved annually.

Lighting

3.27 Electricity for lighting consumes about 11 percent of all electric power in China. Many residential lamps are inefficient and if changed to high-efficiency fluorescent lamps, 75 percent of their electric demand would be saved. In addition, changing fluorescent inductance ballasts to electronic ballasts saves 39 percent of the electricity used in fluorescent lighting systems. CNIS estimates that adopting cost-effective minimum standards for lighting could save 42 TWh by 2010.[aa] (This estimate is now being reviewed by other researchers.)

Household Appliances

3.28 With the improvement of people's living standards, the penetration rate of household appliances in China has greatly increased. From 1985 to 2002, the number of refrigerators increased from 17.21 to 126.4 per 100 urban households and from 0.06 to 14.4 per 100 rural households. Refrigerators now account for half of all residential energy consumption. Color TV sets per 100 urban households increased from 6.58 to 126.4. TV sets (including black and white) increased from 11.74 per 100 households to 108.6 in rural areas. From 1995 to 2002, air conditioners increased from 8.09 to 51.1 per 100 households in urban areas. There are very large opportunities to improve the efficiency of these appliances as their usage grows in China. Some estimates show that annual residential electricity consumption will reach 360 TWh in 2010. If residential electric efficiency improved by as little as 3 percent, the electricity conservation potential would reach 10 TWh. CNIS estimated that cost-effective standards for 10 residential appliances could save about 43 TWh by 2010.[bb] (This estimate is also being reviewed by other researchers.)

Buildings

3.29 Energy efficiency in buildings can provide enormous savings. The total area of building space in China today is about 37 billion square meters (including both urban and rural areas). Most of these buildings are poorly insulated and drafty, and use inefficient air conditioning systems. As a whole, energy intensity per building area is two or three times greater than that of buildings in advanced countries with similar climates, so the energy-saving potential in the building sector is very large. If better design standards were employed for new construction and existing buildings were retrofitted to better standards, perhaps 50 percent of the energy conservation potential in new and existing buildings could be captured. Generally half of the energy savings are due to the use of more efficient equipment and the other half is due to a more efficient building envelope. If all existing public building (hotels, office buildings, shopping malls, and so forth) were renovated, estimated electricity savings due to improved building envelops would be over 75 TWh annually.[cc]

Cumulative Energy Saving and Environmental Benefits

3.30 As the analysis above reveals, active load management can play a big role in reducing the peak load in China, and energy efficiency can reduce both energy demand and peak load. By 2020, about 40–50 GW could be reduced by load management. Total savings from optimizing the electric efficiency potential of end-use equipment in China could total well over 220 TWh in the near term. While some of the specific estimates are being reviewed, it is clear that the DSM potential in China is very large. These findings are consistent with the findings in other developing and advanced countries.

3.31 Over the longer term (to 2020), the potential savings from DSM could be even more significant. With positive public policies and incentives to promote DSM, it will be possible to reduce both energy demand and capacity by as much as 5 percent each year.

For an investment in DSM of less than $5 billion, China could realize a reduction of $60 billion in power sector costs.

3.32 With this reduction, the coal savings would be 4–9.1 million tce each year. (figure 3.3). Emissions of carbon dioxide per ton of clinker will be reduced by 25–58 million tons each year (figure 3.4) and sulfur dioxide emissions would be reduced by 0.61–1.39 million tons each year (figure 3.5). It is clear that there are great social and economic benefits from DSM.[dd]

Figure 3.3: Reduced Coal Consumption (Mtce)

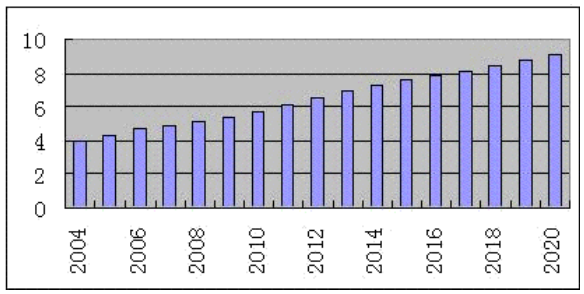
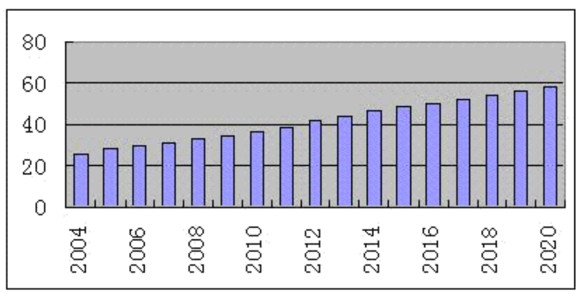


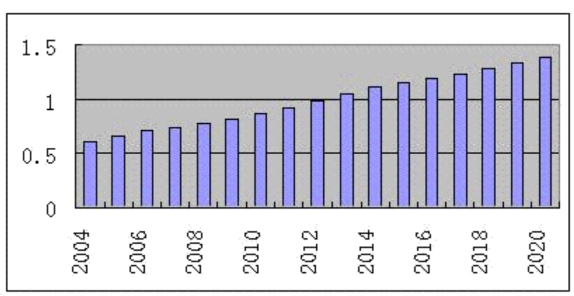
Figure 3.4: Reduced Emissions of Carbon Dioxide per Ton of Clinker (MT)



Source: Study Team.

Note: MT = million tons.

Figure 3.5: Reduced Emissions of Sulfur Dioxide (MT)



Source: Study Team.

Note: MT = million tons.

3.33 If these more efficient technologies were used, China would experience a lower cost of business, improved competitiveness, improved reliability of the electric system, and reduced environmental impacts from the electric system.

4

Major Barriers to Demand-Side Management

4.1 The focus of this report is on pricing (very broadly defined) barriers and options to encourage DSM. Inefficient pricing is not the only, or even the largest, barrier to DSM. For example, consider Pacific Gas and Electric Company California, where average residential retail electricity prices are about US$0.15 per Kwh and increase to more than US$0.21 for usage in excess of a baseline. These prices are in excess of marginal costs and give consumers very strong incentives to investment in energy efficiency. Still, barriers to consumers investing in energy efficiency mean utility DSM programs continue to find electricity savings that cost about US$0.03 per Kwh.

4.2 There are many well known barriers to consumer investment in DSM including lack of capital, lack of information, split incentives between owners and renters, and electricity prices that do not reflect the full direct and indirect costs of power. All of these barriers exist in China. In addition to these common barriers, China has its own unique barriers to DSM as discussed below.

Legal Obstacles

4.3 The laws governing DSM in the United States and other industrial countries have improved steadily for years, at both the national and state levels. These laws and regulations have boosted the development of DSM and paved the way for saving energy and power.

4.4 Addressing DSM barriers in China, such as assigning DSM responsibility, improving pricing methods, creating funding mechanisms, and assuring enforcement, will require the adoption of new and additional laws and regulations. China has approved the Energy-Saving Law and the Law of Power and issued the Measures of Power-Saving Management. However, the legal provisions concerning power, energy saving, and environmental protection need to be revised to reflect the current status of power sector reform, and to realize the potential of DSM to meet growing power needs.

DSM Funding

4.5 DSM programs employ a variety of means to encourage enterprises and consumers to save energy. For example, most successful international DSM programs provide customers with financial incentives to make cost-effective investments in efficiency measures. In many of these programs, a customer receives a rebate designed to cover the extra cost to purchase high-efficiency equipment. These payments, as well as other DSM program management and evaluation costs, are incurred by the utility and must be funded in one way or another.

4.6 International experience shows funds for DSM may come from the following:

- power grid enterprises, through rate tariffs
- government
- end-use customer payments
- energy service companies
- international banking organizations
- other organizations

4.7 Other studies have reviewed international experience relating to funding sources and DSM administration. By far, the most common approach is to fund DSM through electricity prices. As described in Chapter 6, this approach makes most sense in China as well.

4.8 Regardless of the source of funds, international experience is clear that it is most important that DSM funding is adequate and stable. China may need to create special funds to support DSM within the power sector, perhaps as a percentage of the overall power rates as is common in the United States and elsewhere.

Unclear DSM Responsibility

4.9 At the present time, it is not clear which entity or entities have responsibility for DSM implementation. The most successful international DSM experience shows the need for clear policy support and direction from the government, including utility-sector regulators. In China, DSM policy support from the government is improving but more support is needed.

4.10 In China's power sector reform, power grid enterprises were separated from the government and were no longer entitled to exercise governmental functions. In addition, with the elimination of the Three-E offices, the government had no department with clear, ongoing DSM responsibility. With the lack of an institutional home, DSM planning and policy has fallen off. DSM will not succeed unless there is a clear assignment of responsibility. Power grid enterprises are likely to be the main entity to implement DSM.

However, power grid enterprises will not implement DSM without supportive government policies.

4.11 Supportive policies must come from NDRC and SERC, and must include the participation and guidance of local economic and trade commissions and planning departments. Support within these agencies is needed to formulate, implement, and enforce policies. It is important to coordinate with relevant government agencies (such as finance, taxation, price, and standards) to develop the best rules and systems to guide and support the implementation of DSM policies.

Power Pricing

4.12 China has a unique approach to pricing generation that discourages efficient retail pricing and increases grid company disincentives for DSM. TOU prices for larger customers are being implemented on an accelerated schedule, and have shown significant effects in shifting loads and keeping load factors high. However, TOU prices for generation are lagging far behind. As a result, grid companies experience very little change in their costs on a time-of-day basis. Shifting customers to TOU prices without simultaneously reforming generation pricing undermines cost-based ratemaking, provides mixed incentives to power supply companies, and causes serious revenue problems for grid companies.[9]

Tariff-Setting Methods

4.13 Financial policies are also needed to encourage power enterprises to implement DSM programs. Grid companies are generally allowed to include the cost of buying power in the prices they charge consumers. Currently, however, there is no policy that allows grid companies to include the cost of DSM in the electricity price even if meeting consumer needs with DSM is less costly than buying power. In addition, DSM reduces the volume of electricity sales and revenues of the grid enterprises. As a result, regulators may need to change the way tariffs are calculated for grid companies in order to support DSM. This means regulators may increase the price a bit to recover the DSM investment and related losses when power grid enterprises apply for electricity rates.

Energy-Saving Technologies and Methods

4.14 Most of the energy efficiency technologies described in this report are already available in China. However, the technologies and practices are constantly improving. The development of new and better energy efficiency and load management technologies depends in part on scientific and technological progress. Most countries have established

[9] TOU peak-period consumer prices are much higher than peak-period generation costs paid by power supply companies. Similarly, off-peak prices are much lower than off-peak generation costs. As a result, incremental on-peak sales are very profitable to power supply companies, and off-peak sales are made at a loss. This creates incentives to promote off-peak conservation, rather than the on-peak conservation activities that would be more beneficial for society.

DSM technology research institutions to address a number of technical issues in efficient technologies and DSM procedures. China would benefit from increased investment in R&D in energy efficiency technologies, as well as research on DSM potential and DSM best practices in such areas as rate design, innovative regulation, and DSM implementation.

Energy-Saving Product Quality

4.15 Some of China's energy-efficient products have quality problems. For example, energy-saving compact fluorescent lamps of both good and bad quality are available in the marketplace and consumers have no way of knowing the difference. Low-quality bulbs may last no more than a dozen hours. Poor quality deprives the consumer of any economic benefit and injures the reputation of energy-saving lamps.

4.16 Labeling, certification, and quality guarantees have been used successfully to address this issue in other countries. China has had some success with improving the quality. The quality of many licensed brand products is guaranteed, and the performance of some lamps has exceeded factory standards. The decision by the State Council to further strengthen the quality of products will promote the improvement of energy-saving products.

Lack of Education and Awareness of DSM's Potential and Benefits

4.17 Successful DSM programs demonstrate that it is important to give customers information about the best ways to increase efficiency. It is necessary to launch publicity and offer training to power consumers who are lacking general knowledge about efficiency and load management opportunities.[10]

4.18 In China, DSM enjoys a positive reputation in relevant government departments, but it is not well understood among power consumers. Promoting greater awareness of DSM opportunities and its benefits is a challenge. The consumers will take advantage of cost-effective DSM opportunities when they receive useful information.

4.19 Education also leads to consumer support for needed government policies. For example, consumers in northern China supported the collection of fees for the treatment of waste water after they learned that funds were needed to protect the local environment.

[10] One company that has done a good job with public education is the German RWE Energy (Electricity) Company. The DSM program designed by the company addresses residents, commerce, agriculture, industry, and municipal institutions separately. It consists of three parts: energy-saving consulting; energy-saving measures; and financial aid and fixed prices for equipment. It offers all kinds of consulting services for consumers and has set an example for other power grid enterprises. Many ideas, measures, and details of implementation of its consulting activities have been employed by other power grid enterprises.

Shortage of Talented DSM Professionals

4.20 Talented people play an obvious role in DSM. They are needed to develop DSM policy, programs, and finances; develop technology; launch publicity; and conduct surveys. Currently, specialized DSM staff does not exist to implement broad-scale DSM programs in China. The Fujian power grid enterprise has a special DSM position at the provincial company, but there are no similar positions in organizations below the provincial level. DSM work is regarded as one of many jobs for staff members of the government departments.

5

The Impacts of Power Sector Reform on DSM

5.1 Reform of the electric industry in other countries and states has had substantial impacts on investment in demand-side resources, both positive and negative. But only in those places where explicit policy care was given to DSM did the reforms have beneficial consequences for the electric system and its customers.

5.2 A recent study by the IEA's Demand-Side Management Program examined how power sector reform affects DSM. The study found that typical power sector reforms do little if anything to reduce the barriers to DSM and that many reforms, such as China's separation of generation from the grid, actually increase the barriers to DSM. The IEA study also found that the

> *"…overarching policy barrier that affects all electricity industry structures …is the lack of regulatory or legislative attention and interest in energy-efficiency issues."*[ee]

5.3 This chapter lists seven major effects restructuring has had on DSM internationally, including energy efficiency.

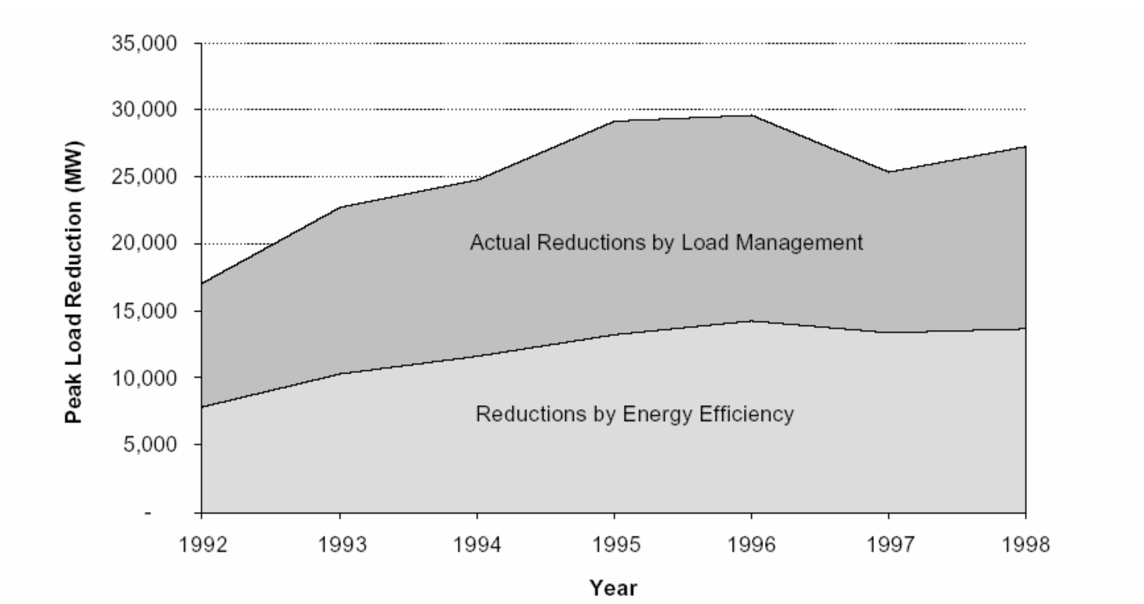
Regulators and Policymakers Shifted Attention and Focus from DSM to Restructuring

5.4 Prior to restructuring, interest in DSM was to a large extent driven by regulatory and policy-maker support for DSM. In the United States, Integrated Resource Planning (IRP) and the experience of a few leading states showed regulators and others that DSM could produce large economic and environmental benefits and could avoid the need to build unpopular and polluting generating plants. This focus yielded substantial policy support for DSM and led to steadily increasing utility investment in DSM and energy efficiency. When the nation's attention turned to restructuring, regulators and utilities focused on issues such as stranded cost recovery, retail access, and the rules for new investment. Uncertainty about who would make new investments and how the costs of new investments would be recovered led to a substantial drop in utility investment in all areas, including DSM and energy efficiency.

5.5 Total spending by utilities in the United States on DSM declined by nearly 50 percent between 1993 and 1998. In 1993, utility spending for all DSM (efficiency and load management) totaled $2.7 billion. At that time, based on the utilities' announced plans, the U.S. Department of Energy projected a 20 percent increase in DSM spending to about $3.5 billion by 1998. Instead, spending dropped to $1.5 billion, a decline of 45 percent in four years, and a reduction of 57 percent when compared to the trend line of 1991–93.[ff]

5.6 Reduction of utility-sponsored DSM programs between 1994 and 1999 dramatically reduced the contribution such programs could have made to meeting both energy needs and peak demands since then. By 1993, DSM-related peak load reductions were growing by about 4,000 MW per year. However, after 1995, progress stalled and total peak load reductions remained virtually flat until 1999.[gg]

Figure 5.1: Peak Load Reductions from Efficiency and Load Management in the United States



Source: Cowart, 2001, p. 27.

5.7 In 2000 and 2001, power crises mounted in California and the western United States, and reserve margins narrowed in the eastern United States. As a consequence, demand-side resources received renewed attention and policy makers restored much of the funding that had been cut back in prior years.

Focus Shifted from Planning To Markets and Choice

5.8 Proponents of restructuring worldwide believed that retail competition would include innovative offerings by retailers and ESCOs that would overcome the barriers to DSM and energy efficiency. It is important to understand that this has not been the case in any electricity market in any country. The market and regulatory barriers to DSM, especially to efficiency, still remain in restructured systems. In fact, by separating previously integrated utility functions, and exposing power suppliers to short-term price pressures, many restructuring plans have actually increased the barriers to DSM.

Unbundling the Utility Also Unbundled the Benefits of DSM

5.9 DSM programs produce generation, transmission, and distribution savings. Worldwide, prior to restructuring, utilities could compare these combined savings to the cost of DSM when deciding whether a DSM program was cost-effective. However, power sector reform in some countries and some U.S. states separated generation from transmission, distribution, and retailing in ways that dispersed the DSM cost savings among two or more separate entities. DSM that would have been cost-effective to a vertically integrated utility might now not be cost-effective to any single industry participant.

5.10 Resources such as energy efficiency (which produces savings in generation), distribution, and transmission are disadvantaged in restructured markets that do not allow participants to capture all those values simultaneously. The separation of generation from monopoly transmission and distribution service is necessary to create fair and competitive generation markets, but it has undermined DSM.[11] The challenge has been to find restructuring options and mechanisms that will capture the benefits of both restructuring and DSM.[12]

Restructuring Increased Disincentives for Power Supply Company Investment in DSM

5.11 Separation of generation from transmission and distribution creates smaller companies with lower earnings that magnify the disincentives for grid company investment in DSM. For grid companies net revenue losses (revenue loss minus variable cost reduction) resulting from DSM are essentially the same as was before restructuring. But after separation, the net revenue loss has to be absorbed by a smaller utility total level of revenues and earnings. The same net revenue loss on a smaller level of earnings accentuates the revenue-losing aspect of DSM.[13]

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[11] In the case of a single-buyer market, separation of generation from the grid is less of a problem for DSM, since the single buyer is still financially responsible for generation, transmission, and distribution.

[12] These effects apply to the typical restructuring plan. The details of any particular restructuring plan can yield different conclusions. For example, the restructuring plan in place during the California electricity crisis provided very strong incentives for the power supply company to invest in DSM. The power supply company was required to buy all power from the spot market and sell to consumers at frozen prices. When market prices skyrocketed, the grid companies lost money on each kWh sold. Investing in DSM also lost money, but the losses were much lower than the cost of power. Cutting losses provided a large incentive to the grid companies to invest in DSM.

[13] This powerful effect is multiplicative, not proportional. On many distribution systems, a sales increase (or decrease) of 5 percent over a rate period can increase (or decrease) profits by 25 percent or more. Sample calculations are contained in Coward (2001). Linking distribution company profits to sales levels, not service quality, is a major barrier to investment in energy efficiency resources.

Loss of Some Pricing Options That Encouraged Customer DSM

5.12 One of the many DSM strategies implemented by regulators prior to restructuring was the increased use of sophisticated meters and pricing options. Many larger customers were required to install real-time or other advanced metering and were required to be on TOU prices. These prices reflected the cost of producing and delivering power at different times and different places. With restructuring and retail access, these customers were free to choose among competing suppliers, or (in most states) to choose a simplified "default service" plan. Customers were no longer required to be on any particular price structure. Many of these customers preferred the certainty of fixed prices to the more efficient TOU prices they were previously required to take. Thus, although the expectation of many was that restructuring would lead to innovative pricing, retail competition helped many customers avoid the price volatility of generation markets, and dampened their interest in load management options that could provide benefits to the grid as a whole.

Increased Price Volatility Encourages Load Management

5.13 Many restructured markets have experienced much higher levels of price volatility. Where restructured markets have exposed customers to this price volatility, customers have responded in a variety of ways. Some have changed to suppliers that offered stable prices and some have invested in load management options.

Retail Access Has Increased Prices for Some Industrial Customers

5.14 In many countries and some U.S. states, industrial customers were given preferential prices below market prices. Restructuring in some places resulted in the loss of these subsidized prices and industrial prices increased. Industrial customers' responses to higher energy prices have included increased investment in DSM and energy efficiency. It is thus important that restructuring plans provide for technical and financial assistance to energy-intensive industries, to lower their costs and improve their competitiveness.

Conclusions

5.15 There are several conclusions that can be drawn from international experience with restructuring and DSM:

- The expectation that the power sector will be reformed leads to significant reductions in existing DSM programs or makes it very difficult to implement such programs.
- Power sector reform will not address energy efficiency or DSM unless the government adopts specific policies that make them a part of the restructuring process.
- Separation of the grid from generation makes it more difficult for any one entity to see the full value of energy efficiency. A single buyer, however, retains the

incentive to capture all of the generation, transmission, and distribution value of DSM, provided that buyer has the proper regulatory incentives and policy support to do so.

- Markets deliver what they are designed to deliver. If the market is designed to deliver energy efficiency, it will. If it is not designed to deliver energy efficiency, it won't.
- To solve these problems, explicit action will need to be taken by decision makers. In the final chapter, an integrated set of policies that will promote cost-effective DSM investment in a reformed Chinese power sector is recommended.

6

International DSM Experience

6.1 Many countries and states have decades of experience with DSM in the power sector. Some of these jurisdictions have restructured their power sector, some have not, and some are in the process of doing so. The fate of DSM programs in the face of power sector reform has varied widely across the globe.[hh] This chapter summarizes some of the most successful DSM experiences with a special focus on DSM aimed at addressing power shortages.

6.2 In some jurisdictions, DSM programs are now coordinated by governmental or other agencies, rather than utilities, and are funded with taxes or general revenues, rather than by ratepayers. However, in most countries DSM is funded through electricity bills and the electric utilities are actively involved in program design and delivery.[ii]

6.3 In the European Union, after liberalization of the electricity and gas markets, energy efficiency programs are continuing to be delivered by energy companies and, in some cases, are even being expanded in member states with policies supportive of DSM.[jj] In member states that are not supportive of DSM, programs have decreased, with only isolated practices by a few innovative companies. Results have been similar in the United States, South America, and Australia. Policies that support the continuation of DSM programs include the following, often in combination:

- an agreed-upon or mandated quantified target for energy savings
- a funding mechanism that strengthens or does not harm the competitive position of the energy companies practicing DSM
- a standardized and mandatory scheme for cost/benefit evaluation of the DSM activities
- price regulation of the remaining monopoly segments (transmission and distribution network and retail supply to noneligible customers) in a manner that removes artificial incentives to increase sales and disincentives to save energy (this is current practice, for example, in the United Kingdom, Italy, Norway, Denmark, and New South Wales, Australia).

6.4 International studies consistently show very large potential DSM benefits for the economy, employment, environment, supply security, and system reliability. Consider the following:

- South Africa's largest electric utility, Eskom, expects to avoid building 7,300 MW of new capacity through the use of energy efficiency and load management, even while adding 5,000,000 new customers by 2007.
- Even in countries with 20 or more years of experience with DSM, the potential for savings and resulting benefits remains high. For example, if the current isolated energy efficiency programs in the EU were expanded to reach the entire EU and were "…continuously developed, they could reduce EU electricity and gas consumption by 10 percent compared to the forecast within the next ten years. This would be equivalent to a net economic gain of around 10 billion euros per year."[kk]
- The southwest is the fastest-growing region in the United States in terms of both population and electricity use. With the accelerated deployment of presently available energy efficiency technologies and other supportive policies, total electricity consumption in the region could be cut 33 percent from the base case (business-as-usual) scenario by 2020. And it could all be achieved at an average cost of $0.02 per kWh.[ll]

6.5 International case studies illustrating cost-effective DSM programs appear in Appendix C. Most of the case studies occur in the restructured electricity market. A few others are included because, with policy support, they could be effective after power sector reform. These DSM case studies demonstrate two remarkable consistencies across many countries:

- Not all cost-effective DSM is delivered in the marketplace. This is true with or without power sector reform.
- DSM programs can be designed and implemented to deliver large amounts of energy efficiency at very low cost.

International Experience Using DSM to Address Power Shortages

6.6 International experience shows that DSM can address power shortages. In designing responses to its current power shortages, China can learn from the successes and mistakes of others. The most important lesson is that aggressive, sustained investment in DSM, especially energy efficiency, can provide a substantial fraction (25 percent and sometimes up to 100 percent) of the load growth needs of a power system. Demand-side options also offer a number of complementary advantages:

- In contrast to short-term crisis responses such as involuntary curtailment, long-term investments in demand-side resources can permanently improve the demand-supply balance without requiring that customers forego use of power when they need it or forcing them to reduce their economic output or quality of life.

- In contrast to conventional generation resources, DSM can lower stresses on the electric grid at the point of consumption, improving reliability of local distribution grids and transmission delivery systems as well as improving the overall demand-supply balance.
- In contrast with the high economic costs of involuntary curtailment and the long-term economic costs of adding supply, low-cost efficiency investments can lower the overall cost of electricity service to the economy and lower the environmental cost of the power sector.

California's Response to the Western Regional Power Crisis—A DSM Success Story

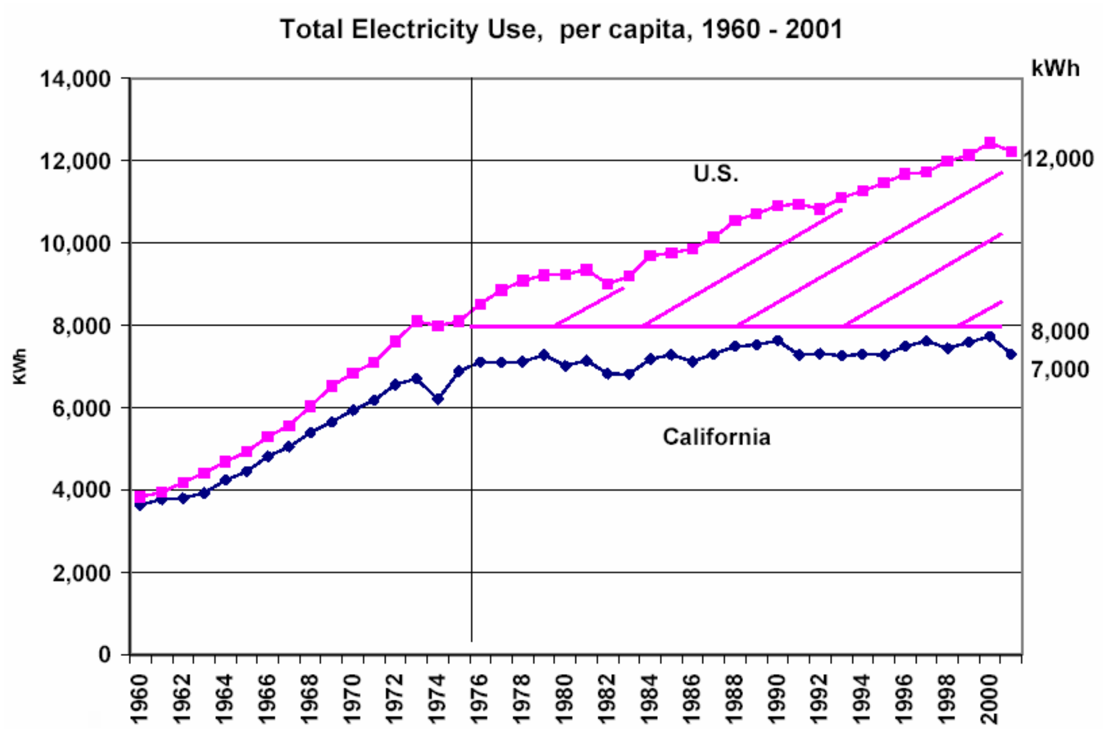
6.7 California's energy crisis provides many useful lessons, most of which are lessons in what not to do. Many painful mistakes were made that led to the crisis and more mistakes were made that prolonged and aggravated the crisis. But there were a few successes, including the demonstration that DSM could play a major role in addressing the power shortage.

6.8 Indeed, the leading example of the use of DSM to help resolve a critical power shortage is California, which experienced severe shortages during the western U.S. power crisis of 2000–01. California's was already one of the most energy-efficient electric systems in the United States. Although the state's economy has grown rapidly in recent years, (California's gross state product more than doubled in real terms during the 1980s and 1990s), electricity consumption grew much more slowly. This was because of a combination of technology-forcing legal requirements, including building codes and appliance standards, and a full range of utility efficiency and load management programs. Compared to the nation as a whole, load growth grew in California at about 50 percent of the national average rate.

6.9 Figure 6.1 shows how DSM policies in California have kept load growth in that state far below the rate of growth in the United States generally.

6.10 There were many reasons for California's success in cutting load growth. Two important ones were (a) California maintained a clear state policy to invest in low-cost efficiency over a long period of time, so benefits could grow, and (b) many complementary policies were used to achieve efficiency savings, including building codes, appliance standards, government spending, utility rate policies, and utility DSM programs supported through utility tariffs.

Figure 6.1: Total Energy Use Per Capita, 1960–2001

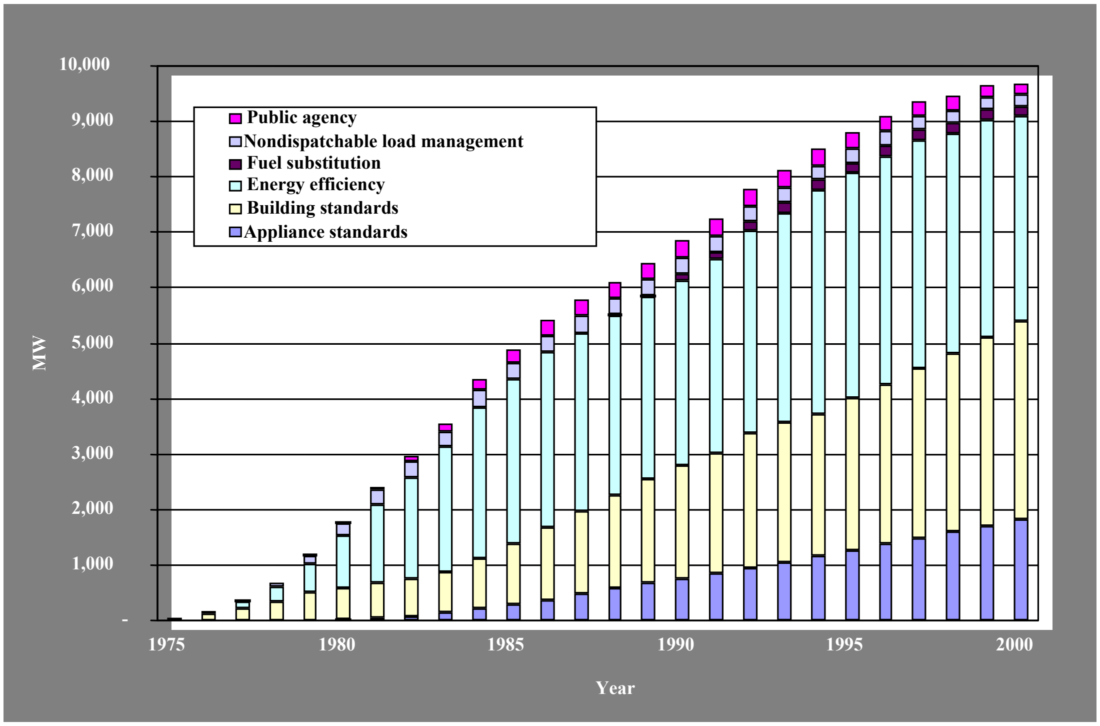


Source: California Energy Commission 2002

6.11 As figure 6.2 shows, these policies worked together and the benefits have grown over time. The largest savings have come from efficiency resources, not short-term load management. (The three largest bar segments are appliance efficiency, building codes, and utility efficiency programs.) These DSM resources had already lowered peak demand in California by 10,000 MW, a substantial fraction of the state's noncoincident peak of about 50,000 MW in 2000.

6.12 In response to the crisis, California's political leaders and utility regulators launched an intensive and broad program of DSM measures, which had the effect of lowering peak summer demand by more than 10 percent and annual electric consumption by an additional 6 percent within one year, even as the economy continued to grow.[mm] These efficiency savings were captured at an average cost of about \$0.03 per kWh, much less than the average cost of power generation in that period. The programs also avoided between 50 and 160 hours of rolling blackouts.

Figure 6.2: California Cumulative Energy Efficiency Savings



Source: California Energy Commission *2002*

6.13 The efforts included load management, energy efficiency, education, and pricing programs. A 2003 study examined the magnitudes, sources, and costs of the savings contributing to California's successful DSM deployment. Table 6.1 summarizes the impacts and costs of California's combined efforts.

6.14 The study found that 218 programs spent a total of $893 million in 2001 to save 3,389 MW of summer peak demand and 4,760,184 MWh of annual energy usage at a lifetime cost of $0.03 per kWh.[nn]

Table 6.1: California's Energy Savings, 2001

Program category a	Number of programs identified	Reported cost ($millions)	Reported first year energy savings (MWh)	Reported demand savings (MW)	Cost per first year kWh saved ($/kWh)	Cost per lifetime kWh saved e ($/kWh)
#1 PGC-funded, IOU administered	149	249	1,254,539	323	0.23	0.03
#2 CPUC-funded summer initiative	16	70	266,556	132	0.26	0.03
#3 CEC programs	8	19	124,766	61	0.15	0.02
#4 Major municipal programs b	31	30	60.660	104	0.49	0.06
#5 Locally administered programs c	10	5	663	n.a	8.21	1.04
#6 Other targeted state programs	2	60	n.a.	152	n.a.	n.a.
#7 20/20 Rebate & residual effects d	2	415	3,053,000	2,616	0.14	0.05
Total	218	893	4,760,184	3,389	0.19	0.03

Source: Global Energy Partners (2003).

na = not applicable

CEC = California Energy Commission; CPUC = California Public Utilities Commission; IOU = Investor Owned Utilities; PGC = Public Goods Charge.

a. For a complete definition of the program categories, please see Table ES-1 in the source document.

b. Los Angeles Department of Water and Power (LADWP) and Sacramento Municipal Utility District (SMUD).

c. City of San Francisco and City of Berkeley.

d. Includes 20/20 Rebate Program (discounted for double counting) and residual effects, including the Flex Your Power public awareness campaign, free media coverage, and increasing rates.

e. Based on weighted average lifetimes of measures for each program category, and a discount rate of 8 percent.

6.15 One of the more successful innovations was the "20/20 Program," a new rate design approved by regulators that gave individual consumers a 20 percent rate reduction if they lowered their consumption during the summer months by 20 percent as compared to their consumption in the year 2000. One-third of all residential customers qualified for this rate reduction, and the program provided about two-thirds of the demand and energy savings captured in the first year of the crisis response program.

6.16 An especially positive effect of the 20/20 Program is that it caused some consumers to change their behavior, and it caused many other customers to buy more efficient appliances and air conditioners and to enroll in utility efficiency programs. Consumers bought record numbers of energy-efficient appliances in 2001, including nearly 100,000 high-efficiency refrigerators (over five times more than in 2000) and four million compact fluorescent light bulbs.[oo]

6.17 The following text box provides an illustration of an interesting residential refrigerator program. It also provides more detail on where and how DSM funds are spent.

Box 6.1: California's 2001 Residential Refrigerator Retirement Program

Refrigerators are of special interest because they are one of the largest residential end-uses and because experience shows that some DSM programs aimed at refrigerators led to the consumer buying a new efficient unit but keeping the old unit operating as a second unit, giving it away, or selling it. Allowing the inefficient unit to remain in-service substantially eliminates the expected energy savings.

California's program was interesting because the program offered rebates to consumers for the pick-up of their old, inefficient (yet operable) refrigerator. In addition to energy savings, the old appliances were sent to a recycling center to safely dispose of hazardous materials and recyclable parts (PCBs, CFCs, mercury switches, and compressor oil).*

The program was run by an ESCO on a full-cost, full-service contract, paid for with public and utility funds. The ESCO was responsible for marketing the program; picking up, dismantling, and recycling the units; and all customer contacts. As shown below, the ESCO essentially was paid a fixed fee of $212 per unit. The ESCO paid customers $50 per unit to "buy" the old unit. This left $162 per unit to pay all other costs.

Most consumers used the $50 to help buy a new refrigerator, which because of stringent energy standards, was much more efficient than the old unit.

Total program cost:	$1.46 million
Total units:	7,052 (phase 1)
Cost per refrigerator:	$212 (decreased to about $170/unit in phase 2)
Customer incentive:	$50 per unit (decreased to $35 in phase 2)
kWh saved per unit:	875 kWh per year
kW saved per unit (peak period):	0.12 kW

Source: Heschong Malong Group and BLW Analytics, May 29, 2003, Measurement and Verification of SB5X Energy Efficiency Programs, HMG Project #0104.

Lasting Effects and Lessons Learned

6.18 It is widely recognized in California that DSM initiatives during the power shortage provided crucial power resources and lowered the state's electric bill. There has been strong political and financial support to continue and extend the success of these programs.

6.19 In April 2001, the California legislature and the governor approved new laws (SB 5x and AB 29x), which directed the California Energy Commission (CEC), the California Public Utilities Commission (CPUC), and other state agencies to implement, as quickly as possible, peak-load reduction programs. This legislation created energy efficiency and demand reduction programs that represent the largest conservation effort ever launched by a single U.S. state. California substantially increased funding for utility DSM programs in 2001 by adding $850 million of government funds to the roughly $240 million collected in electricity prices. Appendix C summarizes the peak reduction programs put in place to help avoid electricity emergencies during the summer of 2001 and beyond.

6.20 The legislature also extended until 2012 the use of the system benefit charge (SBC), a small surcharge on every California utility bill. During that time, this surcharge will raise more than $5 billion of investment in energy efficiency, renewable energy, and technology development, the largest sustainable energy fund ever created by a single legislative action.[pp]

6.21 In addition, reforms instituted since the power crisis have returned to utilities the obligation to buy or build new resources to meet customer needs. Integrated resource planning will be used to decide how to meet customer needs in a least-cost fashion. It is expected that utility resource commitments for new energy efficiency options will be about $750 million per year. Adding the utility resource procurement to California's SBC will bring total annual energy efficiency investment to about $1 billion, or roughly 4 percent of utility revenues.[qq]

DSM Initiatives in Response to the Crisis in the U.S. Pacific Northwest

6.22 The California crisis was felt throughout the western United States in 2001–02. The response in the Pacific Northwest was very impressive although it has received much less publicity than California's efforts. This region's experience may be of special interest to China because it has many energy-intensive industries, and a large fraction of the power generation is government owned.

6.23 As was the case in California, the U.S. Pacific Northwest has had substantial experience in delivering energy efficiency measures and programs to utility customers. Since 1980, when the Northwest Power Act made cost-effective energy conservation the highest priority for meeting new demand for electricity, the region's utilities and the federal Bonneville Power Administration have reduced demand for power by nearly 1,500 MW through investments in energy conservation in homes and buildings, industrial facilities, and irrigated agriculture. The savings were primarily due to energy-efficient water heaters, lighting, windows, and equipment for heating, ventilation, and air conditioning. In addition, new building codes that require energy efficiency saved 735 MW, and new energy efficiency standards for manufactured housing and major appliances captured another 375 MW in savings in the region.[rr]

6.24 Altogether the region's conservation achievements total more than 2,600 MW and energy conservation now accounts for 10.2 percent of the Pacific Northwest's electricity supply. That is, if the energy conservation measures, codes, and standards were not in place, the Pacific Northwest would use 10.2 percent more electricity than it does now. The reduced demand for power helps reduce the region's exposure to the wholesale power market, which was important during the energy crisis of 2000–01 when regional wholesale power prices rose to extremely high levels.

6.25 In addition to that strong base of long-term efficiency investments, the Bonneville Power Administration, utilities, and state agencies launched a number of initiatives to further reduce demand during the regional power shortage. As a result of these additional measures, demand reductions in the Pacific Northwest in 2001–02 exceeded an additional 4,000 MWs. As shown below, the reductions were achieved through a mix of innovative economic incentives and accelerated energy efficiency efforts.

- 2,500 MW: Curtailment of energy-intensive industries (includes 1,160 MW from BPA's buyback program and 1,200 MW of remarketed power)
- 300 MW: Irrigation load buyback (seasonal)
- 500 MW: Industries responding to high prices (includes operating their own generation)
- 160 MW: Suppliers paying consumers to reduce demand
- 150 MW: Consumers responding to rate increases
- 390 MW: Accelerated conservation programs and appeals to the public to reduce demand, and other influences

Lasting Effects and Lessons Learned

6.26 The increased investments in energy efficiency will deliver long-term savings to the region. The region's large-scale industrial and irrigation curtailments, however, are more controversial and are less likely to persist. Curtailments were possible because suppliers had signed long-term, low-cost contracts to deliver power at very low prices to certain irrigation districts and large industrial customers. When shortages and price spikes hit the system, a profitable option was to "buy back" that power from those customers, even if utilities had to pay higher prices to do so. The industrial customers could then curtail their operations or self-generate; irrigation customers could forgo a planting cycle, plant different crops, or install diesel pumps.

6.27 Whether this is a sound energy management strategy in the long term depends on the facts of individual cases. If subsidized electricity was supporting marginal industries, buying back the power and shutting the business (or dramatically upgrading its operations) may be an efficient policy choice. However, where businesses are shut down due to power shortages, indirect economic effects may be quite significant, even where the individual enterprise is compensated.

Widespread National Power Shortage: Brazil

6.28 With a power generation installed capacity of some 79 GW larger than the United Kingdom, Brazil is one of the largest electricity markets in the world and by far the largest in South America. There are approximately 50 million customers and total annual consumption has increased from 70 to 300 TWh in the last 20 years. Currently some 95 percent of the Brazilian households have access to electricity.

6.29 During 2001, Brazil experienced a major electricity supply crisis triggered by rapid load growth[14] and a severe drought. After five years of low rainfall, the hydroelectric power plants that generate 90 percent of Brazil's electricity supply were left with very low reservoirs and the government realized that dramatic steps had to be taken.[15] Under drought conditions, the short-run incremental cost of electric supply in Brazil was a liquid-fuel standby generator, costing approximately 10 times the average cost of hydroelectric supply and 4 times the retail rate. In June 2001, rationing was declared in three of Brazil's four electricity market zones—the Southeast, Northeast, and North—with a reduction target in the range of 20 percent. These markets correspond to roughly 80 percent of the country's GDP and population. The scheme continued into early 2002, and was then relaxed.

6.30 The government tried to alleviate the problem by promoting an emergency thermal plant construction program in which gas prices would be guaranteed for 20 years for plants starting operation before 2003. However, plants would still have to negotiate their supply contracts and project financing. Additional uncertainty about currency exchange hedges and the reluctance of distribution companies to support independent power projects meant that few projects were started.

6.31 In response to the looming power shortage, the Brazilian government created an Electric Energy Crisis Management Board (called the GCE). This board included eight ministers, the heads of public agencies, and other leading officials. It was granted special powers to deal with the crisis, including the following:

- power to set up special tariffs and discounts
- power to implement compulsory cuts and blackouts
- power to authorize public companies to bypass required bidding procedures for the purchase of new equipment

6.32 For the duration of the crisis, the GCE had the power to supersede the authorities of the preexisting national energy regulatory bodies, ANEEL (the national regulatory body), MAE (the power market manager), and ONS (the system operator).

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14 As a result of the economic recovery following the Real Plan implementation, load growth rates in Brazil achieved fairly high levels (more than 6 percent in the first two years). This could not be matched immediately by an increase in supply due to the time large for the construction of new power plants. Also, the government sector did not have enough funds to finance system expansion. Therefore, one of the main objectives of Brazil's power sector reform was to rely on private investment to provide the new generation capacity. This was not very successful and as a consequence of the delayed entrance of new power plants, the supply situation in years 2001 and 2002 became quite difficult.

15 During 2000, it became increasingly clear that the avoidance of rationing in 2001 and 2002 would depend essentially on favorable hydrologic conditions. Rather than beginning a curtailment or efficiency program in 1999 or 2000, the government and utilities hoped that it would rain. Unfortunately, this did not occur so dramatic rationing was needed in 2001.

6.33 In response to the crisis, GCE established five core programs:

- efficiency pricing measures[16]
- emergency increase of generation supply
- structural increase of generation supply
- revitalization of power sector model
- energy conservation

Pricing Measures

6.34 One of the first acts of the GCE was the establishment of pricing measures in the Northeast and the Southeast/Center-West submarkets to achieve energy use reductions. Reductions in energy use, rather than peak load, were necessary because the power system was energy-limited, not capacity-constrained. The system had enough capacity to meet peak loads, but it was necessary to keep the system reservoirs above a minimum level for emergency needs, even at the end of the dry season. This meant that while consumers needed to reduce overall consumption, there was no need to curtail power in any specific area, hour, or day.

6.35 The scheme was based on monthly energy consumption targets for each consumer class. For those residential consumers using more than 100 kWh per month, the target was 80 percent of their average consumption during May–July of 2000. Other targets were 90 percent for rural consumers, 80 percent for commercial consumers, 75 percent to 90 percent for industrial consumers (depending on the type of industry), and 65 percent for government buildings.

6.36 Residential consumers faced higher prices if they exceeded their target, but more important, they could have their service interrupted for a few days in the case of a repeat violation. On the other hand, consumers who saved more than their targets could receive a financial bonus which depended on the revenue from penalties.[17]

6.37 One unique innovation of the program was the ability of commercial and industrial customers to buy or sell quotas. Those customers had the option of selling or buying quotas or of saving part of their monthly quotas for later use. The GCE tried to establish a national market as the main locus for the sale and purchase of quotas, but it

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16 These measures were often called "rationing" measures. However, the actual program used price surcharges and credits to achieve the desired reduction in electricity use.

17 Argentina implemented a similar energy savings plan in May 2004. The plan aims to reduce electricity consumption by 5 percent. Under the plan, commercial and industrial customers with energy use over 600 kWh on a bimonthly basis who do not reduce their use by 5 percent compared to their use in the same period last year will have to pay a penalty on each additional kWh consumed. Commercial and industrial customers will receive a credit if they save more than 5 percent in relation to the amount of energy they consumed in the same period last year. Residential customers will not be penalized if they consume more than last year, as long as they consume less than 600 kWh over two months. If they lower their consumption, they will receive a credit on their bill equal to the cost of the amount of electricity they save in relation to the same period in 2003.

was surpassed by local markets set up by utilities and by other organizations such as state chambers of industry. The trading of quotas contributed to a more economically efficient pattern of energy saving by Brazilian enterprises.

6.38 The support of Brazil's population in energy saving was spectacular, and was the key factor in the avoidance of an economic disaster. Table 6.2 shows the share of savings from June–December 2001 compared with the same period in year 2000 and the share of savings with respect to the projected load in 2001.

Table 6.2: Brazil's Energy Savings, June–December 2001

	Region (%)			
Reference	**North**	**Northeast**	**Southeast**	**South**
Compared to the same period in 2000	18	20	21	2
Compared to the forecasted load in 2001	24	24	25	7

Source: Jannuzzi 2004

6.39 Table 6.2 shows that there was a 20 percent load reduction for seven months, compared with the previous year's consumption. If new customers who entered the system in 2001 are taken into account, these reductions reach 25 percent. It is interesting to see that even in the South region, which was not forced to reduce electricity use, customers participated in the load reduction effort as a result of appeals in the media.

The Role of Energy Efficiency

6.40 Even though the low water situation in Brazil had been developing for years, by the time a response was mounted, the situation was quite urgent. For this reason, the principal response by the Brazilian government and utilities was to impose mandatory electricity rationing. Load management was not needed, and utility-sponsored energy efficiency programs were not a major part of the policy response.

6.41 Nevertheless, some utilities also worked to accelerate distribution of high-efficiency consumer equipment. For example, in São Paulo, a local utility, Electropaulo, implemented a program to change light bulbs in low-income households as part of its effort to match loads to available resources. Over 4 million high-efficiency compact fluorescent light bulbs were given away in this program. Because this was developed as a drought response, Electropaulo was more interested in instantaneous implementation than in either long-term market transformation or programmatic cost reductions from efficiency. In many cases, low-income families were reselling the light bulbs in the market. The utility did not object, since the net effect of this was still to achieve energy savings. By reducing demand for electricity during the drought, the utility avoided high short-run costs and improved reliability for customers.

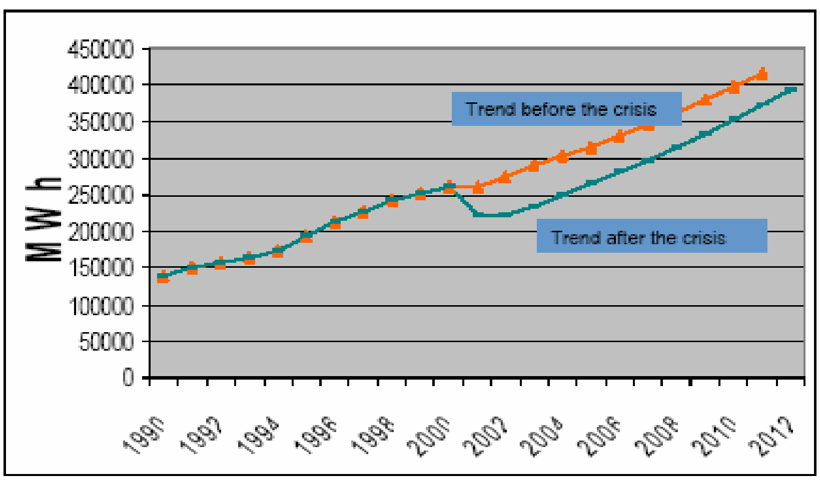
Lasting Effects and Lessons Learned

6.42 Even though Brazil's program lasted less than a year, it had some long-term effects on power consumption levels. During the crisis, the government and many utilities conducted massive energy-conservation awareness programs that taught people ways to save energy and cut costs. Many customers changed consumption habits and invested in more efficient end-use equipment during this period. Sale of compact fluorescent light bulbs increased by 300 percent and sales of incandescent bulbs decreased by 50 percent. As a result of these changes, Brazil used 7 percent less electricity in 2003 than in 2000, even though the economy grew at 4 percent per year in both years (see figure 6.3).

6.43 There are at least two important lessons from Brazil's experience in responding to the nation's acute power shortage. First, Brazil's planning process failed to anticipate the shortage and create responses in time to moderate the problem. Regulators in Brazil did not take the reform steps needed to encourage new investment in supply; they also did not take the steps needed to support cost-effective investment in demand-side resources.[ss]

6.44 Second, when the crisis was finally addressed, it was difficult to launch effective efficiency programs to achieve reductions, so the mandatory targets and pricing scheme was the only realistic option left to the power system. This is largely because utilities in Brazil only have modest experience in administering efficiency programs and there are no other large-scale organizations with this capability.

Figure 6.3: Brazilian Electricity Use Before and After Shortage



Source: Jannuzzi 2004

New York: Localized Shortages and Reliability Challenges

6.45 In the U.S. state of New York, utility spending on energy efficiency was cut by about 75 percent in the mid-1990s, despite projections by the Public Service Commission that increased demand would lower the reserve margin to an unacceptable level by the year 2000.[tt] By the summer of 2000, it became apparent that the combination of increased demand, limited transmission, and a lack of major new plants, particularly in

New York City, was placing unacceptable pressure on reliable service. Power shortages were acknowledged in 2001 and 2002.

6.46 In response, the New York Power Authority launched an emergency program to site 11 new gas-fired generators in the New York City region and the state legislature directed the Energy Planning Board to conduct a reliability study. That study found that demand-side measures, including energy efficiency measures, peak load–shaving measures, and price-responsive load programs, would all have a positive effect on reliability.[uu] The New York Public Service Commission subsequently doubled the funding given to DSM programs through their System Benefit Charges, restoring a portion of the funding lost at the end of the 1990s. The New York Independent System Operator also launched an Emergency Demand Response Program and a Day-Ahead Demand Bidding Program to address the reserve deficiency.[vv]

6.47 Table 6.3 summarizes the package of measures employed in New York to address the power shortage. State agencies responded with a mix of policies including long-term energy efficiency, load control, distributed generation at customer locations, and a public awareness campaign.

Table 6.3: Summary of Savings from Measures Employed to Address the New York Power Shortage

	Savings (MW)		
Energy efficiency and DSM measures	**Summer 2001 total**	**Summer 2002 total**	**Two-year cumulative**
Long-term energy efficiency	77.1	103.0	180.1
Customer generation	28.1	38.0	66.1
Public facility load control	9.8	28.0	37.8
Direct load control	0.0	14.0	14.0
Voluntary load control	155.6	206.0	361.6
Public awareness/appeals	5.6	37.0	42.6
Total	276.2	426.0	702.2

Regulatory Assistance Project. 2003

DSM Lessons Learned from International Experience with Power Shortages

DSM Programs Need To Reflect the Nature of the Power Shortage

6.48 Before designing DSM programs to address system needs, it is necessary to understand the nature of the problem being addressed. Are power shortages widespread or localized? Do they arise only during peak hours or across many hours of the year? There are many DSM options to respond to shortages. One advantage of DSM is that managers can choose the right mix of DSM resources to address the real problem in each case. When the problem is just an occasional high peak load, both energy efficiency and load management are appropriate tools. But when shortages are widespread, extending across many locations and hours, an aggressive program to improve end-use efficiency is the needed response.

6.49 In China, shortages are now widespread. Although shortages across China have different characteristics, the major problems are geographically broad and extend over many hours of the year, not just a few peak hours. Much of the problem is being driven by new commercial construction and increased use of residential and commercial air conditioning. These are areas that have been the focus of many successful energy efficiency programs in the United States and elsewhere.

6.50 Moreover, heavy industry and China's use of load management have led to very high average load factors on Chinese grids (above 80 percent compared to 60–65 percent in the United States). High load factors and the fact that coal-fired plants are on the margin during peak and off-peak periods suggests that the potential for additional economic gains from load management is relatively small. Thus, the focus at this point needs to turn to enhanced energy efficiency.

6.51 In addition, China suffers from weak network configurations, insufficient peaking power, reactive power compensation, and voltage regulations. The transmission capability of the highest voltage level (500 kV) is low and in most regions the 220 Kv level still operates as the trunk network. Much of China's urban power network equipment is or soon will be overextended. DSM can lower loadings on these systems, defer upgrade costs, and be beneficial to the overall power system.

Load Management and "Demand Response" Programs Can Respond to Power Shortages

6.52 A detailed study by the ACEEE of demand-side responses to power shortages and reliability problems found that load management was a nearly universal response. Load management options were widely understood and embraced by utilities. Utilities will adopt load management practices that reduce peak load or shift load from on-peak to off-peak periods because these practices are profitable to the utility. These practices either reduce utility costs more than revenues or they increase utility revenues.[ww]

6.53 One of the major lessons learned from the California power crisis was the critical importance of building "demand response" into wholesale and retail markets. Demand response includes a broad range of load management practices, but also includes increased attention to long-term load management through energy efficiency. This lesson has been accepted worldwide and is rapidly being implemented.[xx]

Energy Efficiency Resources and Programs Can Respond to Power Shortages

6.54 The study also found that "…the potential for the use of energy efficiency programs to help address electric reliability concerns may be greater than is currently being realized."

6.55 Energy efficiency was successfully used to address power shortages where certain conditions existed. The greatest success occurs in the following circumstances:

- **The government adopted policy support for energy efficiency.** The U.S. experience in California, New York State, and the Pacific Northwest provides the best examples. See table 6.4 for a summary of these experiences.
- **Regulatory practices were compatible with utility investment in energy efficiency.** California provides a positive example of regulatory policies aimed at supporting efficiency investments. Brazil provides a powerful counterexample. Brazil's practice of licensing most distribution utilities had the effect of tying utility profits to the rate of sales to customers. This meant that distribution utilities profited from additional sales even as the generators' reservoirs were being drawn down to emergency levels. It took a national emergency to create the environment in which significant energy savings could occur.
- **The nature of the power system meant energy efficiency was needed.** Brazil provides a good example. Brazil's large hydropower system was short of energy, not capacity. Load management would have reduced peak load but it would not have addressed the power shortage.
- **Energy efficiency was used where high-quality data and analysis can guide the government and utility response to the power shortage.** California provides a good example of the value of high-quality data about and analysis of energy use. California had very detailed data on the use of electricity and could design and target energy efficiency programs to precisely address the power shortage. See Appendix E for examples of the type of detailed usage data needed.

Table 6.4: Estimated 2001 Costs and Impacts of Programs for Energy Efficiency and Conservation

	Program spending ($million)	Estimated Savings (MW)
California	971	3,668
Northwest	150	390
New York	72	263

Source: Kushler, Vine, and York, 2002

Addressing Power Shortages with DSM has Many Advantages

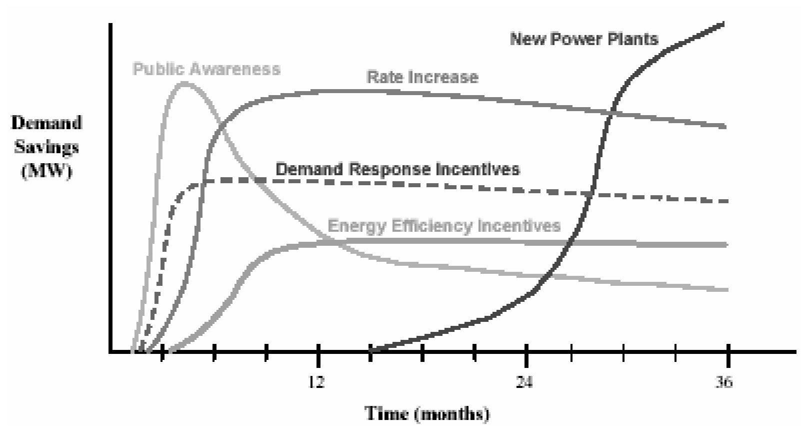
6.56 Power shortages can lead to poor decision making that has negative long-term economic and environmental consequences. For example, power shortages have led to decisions to delay or waive environmental rules and to the acceleration or construction of uneconomic power plants. Many countries, including the Philippines, India, and Indonesia, have entered into expensive long-term power contracts that caused lasting economic and political problems. Signing overly expensive contracts is not unique to developing countries. One of California's responses to the power crisis was to sign numerous long-term contracts, mostly with new gas-fired plants. As the crisis passed, the contracts were widely seen as being far too expensive.

6.57 DSM responses, on the other hand, can help meet electricity demands and provide reserve margins without adding to stresses on already-burdened transmission and distribution systems. By lowering demand at customer sites, rather than relying solely on new central-station generation, DSM allows grid companies to concentrate their capital resources on the most pressing grid upgrade requirements, while deferring other upgrades, lowering the cost of distribution, and improving reliability in many locations.[yy]

There Are Many Advantages to Comprehensive Programs

6.58 The scope and effectiveness of the government's response to the California crisis and similar problems elsewhere in the United States has been analyzed in depth in other works. One lesson is that the best response requires a coordinated mix of actions, some of which deliver immediate help and others that deliver longer-term help. Figure 6.4, from the California Energy Commission, shows the mix of actions and response times. California adopted a wide range of immediate and medium-term supply and demand-side options. Many of these actions can be accelerated in critical circumstances, as shown by Brazil's experience.

Figure 6.4: Reaction Times for Demand Response Activities



Source: California Energy Commission 2002.

DSM Programs Can Be Targeted to Meet Shortages in Several Ways

6.59 Energy efficiency investments can be highly targeted. For example, Commonwealth Edison, the utility serving the U.S. city of Chicago, targeted aggressive energy efficiency investments to neighborhoods where load growth was straining overloaded distribution systems. Other systems have put more emphasis on efficiency measures that have benefits for high peak load (targeting, for example, commercial lighting and air conditioning). In other cases, as in Brazil or the Pacific Northwest during drought conditions, the goal was to save energy in all hours, leading to a number of DSM resource choices. The lesson here is that there are many kinds of DSM resources and they can be strategically deployed to meet system needs in a variety of ways.

Sustained Effort and Sustained Regulatory Support Is Required

6.60 As the case examples above make clear, utilities and government agencies in California achieved dramatic savings from aggressive DSM efforts in 2001–02. Agencies in the Pacific Northwest and in New York also achieved significant savings and system improvements. In contrast, Brazil's response to the crisis was hampered critically by the relatively weak experience of utilities and government agencies in delivering efficiency services to customers.

7

Policy Recommendations

7.1 In the electricity sector, more than 20 years of international experience shows that, under the right circumstances, electric utilities can effectively deliver large-scale, cost-effective energy efficiency programs. To assure that electric utilities have a major role in delivering DSM and energy efficiency, proven policies and practices must be adopted that make successful delivery of energy efficiency services a profitable part of the utilities' business.

7.2 In China, NDRC and SERC are both new agencies. Today, their DSM-related responsibilities are still evolving, and many are shared. Adoption of the policy recommendations contained in this report may be the responsibility of one or both agencies.

7.3 The DSM policy recommendations are divided into short term and long term options. There is no clear line between these two categories of actions. Judgment has to be used to focus on the short term recommendations that are aimed at the current power shortage. The longer-term recommendations, while not requiring immediate attention, are the important steps needed to assure sustainable power sector reform. Given the severity of China's current power shortage, long-term policies are less urgent. However, they are critical to the avoidance of a future shortage and therefore action on them should not be put off for long.

7.4 Because China's experience in implementing load management is already comparatively strong, only two major recommendations relating specifically to load management are made: (a) reforming prices and (b) incorporating demand response in spot-market design and market rules. These are both very powerful tools.

7.5 As discussed in Chapter 4, the creation of open and competitive markets for electricity will not reduce the historic barriers to efficiency investments, and some of China's planned power sector reforms will create new barriers. This is a special concern for China because the potential for cost-effective DSM including energy efficiency is so substantial. Without increased investment in energy efficiency, unconstrained and very rapid growth in electricity demand threatens China's environmental, economic, and social sustainability goals.

Short-Term Regulatory and Policy Options to Promote DSM in China

7.6 There are a number of well-known, proven policies that, if adopted by NDRC and SERC, will substantially increase investment in cost-effective demand-side resources for the benefit of China. In the short term NDRC and SERC should consider adopting the following recommendations:

Make DSM a Priority Policy

7.7 International experience clearly demonstrates that DSM and energy efficiency in the electricity sector will only happen with clear, strong, and consistent government and regulatory leadership. As stated by high-level researchers at the Development Research Center (DRC) of China' State Council:

> *"Energy saving should be put first place in the energy strategy. That is, energy saving should be given priority, and can contribute more than increasing energy supply in satisfying the increasing demand for energy. To establish the important strategic position of energy saving, it is suggested that resource conservation should be incorporated into the country's basic state policies. Thus "population control, resource conservation, and environmental protection" jointly are China's basic state policies for the new era."*[zz]

Make DSM a Service Obligation for Power Supply Companies

7.8 The next most important policy to promote DSM is to establish who has the obligation to deliver DSM and energy efficiency services. International experience shows that barriers to DSM and energy efficiency are not overcome by power sector reform unless the issues are addressed directly. This means the responsibility to assess DSM potential and to design and implement programs must be assigned to a capable implementing entity. It also means that a mechanism to fund DSM must be established.

7.9 Some countries have made DSM and energy efficiency delivery an obligation of the distribution utility. Others have assigned the responsibility to existing or newly established third-party entities.[18] Experience shows that either approach can be successful.[aaa] What is crucial is that the power sector reform process includes the assignment of DSM responsibility to a utility or entity that has the funds and capacity to perform this critical role.

7.10 In China, there are several reasons to assign the DSM/energy efficiency obligation to the distribution, or grid, utilities: (a) the distribution companies possess the relevant customer information; (b) they have well-staffed customer service departments with the

[18] For example, in California and Massachusetts, the distribution utilities retain the DSM obligation. In the United Kingdom, Oregon, and Vermont, independent third parties were created to deliver DSM. In New York an existing third party became responsible for DSM delivery.

needed expertise in electricity matters; and (c) they have long-standing relationships with their customers. The widespread deployment of DSM measures for all customer classes is a new undertaking in China. The grid utilities are well equipped to do the job. Therefore, it is recommended that China's distribution companies be assigned the duty to provide DSM services to end-use customers in all customer classes. Furthermore, NDRC and SERC should adopt the necessary regulatory reforms to ensure that this assignment is consistent with the financial incentives and public responsibilities provided to distribution companies. Those reforms must also include the regulatory policies and oversight capability to ensure that the utilities comply with their DSM obligations. Lastly, the DSM/energy efficiency obligation should be reflected in the electricity law, in NDRC and SERC regulations, and in license conditions.

Remove Financial Disincentives to DSM

7.11 Ultimately, the performance of utility-sponsored DSM programs depends on the effects that the programs have on utility profitability. Therefore, it is critical that China adopt regulatory practices that align financial incentives for power supply companies with the DSM obligations of power supply companies.[19] This has two parts: (a) recovery of DSM related costs, and (b) the adoption of PBR methods that do not reward companies for increases, or penalize them for decreases, in sales.

Permit DSM Cost Recovery

7.12 Under existing practices in China, the power supply company is allowed to include the cost of power purchases in the prices it charges consumers. There is no similar mechanism for the power supply company to recover the cost of investment in DSM, even where the DSM investment replaces a more costly power supply option. The cost of cost-effective demand-side management should be treated like any other utility cost and recovered in the charges paid by retail customers.

7.13 For purposes of calculating prices (ratemaking), regulators will need to determine over what period of time DSM costs should be recovered. This is true regardless of the type of ratemaking methodology used, whether traditional cost-of-service or performance-based (described in the following section). In New York, California, and some other U.S. states, regulators treated DSM costs like the costs of other longer-lived investments (such as generation, wires, and buildings) and required that they be recovered over some number of years, roughly matching, but generally shorter than, the life of the investment. In contrast, in Massachusetts regulators allowed the full costs of DSM investments to be fully recovered in rates within one year. The decision on the

[19] The grid companies are government-owned monopolies. Ordinarily, the lack of private ownership would suggest that cost-recovery, performance-based regulation, and financial incentives would be less important than direct government direction. In China's socialist market economy, however, the distinction between government-owned and investor-owned utilities is not as great as it may be elsewhere. The grid companies are expected to be profitable and management's performance is judged on profitability and quality of services. Power supply company representatives have repeatedly identified the lack of DSM cost recovery, DSM-related revenue losses, and revenue losses from implantation of TOU prices as key barriers to DSM in China.

duration of cost-recovery will be influenced by various factors including, among others, the total amount of costs in question, equity among customers, the relative rate impacts of differing durations, and the impacts of additional borrowing on the company's balance sheet.[20]

7.14 Alternatively, DSM costs can be recovered through a small surcharge on retail sales, generally referred to as a system benefits charge. The money that the SBC raises is often referred to as a public benefits fund. The practical effect of an SBC is no different than the effect of including DSM costs directly in electric prices. Both approaches recognize the fact that acquiring efficiency and load management resources is a utility service obligation just like line maintenance, customer assistance, and power supply.

Ratemaking: Use Revenue-Capped Performance-Based Regulation

7.15 Allowing the electric utility to recover its DSM costs is not enough to assure that the company will deliver DSM programs to the greatest extent possible. Unlike supply-side investments, DSM, though cost-effective, poses a unique difficulty for the utility and regulator. The challenge has been to find ways to align the utility's financial interest with the public interest. In a number of countries and states, policy makers have turned to alternative ratemaking methods, broadly referred to as "performance-based regulation (PBR)," to solve the problem.

7.16 Under the traditional cost-of-service methods of ratemaking, an electric company's revenues are determined by its level of sales. Almost any reduction in sales will result in reduced profits for the company.[21] Thus, DSM investment may be much less costly than new power supply but, for the power supply company, adding supply means increased sales and increased revenue. Generally, the added revenue exceeds the added cost, so the grid utility's profits will increase when it chooses to increase supply. In contrast, the lower-cost DSM option reduces sales and revenues. Even if the cost of DSM is zero, the lower revenue means that the DSM option reduces the grid utility's profit. This is a very powerful disincentive for grid utility investment in DSM.

7.17 Correcting this problem requires the adoption of tariff-setting methods that remove this financial disincentive to DSM. One approach, used successfully in Australia, the United Kingdom, South Africa and parts of the United States, is a form of PBR that sets a cap, or ceiling, on the revenues that a utility can retain.

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[20] The impacts on a company's balance sheet may be less of a concern at this time in China, where the distribution companies are government owned. As a general matter, the more quickly costs are recovered, the less borrowing is required to fund the investments. If, for example, the full costs of an investment are included in the prices paid in the year the investment is made, much (if not all) of the investment can be paid for out of cash flow. Faster cost recovery gives greater certainty to the utility, but it must be balanced against the price and other impacts mentioned above.

[21] This is because, in most hours of the day, the marginal cost to produce and deliver a kilowatt-hour is *less* than the marginal revenue received for that kilowatt-hour. This fact gives utilities very strong incentives to increase sales.

7.18 There are two general categories of PBRs used to set overall prices: price caps and revenue caps. The question of whether to implement a price cap or a revenue cap plan is the most significant structural decision policy makers face when designing a PBR. Both options create incentives for the utility to cut utility costs, but price caps, like cost-of-service regulation, also retain the incentive to increase sales in order to increase profits. Revenue caps, in contrast, remove that incentive because the utility will not be allowed to keep the additional revenues that it receives from incremental sales. Because its total revenues are capped irrespective of sales, the utility has a very strong incentive to cut costs. One of the best ways to cut costs is to reduce its customers' consumption of electricity. Under revenue caps, there are no financial losses to the utility from reduced sales.

7.19 There are several variations of revenue based regulation. Some cap total revenue and allow revenue to increase based on inflation or other factors. Another variation sets initial year revenue and allows revenues in subsequent years to grow in proportion to the growth in the number of customers served. The latter approach is called a per customer revenue caps.

7.20 The logic of per customer revenue caps recognizes that over the long run demand for electric service over the long run that drives the need for new investment in generation and wires. However, in the short run, changes in grid utility investment and other costs are more closely correlated to changes in the number of customers served rather than to changes in the overall level of electricity sales. Thus, it makes sense to cap the utility's revenues on a per-customer basis. Doing so retains the incentive for the utility to make sure its customers use electricity as efficiently as possible while simultaneously giving the utility some measure of revenue protection against changes in its costs associated with changes in the number of customers it serves.[22]

7.21 It is recognized that government-owned companies do not necessarily have the same profit motives that privately owned companies have and that in China the government will remain the majority owner of the distribution companies for the foreseeable future. Even so, it is an objective in China that the utilities operate on a sound financial basis, and the policy of "corporatizing" the companies (separating their historic government functions from their business functions) is in part a reflection of that policy. Giving the companies strong financial incentives to act in ways that promote stated public policies (such as lower costs, reduced environmental impacts, and system expansion) makes good sense regardless of their ownership structure, particularly if

[22] In a number of U.S. states, regulatory commissions chose not to implement comprehensive "decoupling" (breaking the link between sales and profits) through revenue caps or similar mechanisms, but nevertheless wanted to protect their utilities against lost revenues caused by DSM programs. These states continued to set prices on a cost-of-service basis, and they would treat as a cost the net revenues (revenue loss minus cost savings) that a utility lost as a consequence of sales reductions from DSM. That cost would then be included in the next calculation of the utility's retail prices. This approach is less effective than the revenue caps because it does not remove the incentive to increase sales or address revenue losses due to price reforms. Therefore, we do not recommend that China adopt a net lost revenue adjustment.

management's performance is measured by its achievement or failure to achieve those goals.

Improve Internal Organization, Training, and Capacity Building

7.22 DSM and energy efficiency opportunities in China are very large and can have very significant benefits for China. However, two problems can impede the adoption and implementation of DSM options. First, most of the information available on the cost and environmental savings of DSM has relied on simple estimates. Greater use of detailed and more sophisticated analytical tools can improve cost/benefit analysis and reduce uncertainty about DSM investment.

7.23 Second, DSM success requires skilled personnel to design programs, analyze technical options, assist customers, and evaluate savings over time. Power supply companies must be adequately staffed to design, implement, and evaluate DSM programs. Moreover, NDRC and SERC will need the capacity to identify and review DSM and energy efficiency options, and the best policies for bringing them forward. For these reasons, hiring, training, and other elements of capacity building within the government and the grid companies are needed to assure that DSM programs can succeed. Technical training and capacity building should begin as soon as possible, so that DSM programs can expand to meet China's rapidly growing electricity needs.

Adopt Energy Efficiency Programs to Address Power Shortages

7.24 China should require that utilities implement as soon as possible a set of DSM programs specially designed to address near-term power shortages. These programs should target both energy efficiency and load management. Figure 7.1 shows the combined effect of energy efficiency (regarding cooling and lighting) and load management for a typical commercial building in the United States. The top curve shows the typical building's electrical demand in watts per square foot for each hour of the day. The middle curve shows the building's demand after investments in a typical utility-sponsored efficiency program that focuses on commercial lighting and air conditioning efficiency. The bottom curve shows the effect of a load management program, which interrupts a portion of the load during peak hours, when done in combination with energy efficiency. As figure 7.1 shows, it is the combination of strategies that provides the greatest load reductions.

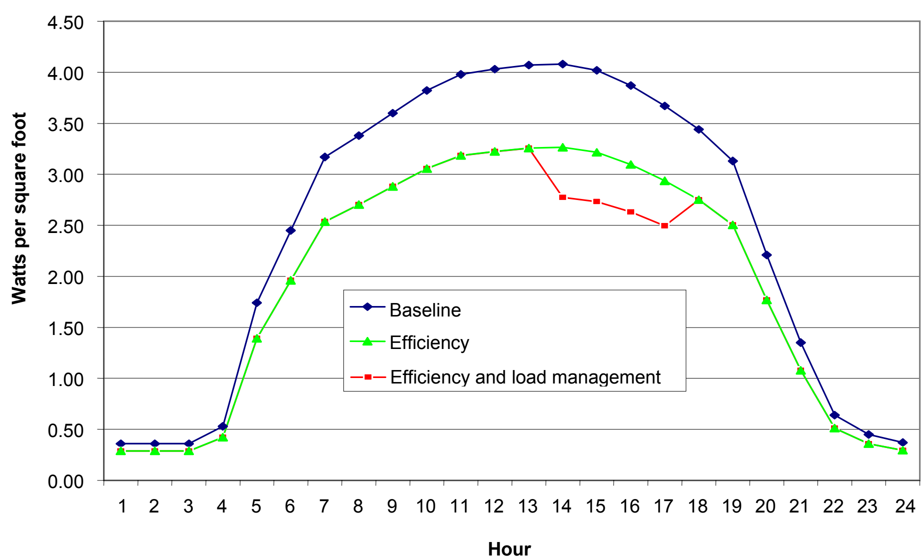
7.25 To expedite the implementation of the best programs, power supply utilities should be required to implement a mandatory minimum set of DSM programs. These include the following programs:

- accelerated retrofits of inefficient air conditioners with readily available Chinese high-efficiency units
- utility involvement in enforcement of energy-efficient building standards through efficiency testing prior to hookup, hookup fees or fines for failing buildings, price surcharges or fines for failing buildings, or similar types of actions

- rate designs that reward "high-efficiency" customers (those making permanent improvements in efficiency) as well as TOU rates that tend to promote load shifting
- accelerated retrofits of inefficient electric motors and other large energy uses in energy-intensive industries
- utilities' involvement in the design and enforcement of new energy efficiency standards
- public education campaigns urging all customers to save electricity during the shortage to avoid mandatory curtailments
- widespread marketing of high-efficiency end-use appliances, lighting fixtures, and bulbs.

7.26 The California electricity crisis demonstrated that DSM programs can quickly and efficiently address power shortages. The ongoing and severe nature of the power shortage in China suggests that SERC should identify a mandatory minimum set of programs that must be implemented by grid utilities.[23]

Figure 7.1: Combined Effect of Energy Efficiency and Load Management



Source: Cowart 2003

[23] As noted above, DSM can be implemented successfully by independent nonutility entities, and this may prove to be a useful alternative in some jurisdictions in China, particularly if it proves difficult to develop a national standard of performance for power supply companies.

Pricing Reforms Are Needed

7.27 Experience in China and elsewhere has demonstrated that consumers will modify their consumption in response to price signals. China's rapid implementation of TOU and interruptible prices are some recent examples. Better pricing will promote DSM. Prices should reflect the full cost of producing and delivering power at different times, different seasons, and different locations. This includes real-time prices, critical peak prices, and demand buy-back schemes. Prices set in this manner will provide consumers with an incentive to invest in the right amount and right type of DSM.[24]

Raising Prices That Are Too Low

7.28 Pricing reform means reforming price levels and price structures. With respect to price levels, there are two areas in China where price reforms may have a significant impact on consumer investment in DSM and energy efficiency. First, prices for some energy-intensive industries are now set at levels that are well below cost. Sales to these consumers are significant, representing about two-thirds of sales in Guizhou Province, one-third of sales in Hunan Province, one-quarter in Hebei Province, and one-fifth of sales in Henan Province. These are the types of customers that are very responsive to price signals. Low electricity prices for these consumers certainly mean they have not invested enough in DSM and energy efficiency.

7.29 Second, it appears that residential prices may be too low. Currently, residential prices are roughly the same as prices for large industrial consumers. This is inconsistent with international trends. Residential consumers may not be as responsive to price as energy-intensive industrial consumers, but the rapid growth in energy demand in the residential sector suggests that more attention should be focused on pricing in this sector. "High-efficiency" pricing options for residential customers could be used to promote investments in high-efficiency end use equipment in the residential sector.

Adopt High-Reliability Price Options or Performance Standards

7.30 Optional high-reliability prices should be made available to large industrial and other customers that are willing to pay higher prices to avoid service curtailments.[25] The price premium, or surcharge, should be used for three purposes:

7.31 First, the funds should be used to pay other consumers to voluntarily curtail their electricity use.

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[24] Even with the best-designed prices, however, many market barriers will remain and vast amounts of cost-effective energy efficiency will remain untapped by consumers. Thus, pricing policy should not be regarded as a substitute for the other policies recommended in this report. Although cost-based pricing will induce some customers to alter their demand, interrupt their usage, and even install high-efficiency end-uses, such pricing cannot overcome all of the barriers to customer investment on the demand side. Consequently, pricing policy should be seen as one in a set of complementary policies to promote DSM.

[25] The use of this option may be limited to consumers connected to the grid that allows their load to be isolated from other customers.

7.32 Second, the funds should be used to provide financial incentives for consumers to purchase and install more energy-efficient appliances, motors, and other devices.

7.33 Third, if involuntary outages can be avoided by purchases of emergency sources of power, the funds can be used to cover the power supply company's incremental cost for that emergency power.[26]

7.34 The allocation of funds to these three purposes should be on a least-cost basis. If a "price premium" policy is not possible, industrial customers and others could be encouraged to contribute to system reliability by a utility policy to award high-reliability service to entities that demonstrate a substantial commitment to lowering their peak loads and investing in energy efficiency technologies. Entities that reduce their consumption by a significant amount (for example, 15–20 percent) over a sustained period of time (for example, 6 months) could be placed very low on the list of customers to be curtailed when shortages arise. Customers would benefit in two ways from participating in this program: they would see enhanced reliability (fewer or no outages) for their operations, and they would benefit from the lower bills resulting from their investments in energy efficiency. The power system as a whole would also benefit from increased efficiency at major customer locations.

Use Critical Peak Prices for Large Industrial Customers

7.35 Many large commercial and industrial customers are already on TOU prices, but the prices extend to too many hours and days during which there is not a high risk of power curtailments. For large customers with real-time metering or other similar communication capabilities, very high prices could be charged for critical time periods, following notice to the customer that a critical peak is being reached. This pricing approach could apply to large consumers that do not elect interruptible service or the high-reliability option described above. Funds collected under this option could also be used as described above.

Give Price Reductions to Consumers that Interrupt or Reduce Electricity Use

7.36 China has already adopted interruptible pricing programs. These should be expanded to include more customers. One of the more successful pricing programs in California was the "20/20 program." This gave individual consumers a 20 percent price reduction if they lowered their consumption during the summer months by 20 percent compared to their consumption in the previous year. One-third of residential customers qualified for this rate reduction, and the program provided about two-thirds of the

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26 This approach is suggested for two reasons. First, China's practice of offsetting on-peak price increases with off-peak price reductions has resulted in off-peak prices that are well below off-peak costs. This leads to inefficient electricity use and poor incentives to invest in energy efficiency. Second, China needs to adopt a DSM-funding mechanism. This and other pricing reforms are aimed at addressing both problems at the same time.

demand and energy savings captured in the first year of the California crisis response program.[27]

7.37 Funds used to compensate consumers for voluntary curtailments and electricity use reductions should be linked to the premium-priced services described above.

Adopt Market Structures That Value DSM

7.38 Market design and market rules can be a very effective way to encourage and implement DSM. These options are especially important to SERC because market design and market rules are fully within SERC's authority.

7.39 One of the main lessons from the California electricity crisis was the importance of designing competitive spot markets to allow full participation by demand-side options. The importance of demand-side participation in these markets has now been widely accepted internationally. Demand-side participation in the market has many benefits, among them increased competition, improved reliability, and protection against abuses of market power.

DSM in Short-Term Spot Market Design[28]

7.40 This section provides a description of market elements that will support demand-side participation in spot energy markets. These measures will support DSM, reduce market power, and generally improve the operation and efficiency of the market. In typical commodities markets, the demand side participates in essentially two ways: first, by making offers to purchase at specified terms (price, quantity, and possibly other conditions) and second, by declining to purchase if the terms of a supplier's offer are unsatisfactory. While the physical characteristics of electricity pose unique challenges in this respect, there are a number of ways in which demand can be enabled to bid or respond to offers in wholesale markets.

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27 Similar economic incentives for demand reductions include the following:

- Demand buy-back programs in the form of wholesale market rules that give customers the right to sell demand reductions back to the utilities or the operator of a wholesale market. The payments to the customer can be structured in ways that encourage the customer to install distributed generation or invest in improved end-use efficiency.
- Credit or incentive programs for efficiency or distributed generation, or cogeneration of heat and power installed in specified, high-cost areas of the network. The aim of the program is to encourage the installation of customer resources that will address the power shortage and avoid the need for more costly investment in wires.

28 DSM and long-term reliability is also a market design issue. Uncertainty continues in China and elsewhere about whether wholesale electricity markets can be designed to assure an adequate supply over the long term. Many options are being tried and studied but none has yet emerged as a demonstrated solution. As a result, long-term planning will continue to be the primary means of assuring long-term reliability. This planning process is where long-term DSM and energy efficiency options can compete against supply-side generation and transmission options. As the power markets develop and mature, long-term capacity obligation and capacity markets may be added to wholesale markets. As this occurs, it will be important to allow demand-side options to compete against other options to provide needed system reserves.

Demand Bidding

7.41 Demand bidding refers to two broad categories of methods by which the demand side expresses its willingness to purchase, or not purchase, electricity. The first, seen in some multibuyer markets, is a requirement that purchasers, like sellers, bid in the advance markets.[29] Whereas sellers bid the prices at which they are willing to sell power (and the amounts and times), buyers bid prices at which they are willing to purchase power (as well also the amounts and times). The market is then "cleared" in each hour to determine the hourly market prices. Sellers whose bids are less than or equal to the clearing price are financially obligated to provide power, and purchasers whose bids are greater than or equal to the clearing price are also financially obligated to purchase power.[30] Unlike systems in which only supply bids against forecast demand, this method of settling the market for bid-based dispatch has the virtue of revealing the value that the demand side assigns to electric service.

7.42 The second approach to demand bidding is to allow purchasers to re-bid reductions in their demand into the advance and real-time markets. Reductions are bid in the same way that supply is bid. If the bid is less than or equal to the market clearing price, then the reduction will be accepted and dispatched in the same fashion as a generating resource. This method of demand bidding does not require that the first method be in practice, but in fact the two methods are complementary.[31] Where the second method is used, market operators must take additional care to be assured that the offered demand reduction will actually occur.

Ancillary Services

7.43 Supply and demand must be balanced in real time. System operators use a variety of resources, typically quick-start generation, to assure that voltage levels, power quality, and operating reserves are maintained within specified engineering standards. Short-term demand response can also be used to meet some of these needs, called ancillary services. Customers can react quickly to the call of a system operator and can reduce load. That load reduction can, for example, avoid the need for short-term spinning reserves. China should develop market rules that allow demand response to provide and be paid for by ancillary services.

Demand Reductions by System Operators

7.44 The use of involuntary outages to manage a power shortage is very costly and disruptive. International experience shows that voluntary demand reductions through payments to customers are effective and least costly to the economy as a whole.

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[29] Demand bidding has been incorporated in the three northeastern U.S. markets, Pennsylvania-New Jersey, Maryland, and New York State. Argentina, by comparison, uses a three-month advance market.

[30] In principle, this kind of bidding should also be applicable in a single-buyer market.

[31] Where both methods are used, as in the northeast United States, the bidding systems are referred to as "multi-settlements."

7.45 It is recommended that China develop a set of voluntary demand-reduction programs to be implemented by the system operator. These programs will be similar to the interruptible-load management programs that utilities offer, except that they are managed by the system operator in response to system needs, and are funded by surcharges paid by all participants in the market. Experience in other regions (such as New York) and a number of studies have demonstrated that voluntary demand reductions of this type can enhance system reliability if there are capacity shortfalls and can substantially reduce market-clearing prices during tight market conditions.

7.46 Program participants that curtail their loads are typically paid either the energy market-clearing price or a floor price that reflects an estimate of what that price would have otherwise been in the absence of the demand reductions. The offer of payments to customers identifies those who are most willing and able to curtail their demand and, in most cases, the programs avoid the more severe involuntary outages.

Longer-Term DSM-Related Policies

7.47 For the longer term, China should adopt the following policies to maximize cost-effective investment in end-use efficiency resources in China.

Integrate DSM and Energy Efficiency in Planning and Investment

7.48 In the longer term and apart from the current power shortage, DSM programs and investment should be based on a sound analytical footing. China should improve its power sector planning methods to better match supply and demand.[bbb] These advanced planning methods need large amounts of high quality and timely data on both the supply and demand sides. In China, these data are not always available or reliable. For example, the data obtained from different sources showed that the total new installed generation capacity in 2004 varied from 35 GW to 48 GW. Information detailing the construction period and expected completion dates was incomplete or inconsistent.

7.49 On the demand side, detailed end-use energy data such as the number and efficiency of new buildings, appliances, and factories is either not available or incomplete. Forecasting energy needs and planning least-cost solutions are not possible without fundamental data of this type.

7.50 China needs to adopt advanced planning methods capable of recognizing the costs of boom/bust cycles and the value of avoiding these cycles with a diverse portfolio of options. Some resources like DSM, wind power, and combined heat and power (CHP) have much shorter lead times and can more quickly respond to changing circumstances. But the economic value of short lead times and flexibility is not recognized in the current planning process.

7.51 China should adopt sophisticated IRP methods that can measure and take account of diversity, short lead times, financial and operating risk, and the environmental impact of different resources. Grid companies should be required to use these methods to integrate DSM and energy efficiency options into their investment decisions.

7.52 At least during the initial stages of China's power sector reform, the grid companies will act as the buyers of power on behalf of consumers. Grid companies should work hard to meet consumers' needs with a mix of supply- and demand-side investments that minimizes consumers' long-term total costs. DSM and energy efficiency options should be evaluated and compared to investments in, or contractual commitments to, generation and transmission. The utilities' obligation should be to invest and commit only to the least-cost mix of options.

Reward Success: Standards and Rewards for DSM Performance

7.53 Correcting many of the DSM-related incentives in the tariff-setting process is a high near-term priority. In the longer term China should consider targeted incentives to reward superior DSM performance. Such incentives are also considered a form of "performance-based regulation," but are distinct from PBRs of the type that apply to a utility's overall revenues described in the previous section. Targeted rewards for meeting specified performance standards are often referred to as shareholder incentives, because any additional cash that the company receives because of these incentives goes directly to its bottom line, that is, to its earnings.

7.54 Shareholder incentives typically work as follows. The regulatory commission sets specified targets for DSM savings (differentiated by end-use, customer class, year, and so forth) that the utility must achieve through the deployment of cost-effective energy efficiency programs. These targets (that is, performance standards) are worked out through a regulatory process that involves policy makers, the utility, DSM experts, and other interested parties. The targets should be rigorous but reasonable and the savings must be verifiable.

7.55 Associated with the targets is a set of financial rewards. The rewards may be defined as actual amounts of cash, as percentages of revenues, or in some other manner; but however they are specified, they should in some way be related to the savings, in yuan, that the DSM programs yield. For example, if the successful delivery of a DSM program in a particular area (say, a commercial high-efficiency lighting program) is expected to reduce the utility's costs by Y 10 million in the first year, a reward of Y 1.5 million might be deemed appropriate. The reward would be paid to the utility in the form of an increase in the revenues that it is allowed to retain in the following year. Such rewards are also referred to as "shared savings" because the benefits of the DSM program are split between the customers and the utility.

7.56 There are many ways to design shareholder incentives for DSM, and a discussion of the options is beyond the scope of this report. As a general matter, if policy makers conclude that such rewards are appropriate, they should be given for superior performance only and should be linked to specified achievements across a broad range of DSM programs.

Use Congestion Pricing

7.57 It often happens that the transmission system is limited, or constrained, so power cannot flow freely from one area to another. As a result, low cost generation in one area is must be reduced and replaced with higher cost generation in another area that is unaffected by the transmission constraint. The fact that the transmission is constrained is called system congestion and the added cost of using more expensive generation is called congestion cost.

7.58 Typically, conventional transmission pricing (one price for all) does not assign the congestion cost to any particular transmission user. As a result there is no market mechanism to allow generators or consumers willing to reduce demand to respond in ways that reduce or eliminate the congestion cost.

7.59 A more efficient transmission pricing system would more accurately reflect congestion costs to encourage greater demand response and geographically targeting energy efficiency in areas suffering from congestion costs.

7.60 In the absence of a market-based method of congestion pricing, also referred to as "locational marginal pricing," it is still possible to identify high-cost constraints in the transmission system and solicit demand-reductions to solve them. This should be an obligation of the grid companies. Any payments made to end-users for demand reductions under these circumstances would, for ratemaking purposes, be treated like any other transmission cost and be recovered in transmission rates.[32]

Promote Environmental Quality

7.61 One well-known market failure that contributes to inadequate investment in DSM is that most of the environmental cost associated with electricity production is not internalized in the cost of electricity. Moving to a competitive generation market does not address this problem. Indeed, moving to a competitive generation market makes matters worse. With competition, highly polluting plants will be competing against cleaner plants for the right to produce and sell power. Polluting plants often have a competitive advantage because they do not incur the capital or operating costs of the cleaner combustion technologies or pollution control equipment.

7.62 Correcting this problem should be a priority for China. Chinese researchers have identified several possible solutions.[ccc] Most of the options identified to correct the problem will indirectly support DSM investment by requiring low-cost polluting plants to internalize environmental costs. Some options go further and use pollution fees collected from polluting generators to fund DSM and energy efficiency investments.

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[32] Transmission companies should be given a similar obligation with respect to new investment in transmission assets. Where end-use energy efficiency can cost-effectively avoid new investment in transmission, grid companies should be required to make those investments in energy efficiency.

Improve Governmental Coordination

7.63 Various departments of the government will be responsible for developing and implementing the full complement of policies needed to promote DSM. For example, appliance and building standards involve CNIS, pricing and planning involve NDRC, monitoring and enforcement involve SERC, and environmental reforms involve SEPA.

7.64 All of the activities of the relevant government agencies should be coordinated to improve administrative efficiency and maximize the effectiveness of the programs. To this end, it would be reasonable to establish a DSM steering committee, made up of key officials from the different departments, who would meet regularly to share information, discuss initiatives, and develop policies and action plans to implement them.

Appendix A

Electricity Price (US$ per MWh) in Selected Provinces in 2004

Province	Item	Urban residential	Rural residential	Non-residential lighting	Commerce	General industry	Large industry	Agricultural production	Agricultural Irrigation	TOU periods
Beijing	Typical price1	53.2	53.2	76.6	77.4	68.5	50.1	57.9	36.1	
	High load3			1.577	1.576	1.567	1.413	1.475		08:00–11:00 18:00–23:00
	Low load3			0.458	0.459	0.468	0.621	0.559		23:00–07:00
Tianjin	Typical price	49.6	49.6	75.9	71.3	67.7	46.7	52.7	21.2	
	High load			1.568	1.573	1.543	1.412	1.516		08:00–11:00 18:00–23:00
	Low load			0.467	0.464	0.493	0.624	0.523		23:00–07:00
Liaoning	Typical price	52.6	52.6	76.8	87.1	73.3	44.7	47.2		
Shanghai	Typical price	73.2	73.2	89.6	77.1	79.7	67.2	66.1		
	High load				1.403	1.503	1.545			08:00–11:00 18:00–21:00
	Low load				0.470	0.409	0.509			22:00–06:00
Jiangsu	Typical	61.7	47.5	94.8	106.9	78.5	53.6	49.7	33.0	

Province	Item	Urban residential	Rural residential	Non-residential lighting	Commerce	General industry	Large industry	Agricultural production	Agricultural Irrigation	TOU periods
	price									
	High load	1.0784				1.501	1.501			07:00-11:00
										17:00–21:00
	Low load	0.5884				0.501	0.501			23:00–07:00
Fujian	Typical sales price	51.0	51.0	60.8	93.5	71.6	57.7	23.6		
	Peak load3						1.700			19:00–21:00
	High load						1.500			08:30–11:30
										14:30–17:30
	Low load						0.500			23:00–07:00
Hubei	Typical price	61.4	61.4	80.7	110.3	68.2	44.6	53.8	26.0	
	High load				1.800	1.800	1.800			10:00–12:00
										18:00–22:00
	Low load				0.480	0.480	0.480			00:00–08:00
Sichuan	Typical price	50.8	50.8	75.0	86.8	63.5	47.5	52.0	13.9	
Guangdong	Typical price	75.0	75.0		108.0	83.9	72.8	72.6		
	High load						1.342			07:00–12:00
										19:00–22:00
	Low load						0.609			22:00–07:00
Shannxi	Typical price	59.3	59.3	77.6	92.1	62.4	47.2	50.7		

Province	Item	Urban residential	Rural residential	Non-residential lighting	Commerce	General industry	Large industry	Agricultural production	Agricultural Irrigation	TOU periods
	High load			1.465	1.471	1.470	1.581	1.472		08:00–11:00 18:30–23:00
	Low load			0.535	0.529	0.530	0.419	0.530		23:00–07:00
Qinghai	Typical price	43.8	43.8	53.3	79.6	40.0	30.5	33.1	24.3	
	High load			1.473	1.482	1.464	1.570			09:00–12:00 18:00–23:00
	Low load			0.529	0.518	0.539	0.430			0:00–08:00
Ningxia	Typical price	54.1	54.1	71.6	90.0	60.7	36.5	43.8	26.0	

Source: Study Team

1. Typical sales price is the typical sales price used for the normal-load-duration.

2. Peak load is the multiple of price of peak-load duration to price of normal-load duration; high load is the multiple of high-load duration to price of normal-load duration; low load is the multiple of low-load duration to price of normal-load duration.

3. Nanjing and Changshu City of Jiangsu Province began to implement the time price for some citizens from August 7, 2003, and February 13, 2004 respectively.

4. Some provinces are using the price which varies with the rainy season and dry season. The price in dry season is 1.1 times that in normal season and the price in rainy season is 0.9 times that in the normal season.

Appendix B

Energy Intensity

Table B.1: World Energy Consumption per GDP from 1980 to 1997 (toe per million)

Year	1980	1985	1990	1994	1995	1996	1997
United States	369	322	304	300	297	294	278
Canada	478	418	394	407	404	405	389
Mexico	426	455	468	449	464	455	440
Chile	260	237	260	240	233	239	258
OECD Countries	216	204	184	179	178	182	176
England	252	231	205	206	203	206	194
Germany	199	185	158	142	141	144	139
France	165	161	157	154	157	163	155
Italy	168	152	149	145	148	147	147
Russia	n.a.	1,771	1,589	1,712	1,747	1,770	1,700
Asia	248	244	245	261	267	268	267
China	2,479	1,899	1,649	1,255	1,218	1,159	1,067
Japan	107	96.2	91.8	95.4	96.7	95.6	95.6
Korea, Republic of	308	270	287	325	325	335	342
Singapore	217	207	237	316	252	262	274
Indonesia	347	366	419	396	401	406	412
Malaysia	295	367	379	419	372	410	451
Philippines	236	258	277	322	335	336	350
Thailand	231	232	259	285	301	323	336
India	620	661	688	708	719	706	688
Australia	305	275	283	264	259	269	266
New Zealand	213	227	273	258	256	265	263
OECD	252	228	211	210	210	210	204
Non OECD	689	724	718	640	633	623	603
EU15	194	183	168	164	163	166	161

Year	1980	1985	1990	1994	1995	1996	1997
APEC19	316	285	273	277	278	277	269
ASEAN17	284	301	329	350	343	365	382
World total	331	317	301	290	289	289	281

Data Source: Overview of Energy and Economic Statistics. The Research Institute of Energy & Economics in Japan, Year 2000. Computed as U.S. dollars constant price in 1995.

Table B.2: International Comparison of Unit Energy Consumption of Main Products in 1997

No.	Unit energy consumption of main products	Average value in China A	Value of international advanced level B	% Difference between A and B (A/B–1) × 100
1	Electricity consumption unit run coal in state key mine(kWh/T)	30.93	31.0	–0.23
2	Comprehensive energy consumption in matching oil (Kgce/T)	118.3	102.4	+15.5
3	Energy consumption in oil refining (Kgce/T)	20.0	19.46	+2.8
4	Comprehensive energy consumption unit ethene (Kgce/T)	1,210	870	+39.1
5	Heat consumption in coal plant (Gce/kWh)	408	324.3	+25.8
6	Rateable energy consumption unit steel (Kgce/T)	976	656	+48.8
7	Energy consumption in copper refining (Kgce/T)	1,352	820	+64.
8	Comprehensive energy consumption in cement (large & middle) (Kgce/T)	181.3	124.6	+45.5
9	Comprehensive energy consumption unit tabulate glass (Kgce/Box)	25.7	14.1	+82.3
10	Comprehensive energy consumption in synthesizing ammonia (Gce/T)	1,399	970	+44.2
11	Comprehensive energy consumption unit paper and cardboard (tce/T)	1.57	0.70	+124.3
12	Comprehensive energy consumption in sugar by sugar cane (tce/T)	6.16	4.50	+36.9
13	Electricity consumption in cotton yarn (kWh/T)	2,349	2,129	+10.3
14	mucilage glue short fiber heat consumption (Kgce/T)	2,052	1,450	+41.5
	electricity consumption (kWh/T)	1,937	1,200	+61.4
15	Oil consumption of truck carrying cargo (litre/100-ton-Km)	7.55	3.40	+122.1

Source: Strategic Research for Improving Energy Efficiency in China. The press of China Power, in Jan. 2001

Note: Gce = grams coal equivalent. Kgce = kilograms coal equivalent. T = ton. "International advanced level" refers to the average value of advanced level countries.

Appendix C

International DSM Case Studies

Case Studies of the Commercial and Industrial Sector: Comprehensive Approaches

Many DSM programs focus on small- and medium-size commercial and industrial consumers. In a competitive power sector, large, energy-intensive facilities are in a better position to negotiate for favorable rates and services from both energy suppliers and ESCOs. Large facilities often have energy management staff focused on efficiency opportunities. Smaller plants collectively have the potential to achieve significant demand and energy savings. However, individually they may not have the staff capability or capital flexibility to identify and implement these savings opportunities, even though energy costs are of great importance to their financial viability.[ddd]

International experience has shown that many of the opportunities for increasing energy efficiency and decreasing utility bills in smaller manufacturing and commercial facilities are in areas such as motors, lighting, compressed air systems, HVAC systems. These systems are more straightforward and replicable in small facilities than at large process-intensive industrial plants.

Alliance to Save Energy's "Watergy" Program in Fortaleza, Brazil

Target: Water and wastewater utilities.

Context: In developing countries, the cost of energy to pump and treat water significantly reduces the funds available to local governments for other purposes. The Alliance to Save Energy (ASE) estimates that energy consumption in water systems worldwide could be trimmed 25 percent through cost-effective efficiency efforts. Because this sector consumes 2.3 percent of the energy used in Brazil (over 7 billion kWh per year) and Brazil was anticipating a 20 percent electric power shortfall in 2001, a case study begun in Brazil in 2000 was a good match.

Objective: The ASE partnered with the Ceara State water utility, CAGECE, in the arid, energy-short northeast region of Brazil to save energy and water while expanding services to unconnected customers.

Process: The program was multifaceted and included diagnosing system improvement options; reducing loss and leakage; improving measurement, monitoring, and information sharing; making efficiency upgrades to motors, pumps, and valve systems; increasing automation; developing an energy management procedures manual; building staff capacity building; and conducting educational campaigns to promote more efficient water use by customers.

Of interest: These water system improvements allowed the utility to expand services to 88,000 families. Previously, these new customers bought their drinking water from vendors that trucked in water to their neighborhood. Service was irregular and cost as much as eight times what formally connected users paid. Through efficiency, these previously underserved neighborhoods now have formal connections that link them with a regular supply of water. They can now focus upon the many other challenges common to daily life.

This effort helped lead to the creation of the nonprofit organization BWEN (Brazil Water Efficiency Network), whose members will continue to share energy and water efficiency opportunities. ASE has conducted similar "Watergy" projects in India, Mexico, the Philippines, South Africa, and Sri Lanka.

Results in Fortaleza:[eee]

- Participants: over 2,000,000 residents plus business and industry
- Energy savings: 88 GWh over 4 years
- Demand savings: over 7 MW
- Water savings: over 450,000 cubic meters per year
- New customers: over 88,000 added
- Savings: over US $2,500,000 with an initial investment of US $1,100,000

Similar approach in South Africa: The electric utility, Eskom, paid a large water company (Midvaal) to install variable-speed drives, digital radio communication, and automation. The result was the average maximum demand of 4.6 MW was cut to 2.3 MW during evening peak hours.[fff]

Shared Savings Plan in South Africa

Target: Large electricity customers.

Context: South Africa expects to exhaust its surplus capacity by 2007 because of rapidly growing peak demand. It is also moving towards power sector reform. The electric utility, Eskom, has taken responsibility for coordinating DSM initiatives to avoid a power crisis by using load shifting, interruptible load, and energy efficiency. Eskom spent half a billion rand on these efforts in 2003. It hopes to add 5 million connections by 2007.

Objective: Eskom hopes to defer the need for new generation, transmission, and distribution by reducing overall electricity consumption, and by designing incentives that encourage large commercial and industrial customers to shift electricity use away from peak periods. Eskrom also hopes to stimulate ESCO activity, release funds for future projects, and reduce water usage and pollution.

Process: ESCOs propose specific commercial or industrial DSM projects after completing an audit. Eskom agrees to pay the capital costs of accepted projects. Over the next 10 years, Eskom receives 35 percent of the resulting energy savings and the remaining 65 percent are shared by contractual arrangements between the customer and the ESCO.

Results:[ggg]

The Carlton Centre, a 52-story commercial and retail complex covering 6 acres, spent over $150,000 per month on electricity. The ESCO proposed a variety of interventions including upgrades to lighting, ventilation, air conditioning, heating, and cooling systems. The customer will save hundreds of thousands of dollars over the 10 year contract. Eskom and the ESCO also gained financially.

- The lighting retrofit alone gave these results:
- Demand savings: 1.15 MW
- Energy savings: 2.125 GWh per year

Similar approach (France):

In France, HVAC (heating, ventilating, and air-conditioning) contractors operate as ESCOs. The HVAC companies carry out energy audits and implement the improvements. They contract with customers and guarantee energy savings (usually expressed in Euros) and a certain level of reliability. Contracts often cover a period of several years, consistent with the ESCO's involvement. French law requires that the various components of the contracts be separated, so the client knows the energy savings achieved by the service at every stage.[hhh]

DSM Bidding Program in Germany

Target: Medium-size industrial and commercial customers.

Context: In the new competitive market, some utilities hoped to distinguish themselves and improve the bottom line by providing energy efficiency services.

Objective: The municipal utility of Düsseldorf (Stadtwerke Düsseldorf AG) was not interested in funding energy efficiency via their electricity prices, as in "classical" DSM bidding. Instead, they hoped to achieve the following:

- "Improve their understanding of the needs of their customers,
- Gain experience in technology fields attractive for third-party financing (TPF),
- Gain customers interested in TPF projects, and projects for these customers,

- Present themselves as a provider for energy efficiency services,
- In short, to give their TPF business a kick-start."[iii]

Stadtwerke Düsseldorf AG thought their large customers would be more interested in cost-effective carbon dioxide emission reductions than in energy efficiency services. Therefore, the primary objective for the DSM bidding was expressed as reducing carbon dioxide emissions by at least 2,000 tons per year, not as energy savings. However, energy savings would be keys to the project's cost-effectiveness.

Process: Stadtwerke Düsseldorf AG offered to implement any cost-effective project with TPF. Projects were not restricted to electricity savings. However, since the utility saw TPF for electric efficiency as more innovative and cost-effective than heat conservation, each bidder had to allocate at least 50 percent of the investment for electric efficiency measures and had to have as a target at least 100,000 kWh per year of electricity savings. Pure load management was excluded. Any additional investment could be for innovative heat conservation or renewable energy sources.

In one of the winning bids, an ESCO proposed HVAC and motor upgrades for a large service sector company. The energy conservation measures undertaken included the following:

1. Air leakage was reduced by closing "short-cuts" between air inflow and air outflow.

2. Seven fans that were no longer needed after the reduction of the leakage were closed down.

3. Variable-speed drives were installed in the remaining 12 ventilation fan motors, which reduced circulating air quantities as well as electricity demand.

Of interest: The case study was evaluated with the aim of testing the applicability of the International Performance Measurement and Verification Protocol (IPMVP). Therefore, the Wuppertal Institute proposed the methods for verification of the savings based on the IPMVP. The IPMVP is the evaluation method proposed for monitoring and verification of energy service company projects. It is described in Section 6.6 of the "European Ex-post Evaluation Guidebook" (SRC International 2001).

Stadtwerke Düsseldorf AG offered a total of DM 150,000 (€ 76,700) in awards to the 10 best proposals.

Results of one project:

Table C.1: Measurement Findings

Circuit (Room) 19		Circuit (Room) 23	
Before		**Before**	
Number of fans	10	Number of fans	9
Nominal air flow/unit	7,100 m3/h	Nominal air flow/unit	7,500 and 10,000 m3/h
Measured power/unit	7.2 kW	Measured power/unit	9.5/10.2 kW
Measured air flow/unit	6,400 m3/h		7,500 and 10,000 m3/h
Operating hours	8,760 h	Operating hours	8,760 h
Electricity consumption	631,000 kWh/a	Electricity consumption	774,000 kWh/a
After		After	
Number of fans	6	Number of fans	6
Measured power/unit	3.3 to 5.9 kW	Measured power/unit	2.0 to 3.0 kW
Measured air flow/unit	Average 6,400 m3/h	Measured air flow/unit	Average 5,000 m3/h
Electricity consumption	264,000 kWh/a	Electricity consumption	145,000 kWh/a
Electricity saving	373,000 kWh/a	Electricity saving	629,000 kWh/a

Source: SRC International (2001)

- Note: kWh/a = kilowatt-hours annually; m3/h = cubic meters per hour.
- Energy savings = 1 GWh per year (70 percent of the electricity that was consumed before the measures)
- Budget = no more than € 30,000
- Cost/lifetime kWh = € 0.37 per kWh (at 4 percent societal discount rate and 10 years residual life of the fans, which is a conservatively low estimate, based on the fact that used fan/motor systems were upgraded with the variable-speed drives).
- Simple payback = 7 months

Case Studies of the Commercial and Industrial Sector: Approaches Specific to End-Use

Energy-Efficient Technologies for Business Customers in Spain

Target: Small and medium-size businesses.

Context: Although this program was implemented prior to liberalization in the EU, it could be implemented in restructured markets, with supportive policies. Similar programs existed or continue to exist in Belgium and the Netherlands.[iii]

Objective: To reduce electricity consumption due to motors and lighting in small- and medium-size businesses.

Process: All major Spanish electricity distribution companies carried out the Pyme-Energia Programme in 1998. The companies offered rebates totaling 30 percent of investment costs in variable-speed drives, higher-efficiency motors, and efficient lighting. Customers had three months to request the rebate and three months to implement the investments.

Table C.2 Energy Savings and Costs

Pyme–Energia program		Iberdrola	ENDESA Group
Energy saving objective	MWH/year	58,672	20,152
Actual energy savings	MWH/year	63,953 (109%)	19,527 (97%)
Foreseen power saving objective	MW	14.67	5.08
Actual power savings	MW	15.99 (109%)	4.97 (98%)
Foreseen total costs	Million €	3.15	2.69
Actual total costs	Million €	3.38 (106%)	2.66 (99%)
Actual levelized costs of conserved energy (4% interest rate; 10 years useful life)	Cent/kWh	0.78	2.02

Source: Wuppertal et al. (2002)

Note: Cent = $0.01

Of interest: The energy companies received full recovery of the incentives given to the customers, plus a lump sum per watt covering management, promotion, and diffusion costs. The companies received the following lump sums:

- 5 pesetas ($0.03) per speed-controlled watt for control system introduction
- 5 pesetas ($0.03) per substituted watt for substitution of motors by high-efficiency motors
- 25 pesetas ($0.15) per saved watt for any lighting intervention that reduced installed power

Results:

Two energy utilities, Iberdrola and the ENDESA Group, were responsible for almost 90 percent of the program's energy savings.

Case Studies of the Residential Sector: Comprehensive Approaches

Energy Efficiency Commitment in the United Kingdom

Target: Existing housing stock.

Context: As power sector reform progressed, it was noted that the market did not deliver energy efficiency benefits. As a result, the United Kingdom required their electric (and gas) distribution suppliers to achieve energy efficiency-related targets, allowing costs to be passed through to consumers.

Objective: In the United Kingdom, the goal is to meet climate change (Kyoto) obligations in part through energy efficiency improvements in the residential sector. Additional goals include reducing energy bills for low-income families and improving home comfort.

Process: This section describes activities of the Energy Efficiency Commitment (EEC) and its predecessor program the Energy Efficiency Standards of Performance Program (EESoP) in the United Kingdom. From 1994–2002, under the EESoP, electricity suppliers (and later, gas suppliers) were obliged to achieve specified energy savings in the residential and small business sectors using a special, uniform, per-customer revenue allowance. Beginning in 2002, the electricity and gas suppliers were required to meet environmental targets set by the government by installing energy efficiency measures in the domestic sector, with an emphasis on low-income and elderly households. Energy savings goals have been increased three-fold over the EESoP goals. There is no specific revenue allowance. Suppliers may pass costs on to customers. These obligations are also intended to alleviate "fuel poverty."

The energy supplier must directly or indirectly (for example, through subcontractors or trading) install energy efficiency measures adequate to meet its obligation. Approved measures include the following:

- energy-efficient refrigerators, boilers, and other appliances
- cavity and loft insulation
- efficient heating controls
- compact fluorescent lighting and other efficiency measures

Of interest: The IEA DSM Program Task IV group considered this mechanism to be useful or relevant during all phases of electricity industry restructuring. They expect this mechanism to be useful even with retail competition, because electricity businesses can use the obligation to gain a competitive advantage by offering energy efficiency services to customers.

Results from 1994–98:[kkk]

According to the Energy Savings Trust, the benefits to customers and the society on average exceeded the program costs by more than a factor of 4.

Energy savings: 6.8 billion kWh, 12 percent more than obligation targets set by the regulator

Total energy savings: about 1.5 percent of the total electricity used by that sector; 3 million customers' energy bills were reduced

CO2 reductions: about 6 million metric tonnes over the lifetime of installed measures.

It is estimated that the EEC proposed for 2002–05 will raise prices by 1.2 percent over that period. However, because of energy savings, energy bills should be reduced by about 1.6 percent by 2005 and this reduction should persist for the lifetime of the relevant measures (8–40 years).

The Wuppertal Institute et al. (2002) projected that if the EEC's energy-saving targets were valid for the whole EU-15; this would mean an annual saving of 16 TWh per year of electricity and 46 TWh per year of gas. Extending the effort over 10 years would bring the EU savings of 54 TWh per year of electricity and 155 TWh per year of gas.

Similar Approaches in New South Wales, Australia and Texas, USA: In New South Wales, Australia, electricity suppliers have an obligation to reduce greenhouse gas emissions. Electric energy efficiency in all sectors is a prime mechanism for achieving the reduction. In Texas, utilities must acquire energy efficiency savings equal to at least 10 percent of the utility's annual growth in demand.

Note: The IEA DSM Task VI[lll] group determined that, for effective operation, this "obligation" approach requires the following:

"A government body capable of developing appropriate mandatory requirements in relation to sourcing of energy efficiency;

Quantified energy efficiency targets as part of the requirements which will lead to significant reductions in electricity use but which are viable (and profitable) for electricity businesses to achieve;

A system capable of effectively monitoring compliance, and acceptable to those parties being monitored;

An organization capable of carrying out this monitoring; and

Appropriate penalties for non-compliance."

Sustainable Homes Initiative in South Africa

Target: New, low-income, home construction.

Context: Under Nelson Mandela, South Africa set a massive housing goal: to build one million new homes for low-income families. Many of the early homes were poorly constructed and insulated. They were uncomfortable and did not use energy efficiently, particularly during peak hours. As South Africa attempts to reach another social goal—to connect 5 million new households to the electric grid by 2007—it is estimated that the country will exhaust its surplus peak capacity by 2007. The country, the electric utility, and aid agencies were looking for interventions that would improve the energy efficiency of new housing stock.

Objective: To promote energy efficiency, water efficiency, and sustainable transportation principles in new housing developments; to bring health, productivity, safety, comfort, and savings to new homeowners.

Process: The International Institute for Energy Conservation developed the Sustainable Homes Initiative (the "Initiative") with the support of South Africa's electric utility, Eskom, and aid from the United States and the United Kingdom. The Initiative placed "green" professionals (such as architects, engineers, and transportation planners trained in environmental and energy-efficient design) in needy communities. By providing two days to two weeks of technical assistance to the community, these green professionals would introduce low-cost interventions such as the following:

- energy-efficient and low-smoke appliances
- ceiling and wall insulation
- energy-efficient lighting and water heating
- ventilation
- optimal orientation for solar gain in the winter and reduction in the summer
- maximum natural light

Of interest: To broaden its impact, the Initiative also developed "green" training programs for contractors and developers to increase their understanding of energy-efficient design.

Results:[mmm]

- The Initiative cooperated with Eskom regarding 1,200 low-cost homes in the Alexandra East Bank Housing Development. The homes built used 70 percent less energy than conventionally built homes and had reduced indoor pollution.

Case Studies of the Residential Sector: End-Use Specific Approaches

Rebate Programs in the Domestic Sector in the Netherlands

Target: A wide variety of energy savings in the residential sector.

Context: During the 1990s, the energy distribution companies agreed with the Dutch government to achieve quantified energy savings targets. These agreements ended in 2000 with the liberalization of the energy markets in the Netherlands. However, the electricity and gas companies continue to use their experience with DSM programs to promote energy efficiency. The government contracts with the energy distribution companies to administer rebates and programs funded by the Dutch Regulatory Energy Tax (ecotax).
Objective: Energy savings, increasing the market share of efficient technologies, and CO2 emission reductions.

Process: Theoretically, the consumer pays the ecotax on electricity and gas to the state. In reality, the energy companies collect it from consumers and then pay the government. The customers can get a rebate paid by the energy company for specific energy efficiency measures. The energy companies then subtract these energy rebate payments from their ecotax debt. The energy companies are also reimbursed for the costs incurred implementing the program. The companies have to document expenses and implementation. They are monitored by an independent state agency.

The list of the technologies eligible for rebates includes the following:

- energy-efficient refrigerators, freezers, dishwashers, washing and drying machines
- LCD monitors and TVs
- floor, ground, or wall insulation
- heat-reflecting glass
- high-efficiency condensing boilers
- low-temperature heating systems
- lighting systems control

Also, a grant for the energy audit is given when at least one of the measures recommended in the audit is carried out. The program is supported by a wide-scale information campaign, including national campaigns on television and in national newspapers, advertisement in shops, actions targeting installers, and Websites (such as www.energielabel.nl).

Of interest: Other important measurable side effects of the energy rebate scheme were increases in VAT, taxes on profit, and avoided unemployment benefits.

Results:[nnn]

15 percent of the ecotax was used for the energy rebate scheme.

- Funds available to consumers for 2000 and 2001 were € 158 million.
- 97 percent of the ecotax was actually spent.
- 20 percent of this expenditure covered the utilities' implementation expenses.
- Total estimated annual savings from the rebate program were around 300 GWh per year for the white goods sector only from the years 2000 and 2001 combined, including the market share improvements shown in Table C.3.
- Total estimated annual savings in the heat sector were around 500 GWh per year.
- Total CO_2 emission reductions achieved by the two-year scheme amount to around 0.3 million metric tonnes per year.
- This program appears to have created a considerable gain in the market share of efficient appliances in the Netherlands, compared to the rest of the EU, as seen in the following table.

Similar target: Thailand also attempted to influence the market share of efficient light bulbs and appliances. The state-owned utility, EGAT, chose not to use rebates or other consumer incentives. Instead they focused more on voluntary manufacturer negotiations, labeling, and public education efforts. Domestic manufacturers completely switched production to efficient thin tube fluorescent lamps. Labeling efforts dramatically improved the percent of efficient refrigerators sold, but had less of an impact on air conditioner sales.[ooo]

Table C.3: Market Share of Efficient Appliances in the Netherlands and the EU, 1999–2001 (Percent)

		1999	2000	2001
Refrigerators	Netherlands	26	55	67
	European Union	12	19	27
Freezers	Netherlands	29	55	69
	European Union	12	16	
Washing machines	Netherlands	40	71	88
	European Union	15	26	45
Dishwashers	Netherlands	27	55	73

Source: Belastingdienst (2002)

Taken from: Wuppertal Institute et al. (2002)

Case Studies: America's Leading Energy Efficiency Programs

Recently the ACEEE solicited nominations for exemplary energy efficiency programs. They described the following factors to be considered in identifying exemplary programs:

- direct kWh and kW savings (programs could be noteworthy because of overall magnitude of impact or because of cost-effectiveness)
- market transforming effects
- ex post evaluation/verification methodologies
- qualitative achievements (such as customer participation, stakeholder support, and program performance)
- innovation with promise for the future
- replicability

ACEEE convened an expert panel and received over 100 noteworthy nominations. Programs were implemented by a variety of actors and addressed the needs of diverse end-users. All of the exemplary programs addressed DSM opportunities identified for China by Finamore et al. (2003). The following "exemplary programs" were chosen to illustrate a variety of possible DSM approaches. All three programs are run by electric distribution utilities.[ppp]

New Jersey CoolAdvantage Program

Target: Electric central air conditioner and heat pump applications.

Context: The state of New Jersey passed power sector reform legislation in 1999. The resulting electric and gas distribution utilities were required to administer and implement cost-effective energy efficiency programs. The regulatory authority determined system benefit charges for each utility to finance the programs. The utilities chose to work together to offer consistent, statewide programs when possible.

Objective: The objective of the CoolAdvantage Program is to save energy and reduce peak demand by improving the energy efficiency of new electric central air conditioners and heat pumps. The program promotes the sale of qualifying energy-efficient equipment, improvements in proper system sizing, and installation "best practices" that improve operating efficiency.

Recent studies show that the average electric central air conditioner consumes twice the energy it should, resulting in hundreds of dollars wasted on energy bills by individual consumers. In addition, improper installation can lead to comfort problems, higher energy bills and maintenance costs, and shorter equipment life.

Process: This utility-funded program provides rebates of \$300–\$650 towards the purchase and installation of energy-efficient electric central air conditioners or heat pumps, based on the unit's seasonal energy efficiency ratio (SEER) and energy efficiency ratio (EER) and documentation that the proper installation requirements have been met.

The program also supports aggressive marketing to consumers, direct marketing to HVAC distributors and contractors, HVAC contractor training, sales training to promote efficiency, and promotion of HVAC certification.

Of interest: This is the first energy efficiency program in the U.S. to require the installing contractor to submit documentation that the air conditioner or heat pump has been properly sized and installed before the rebate is processed.

Results from 1999–2002:[qqq]

- Participants: 66,000
- Energy savings: 52,800 MWh
- Peak demand savings: 47.5 MW
- Lifetime cost/ in kWh: NA
- 2001 budget: $11.2 million
- 2002 budget: $17 million
- Market penetration: 30 percent for units with SEER of 13 or above, compared to 4–5 percent nationally; 20–25 percent for units with SEER of 14 or above, compared to 1–2 percent nationally

National Grid's Small Business Services Program in Massachusetts

Target: Small commercial and industrial consumers with an average monthly demand of less than 100 kW or an annual energy usage of less than 300,000 kWh.

Context: The electric distribution utility, National Grid, and its subsidiaries (such as Massachusetts Electric) operate in several U.S. states that have undergone power sector reform and require utility-run efficiency programs. In the state of Massachusetts, the distribution utilities use public benefit funds to offer a variety of energy efficiency programs to all end-users. The state regulatory body approves utility programs and budgets, conducts extensive evaluations, and provides performance incentives to utility shareholders for a job well done.

Objective: The Small Business Services Program attempts to provide energy and capacity savings to small commercial and industrial customers who tend to have a significant lighting load (as a percentage of total load) and a historical reluctance or inability to fund efficiency improvements. They are generally too small to benefit from ESCO services in the present environment.

Process: The utility provides direct retrofit installation of energy-efficient lighting and other energy saving measures. The company pays for 80 percent of total project costs, and customers may finance the remainder for up to 24 months interest free. The utility hires delivery contractors using competitive bidding. These contractors market the program, conduct energy audits, make recommendations to the customer, purchase materials (using suppliers awarded competitive bids by the utility), install the measures, and provide data for evaluation and progress reports. A separate contractor recycles ballasts and lighting fixtures in an environmentally sound manner.

Cost-cutting, energy-efficient equipment available through this program includes the following:

- lighting upgrades
- energy-efficient time clocks
- photo cells for outdoor lighting
- occupancy sensors
- programmable thermostats
- walk-in cooler measures
- novelty cooler night setbacks

Of interest: Although this program offers fairly comprehensive services, 90 percent of the energy savings come from lighting measures. Also, customers appreciate the convenience of financing their co-pay (20 percent) interest-free for 24 months, and paying this on their monthly utility bill.

Results for Massachusetts Electric, only:[rrr]

- Participants: since 1989, 35,000 customers (33 percent of eligible population) have been served
- 2002 lifetime energy savings: 116,352 MWh
- 2002 summer peak savings: 2,758 MW
- 2002 total cost to utility: $3.2 million*
- Cost/lifetime energy savings: $0.027/kWh
- Present value of lifetime savings: $9.3million
- Shareholder incentives: $185,738

*Includes planning and administration, marketing, customer incentives, implementation, evaluation, and shareholder incentives.

See also: http://www.nationalgridus.com/masselectric/business/energyeff/3_small.asp.

National Grid's Design 2000plus Program (Massachusetts, Rhode Island, New Hampshire)

Target: Opportunities for new construction, renovation, remodeling, and failed equipment replacement in the commercial and industrial sectors.

Context: The electric distribution utility, National Grid, and its subsidiaries (such as Massachusetts Electric) operate in U.S. states that have undergone power sector reform and require utility-run efficiency programs. In Massachusetts, the distribution utilities use public benefit funds to offer a variety of energy efficiency programs to all end-users. The state regulatory body approves utility programs and budgets, conducts extensive evaluations, and provides performance incentives to utility shareholders for a job well done.

Objectives: The utility hopes to influence architects, engineers, and the building design community to incorporate energy efficiency design strategies and equipment early in the design phase.

Process: The utility provides rebates for energy-efficient equipment installation. The program also offers technical assistance, custom services for complex projects, and the Comprehensive Design Approach (including computer simulation of a building's energy use).

Customers are eligible for both prescriptive measures and custom measures. Prescriptive measures include energy-efficient lighting, premium efficiency motors, high-efficiency HVAC equipment, compressed air equipment, and variable-speed drives. Custom applications allow more site-specific and comprehensive efficiency measures.

Of interest: Savings from the Custom and Comprehensive Design Approach applications accounted for 71 percent of the net energy savings in 2002. When lighting measures are added, these three applications are responsible for 88 percent of the savings.

Results for Massachusetts Electric, only:[sss]

- 2001 participants: 766 (over 700 each year, 1998–2002)
- 2001 lifetime energy savings: 878,883 MWh
- 2001 summer peak savings: 8,552 MW
- 2001 cost to utility: $15.4 million*
- Cost/lifetime energy savings: $0.0175 per kWh
- Present value of lifetime savings: $49.6 million
- Shareholder incentives: $1,016,818

*Includes planning and administration, marketing, customer incentives, implementation, evaluation and shareholder incentives.

Both the Small Business Services Program and the Design 2000plus Program provide cost-effective energy savings. However, a comparison of their results supports a separate finding:

> While providing energy-efficient improvements to existing processes can incrementally improve a facility's overall efficiency, truly dramatic improvements in energy efficiency occur when a total concept of optimization and efficiency is integrated into a complete plant design.[ttt]

Case Studies: Transmission and Distribution DSM

Power sector reform can create significant incentives for transmission and distribution providers to invest in DSM, or it can create disincentives that are very difficult to overcome. Regulatory policy is crucial to the outcome. Timely implementation of energy efficiency or load management (or both) can reduce system constraints, improve reliability, and delay or even remove the need for costly system upgrades. A single intervention or a diverse mix of DSM activities may be chosen to accomplish the goal. Regulatory policy is needed to assure that the transmission and distribution providers recover costs, just as they would for the capital outlays they are avoiding.

The IEA DSM Task VI Programme group anticipates that regulatory policy will be used more often as countries become more experienced with power sector reform. Regulators can require network operators to determine whether demand-side alternatives are more cost effective than network augmentation. This may require that network planning processes become more open to public scrutiny and involvement by stakeholders. According to the IEA DSM group, this concept works best in conjunction with a network revenue cap and with mechanisms for competitive sourcing of demand-side resources.[uuu]

In 1999–2000, Integral Energy, an Australian energy supplier, "reportedly deferred nearly 29 million USD in capital investment in network expansion for a cost of 1.2 million USD" in DSM activities.[vvv]

Appendix D

California DSM Programs

Table D.1: Peak Demand Reduction Programs

Funding source	Agency	Measure	Funding source	Total appropriated ($ million)	Summer 2001 peak reduction goal (MW)
SB 5X	CPUC	Residential Incentives and Rebates	SB 5X	50.0	61
SB 5X	CPUC	Increase CARE Program	SB 5X	100.0	
SB 5X	CPUC	Low-Income Weatherization	SB 5X	20.0	8
SB 5X	CPUC	Oil and Gas Pumping Efficiency	SB 5X	12.0	16
SB 5X	CPUC	Incentives for High Efficiency Lighting	SB 5X	60.0	44
AB 970	Energy Commission	Light Emitting Diode Traffic Signals	AB 970	10.0	6
AB 970		Innovative Efficiency and Renewables	AB 970	8.0	32
AB 970		Demand Response Systems	AB 970	10.0	65
AB 970		Cool Roofs	AB 970	10.0	25
AB 970		State Buildings and Public Universities	AB 970	5.5	200
AB 970		Water and Wastewater Treatment	AB 970	5.0	20
SB 5X		Municipal Utility	SB 5X	40.0	35

Funding source	Agency	Measure	Funding source	Total appropriated ($ million)	Summer 2001 peak reduction goal (MW)
		District Programs			
SB 5X		Demand Responsive Systems	SB 5X	35.0	120
SB 5X		Cool Roofs	SB 5X	30.0	15
SB 5X		Innovative Peak Programs	SB 5X	50.0	90
SB 5X		Agriculture Programs	SB 5X	70.0	22
SB 5X		Municipal water district generation retrofit	SB 5X	10.0	25
AB 29X		Time of Use and Real Time Meters	AB 29X	35.0	500
AB 29X		Local government loans and grants	AB 29X	50.0	20
AB 29X		Geysers Injection System	AB 29X	4.5	0
AB 29X		Emerging Renewable Account	AB 29X	15.0	0
AB 29X		Transfer from Renewable Trust Fund	AB 29X	15.0	0
SB 5X	Dept. of Consumer Affairs	Public Awareness Initiatives	SB 5X	10.0	1,000
SB 5X	Dept. of General Services	State Energy Projects	SB 5X	40.0	30
SB 5X	Dept. of Community Services and Development	Low-Income Assistance	SB 5X	120.0	
AB 29X	Technology, Trade and Commerce Agency	Renewable Loan Guarantee Program	AB 29X	40.0	10
AB 29X	Ca. Conservation Corps	Mobile Efficiency Brigade	AB 29X	20.0	10
AB 29X	Ca. Alternative Energy and Advanced Transportation Financing Authority	Renewable Energy Financial Assistance	AB 29X	25.0	

Source: California Energy Commission (2002)

Appendix E

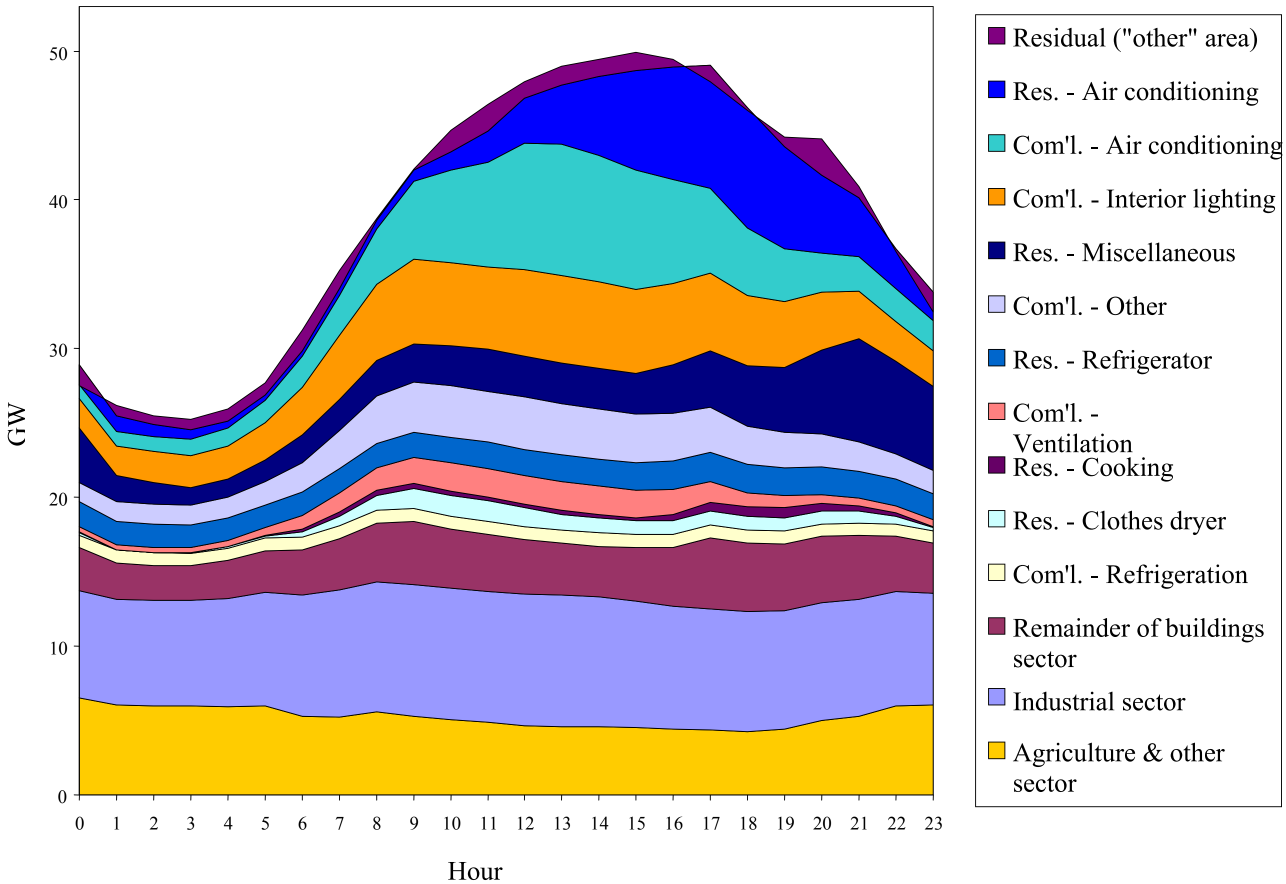
California Energy Data

Sector & End-Use	Coincident Load		Annual Energy		Load Factor	MWh/ kW	kW/ MWh
	GW	% of Total	TWh	% of Total			
Commercial Sector							
Air Conditioning	7.1	14%	13.8	5%	22%	1.9	0.51
Interior Lighting	5.4	11%	30.3	12%	64%	5.6	0.18
Other	3.1	6%	19.9	8%	73%	6.4	0.16
Ventilation	1.7	3%	9.1	4%	62%	5.5	0.18
Refrigeration	0.9	2%	6.5	3%	87%	7.7	0.13
Office Equipment	0.3	1%	1.6	1%	69%	6.1	0.16
Domestic Hot Water	0.1	0%	0.5	0%	53%	4.6	0.22
Exterior Lighting	0.1	0%	5.0	2%	606%	53.1	0.02
Cooking	0.1	0%	0.6	0%	77%	6.8	0.15
Space Heating	0.0	0%	2.1	1%	-	-	0.00
Total - Commercial	18.7	38%	89.5	36%	55%	4.8	0.21
Residential Sector							
Air Conditioning	7.5	15%	4.8	2%	7%	0.6	1.56
Miscellaneous	3.1	6%	24.6	10%	92%	8.1	0.12
Refrigerator	1.8	4%	13.7	5%	85%	7.5	0.13
Cooking	1.2	2%	3.6	1%	33%	2.9	0.34
Dryer	0.9	2%	5.7	2%	71%	6.2	0.16
Pools & Spas	0.8	2%	4.1	2%	60%	5.3	0.19
Domestic Hot Water	0.6	1%	4.2	2%	86%	7.5	0.13
Television	0.5	1%	3.4	1%	83%	7.3	0.14
Freezer	0.3	1%	2.5	1%	83%	7.3	0.14
Dishwasher	0.3	1%	2.0	1%	71%	6.2	0.16
Waterbed Heater	0.1	0%	2.1	1%	175%	15.3	0.07
Clothes Washer	0.1	0%	0.7	0%	75%	6.6	0.15
Space Heating	0.0	0%	4.0	2%	-	-	0.00
Total - Residential	17.2	35%	75.4	30%	50%	4.4	0.23
Industrial Sector							

Sector & End-Use	**Coincident Load**		**Annual Energy**		**Load Factor**	**MWh/ kW**	**kW/ MWh**
	GW	**% of Total**	**TWh**	**% of Total**			
Assembly	5.4	11%	33	13%	71%	6.2	0.16
Process	2.0	4%	14	6%	79%	6.9	0.14
Other	0.9	2%	6.1	2%	78%	6.8	0.15
Total - Industrial	8.3	17%	53.5	21%	73%	6.4	0.16
Agricultural Sector							
Total - Agricultural	2.3	5%	17.8	7%	88%	7.7	0.13
Transport & Street Lighting							
Total - Transport & Street. Lighting.	2.9	6%	15.3	6%	60%	5.3	0.19
Statewide Total							
Total – Statewide	49.6	100%	251.6	100%	58%	5.1	0.20

Source: Brown and Koomey, 2002

Figure E.1: California 1999 Summer Peak-Day End-Use Load (GW)

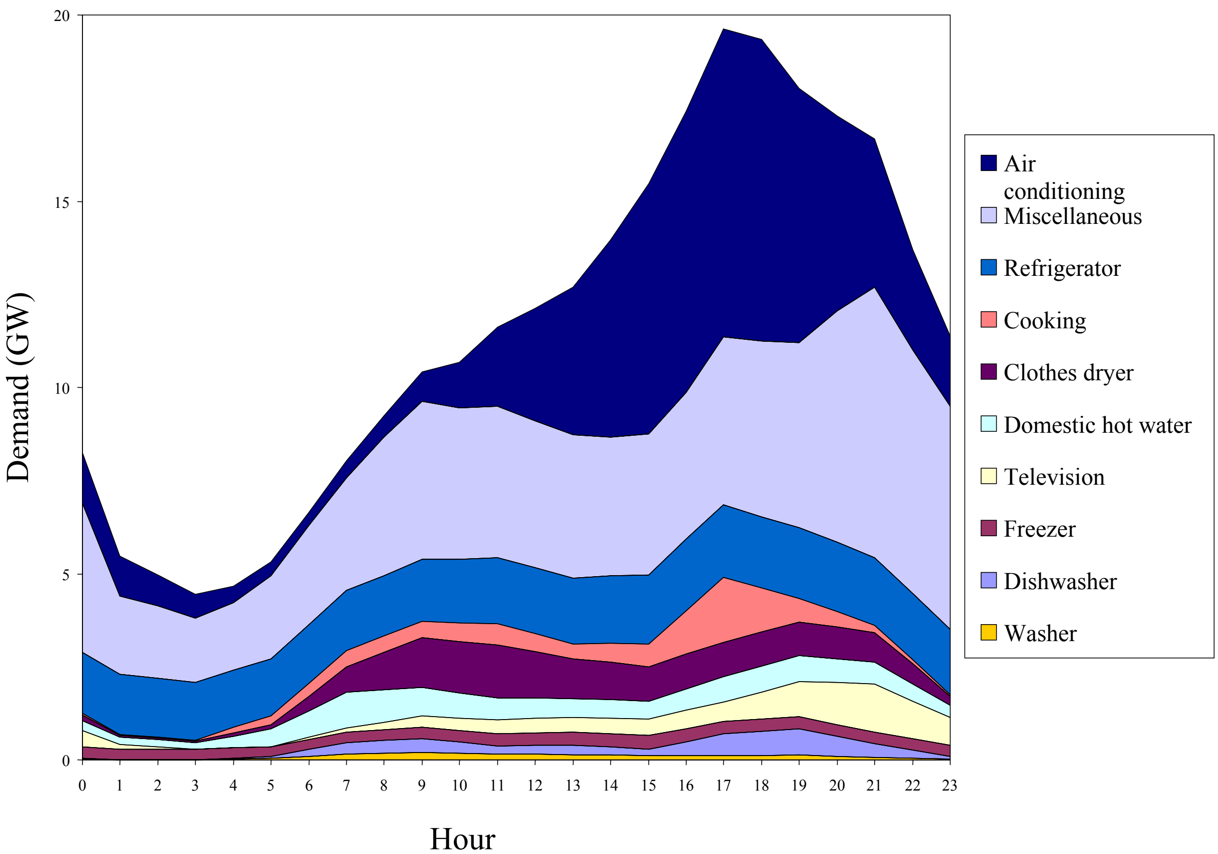


Source: Reprinted from Brown and Koomey, 2002.

Note: The 10 largest coincident building-sector end uses are shown separately.

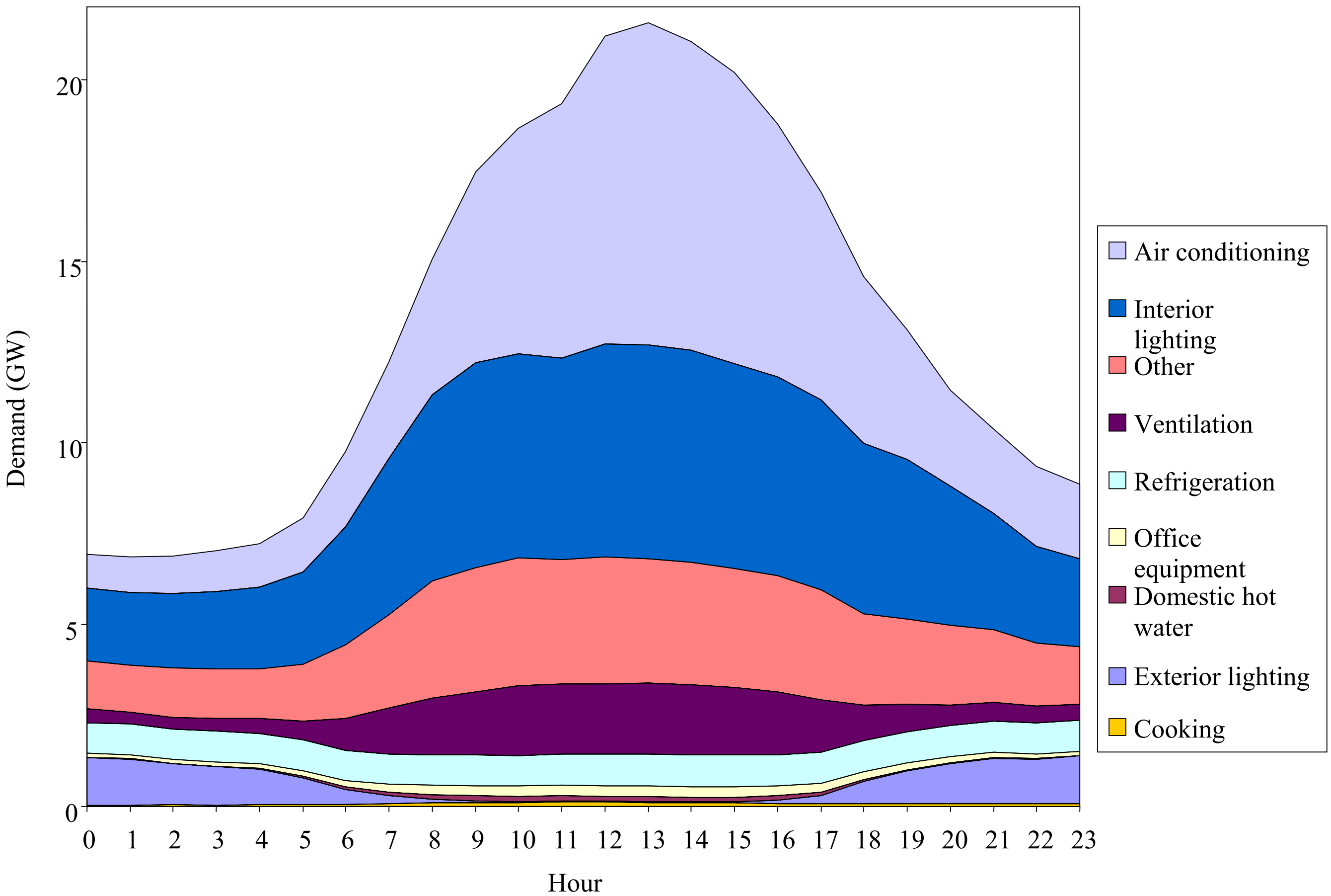
Res. = residential; Com’l = commercial.

Figure E.2: California 1999 Summer Peak-Day Residential Building End-Use Load (GW)



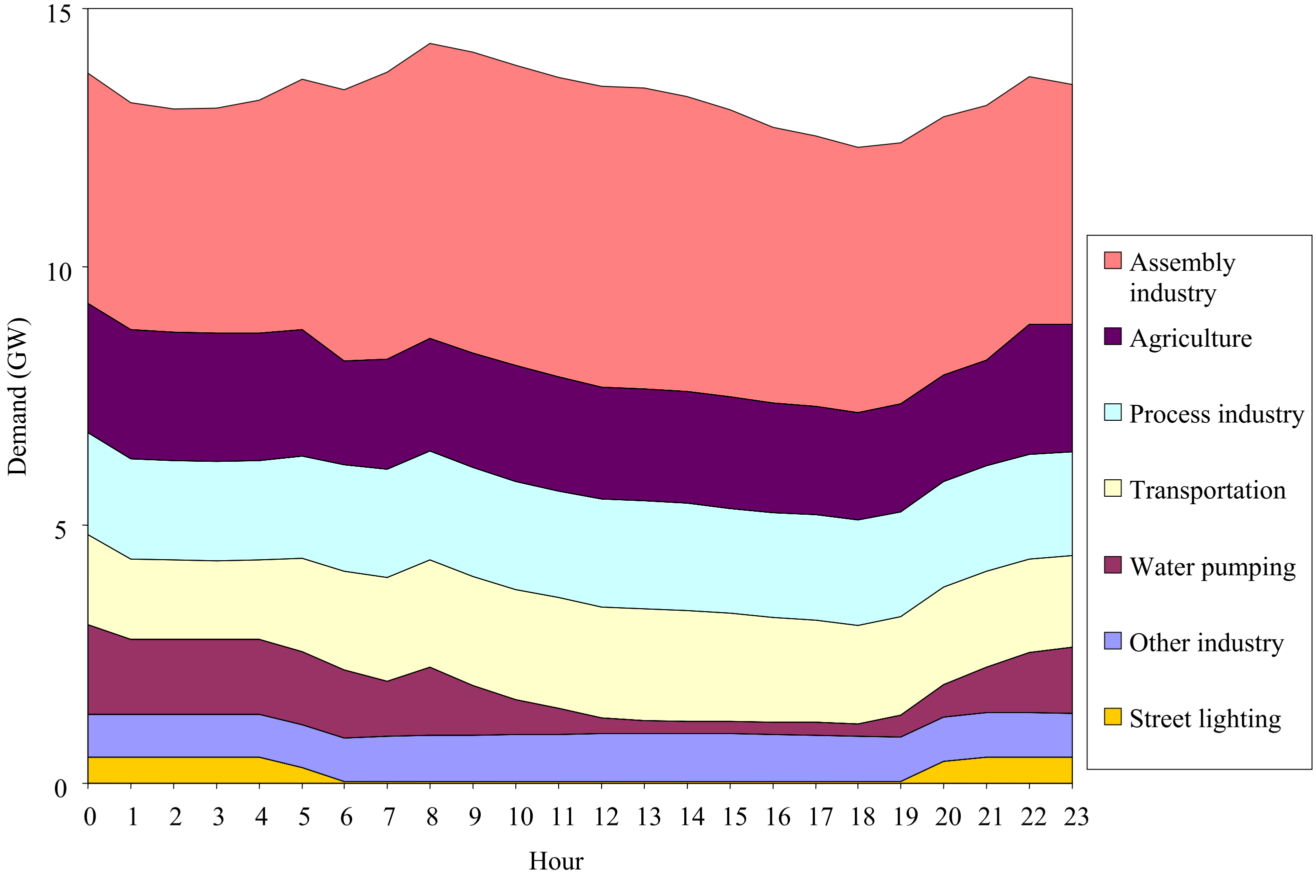
Source: Reprinted from Brown and Koomey, 2002.

Figure E.3: California 1999 Summer Peak-Day Commercial Building End-Use Load (GW)



Source: Reprinted from Brown and Koomey, 2002.

Figure E.4: California 1999 Summer Peak-Day Industrial, Agricultural, and Other Sectoral Load (GW)



Source: Reprinted from Brown and Koomey, 2002.

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