Policy Brief

China

Energy Efficiency as a Resource for the Power Sector in China

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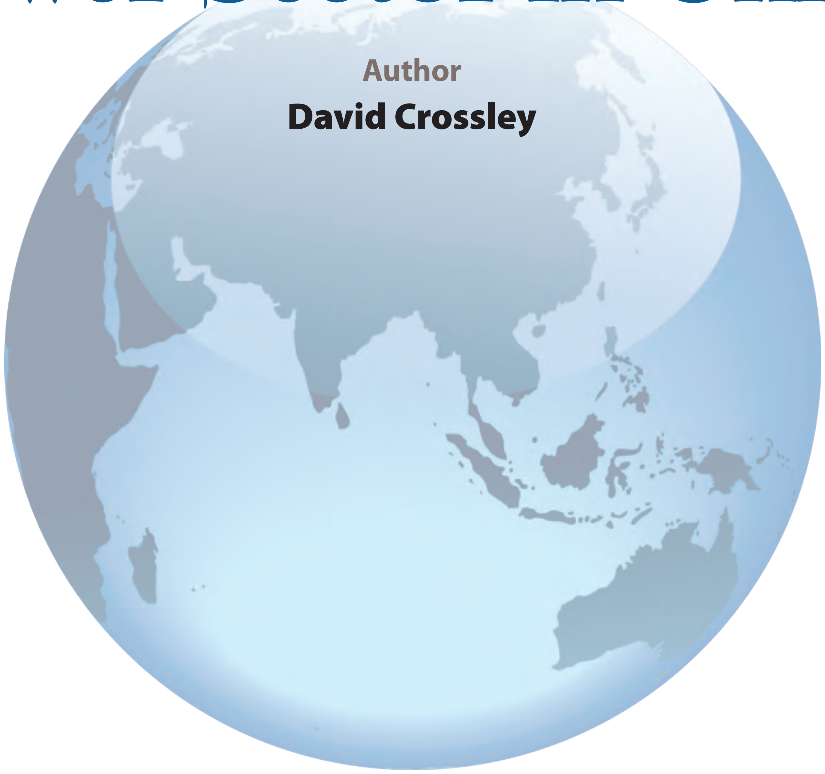

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List of Acronyms

ADB	Asian Development Bank
CNY	Chinese Yuan or Renminbi (currency unit)
CPP	Conventional Power Plant
DSM	Demand-Side Management
EERS	Energy Efficiency Resource Standard
EM&V	Evaluation, Measurement, and Verification
EPA	(U.S.) Environmental Protection Agency
EPP	Efficiency Power Plant
ESCO	Energy Services Company
ESF	Energy Saving Fee
FERC	Federal Energy Regulatory Commission (United States)
IOU	Investor-Owned Utility
IRP	Integrated Resource Planning
ISO	Independent System Operator
kW	Kilowatt
kWh	Kilowatt-Hour
M&V	Measurement and Verification
MW	Megawatt
MWh	Megawatt-Hour
PMO	Project Management Office (Guangdong EPP)
POU	Publicly Owned Utility
RTO	Regional Transmission Operator
tce	Tonne of standard coal equivalent; by convention one tce equals 29.3076 gigajoules. China typically converts all its energy statistics into tce.
USD	United States Dollar (currency unit)

Executive Summary

This paper shows that, in several jurisdictions around the world, electricity utilities employ end-use energy efficiency as a resource in meeting their customers' needs for energy services. Energy efficiency is seen as a cost-effective alternative to investing in supply-side resources, such as building power plants and expanding the electricity grid. Used in this way, energy efficiency provides multiple benefits to the power system, to electricity customers, and to society as a whole.

Methods for integrating energy efficiency into power system resource planning are readily available and are in active use in many jurisdictions. Some jurisdictions have established comprehensive policy, regulatory, and organisational systems that enable energy efficiency to bte used as a power system resource. The paper presents three case studies, including one from China. The Chinese case study, of the Guangdong efficiency power plant, demonstrates that energy and capacity savings can be successfully acquired at a lower cost than conventional electricity generation, with all the additional benefits that energy efficiency provides.

Using energy efficiency as a power system resource is particularly important in China, where air pollution from coal-fired power plants is a large and growing problem. Energy efficiency can meet a portion of China's needs for energy services while also contributing to reducing air pollution and could make an important contribution to China's current Clean Air Action Plan.

China has a long history of establishing government policies that require extensive energy efficiency programs, particularly in the industrial sector. More recently, the central government has established a Rule that requires grid companies to implement energy efficiency. What is needed now is for government to strengthen policy and regulatory mechanisms to both expand the energy efficiency programs delivered by grid companies and to enable energy and capacity savings achieved by all energy efficiency programs implemented in China to be used as power system resources. This will reduce the number of new power stations and augmentations of grid infrastructure that must be built in the future.

Grid companies are the key to using energy efficiency as a power system resource in China. In common with many electricity utilities in other countries, Chinese grid companies may be initially reluctant to consider energy efficiency as a resource; they may have questions about whether energy efficiency is as predictable or as "firm" as supply-side resources. The practical experience with utility energy efficiency programs described in this paper should alleviate these concerns.

Grid companies are also concerned about the reduction of revenue that results from encouraging customers to use electricity more efficiently. As long as the State-Owned Assets Supervision and Administration Commission evaluates grid company performance primarily on the revenue they earn and the profit they make, revenue reduction will be a major barrier to grid company implementation of energy efficiency. This barrier could be removed by changing the metrics for evaluating grid company performance, particularly by developing a metric that measures grid company performance in delivering energy efficiency. The multiple benefits that using energy efficiency as a power system resource will bring to China provide ample justification for changing the evaluation of grid company performance in this way.

1. Introduction

1.1 Energy Efficiency as a Resource

In several jurisdictions around the world, electricity utilities employ end-use energy efficiency as a resource in meeting their customers' needs for energy services. Energy efficiency is seen as a cost-effective alternative to investing in supply-side resources, such as building power plants and expanding the electricity grid. The purpose of this paper is to further develop this concept to enable both grid companies and governments in China to routinely rely on energy efficiency as a reliable component of the portfolio of resources used to supply electricity customers' needs.

For many people, thinking about energy efficiency as a resource is a novel concept. Energy savings resulting from more efficient use of energy are not something that can be seen – they are energy that is not being consumed. However, energy savings can be measured reasonably accurately by comparing energy used before and after an energy efficiency measure is installed. In fact, there is a wealth of experience over more than 30 years in how to define and calculate energy savings from a wide range of energy efficiency projects and measures.[1]

Energy savings resulting from energy efficiency projects can be defined and analysed in terms of the total quantities of unserved energy that can be relied on per year; over a particular lifespan (number of years) of energy savings delivery; and at consistently estimated levelised average costs per kilowatt (kW), kilowatt-hour (kWh), or tonne of coal equivalent (tce) per year.

Therefore, energy efficiency resources can be fairly easily compared with energy supply resources, such as energy from power plants or coal mines. For example, building on the concept of energy efficiency as a resource, it is now popular in some parts of China to focus on the development of "efficiency power plants."[2] These are bundles of energy savings projects packaged together to be conveniently compared to electric power plants in terms of capacity, energy service delivery, and cost.[3]

In China, grid companies typically purchase electricity in bulk from generation companies, transport the energy through transmission and distribution grids from power plants to end-use customers' premises, and then sell the electricity to end-users. Grid companies are not usually responsible for developing resource investment plans to ensure that supply resources are adequate to meet end-user demand over the long term – that is the responsibility of provincial and local governments. Therefore, in China, using energy efficiency as a resource will require collaboration between grid companies and government agencies responsible for ensuring that supply resources are adequate to meet long-term end-user demand.

1.2 Experience in North America

In North America, electricity utilities commenced offering "energy conservation" programs during the energy crises in the 1970s to help customers cope with soaring energy prices. Over time, this led to the development of an expanded set of customer energy efficiency programs provided by electricity utilities. Since then, energy efficiency has evolved to become recognised as an integral and highly valuable element of utility investments and operations. Utility energy efficiency programs have yielded significant energy and economic benefits to the power system and to electricity customers. Today, energy efficiency is regarded as an important power system resource that can also reduce greenhouse gases, save money for customers, and generate jobs.[4]

1 Taylor (2013).

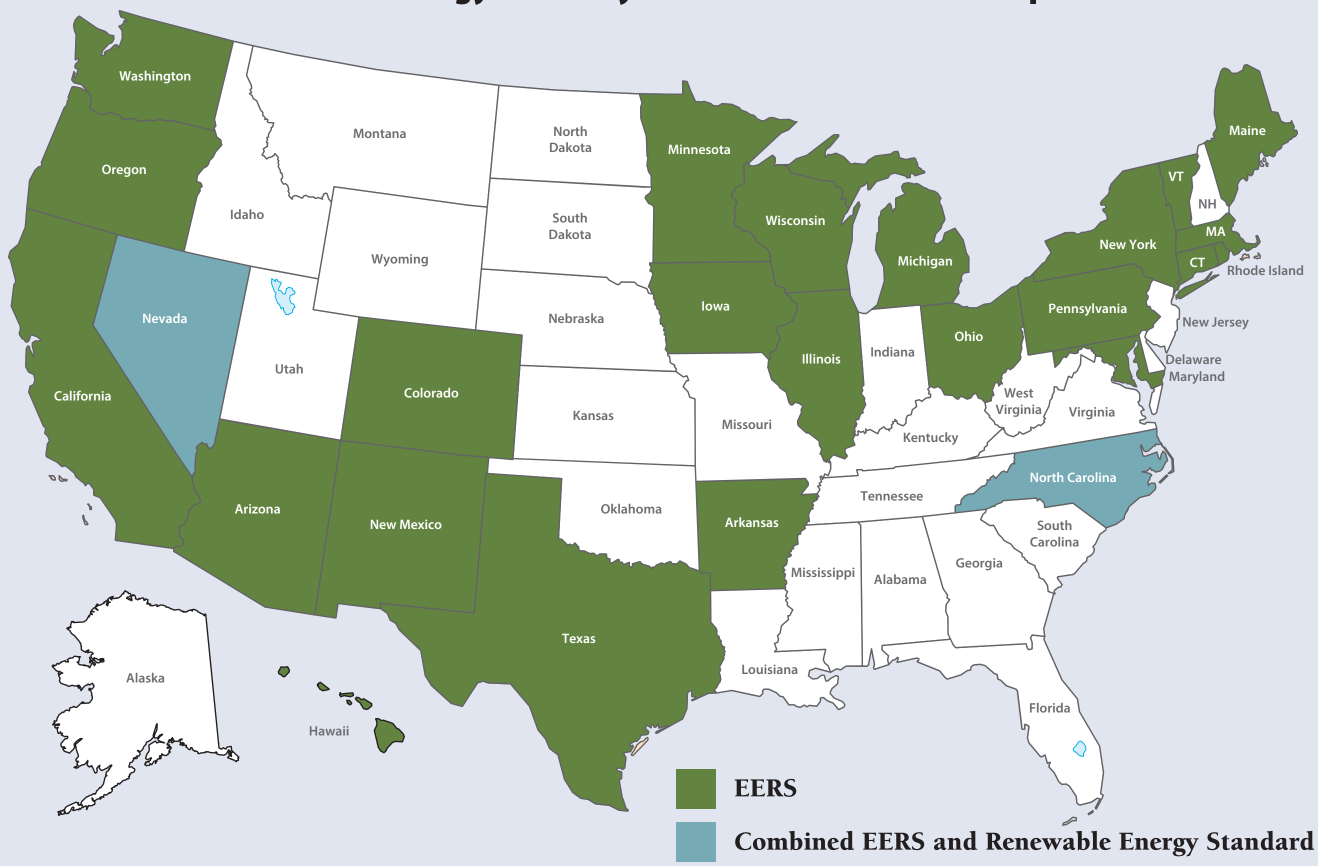
2 Zhou and Hu (2010).

3 Schultz (2009).

4 American Council for an Energy-Efficient Economy (2014a).

Figure 1

US States with Energy Efficiency Resource Standards as at April 2014[5]



In response to both economic concerns and climate change, legislators and regulators in North America are now supporting the acquisition of energy efficiency as a power system resource at unprecedented levels. In the United States, electricity industry regulators are instituting Energy Efficiency Resource Standards (EERS) that establish specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through implementing customer energy efficiency programs. Figure 1 shows that, in April 2014, 25 US states have enacted long-term (3+ years) EERSs. These 25 states make up nearly 60 percent of electricity sales in the United States. If each of these states maintains its current EERS target out to 2020, the overall savings would be more than 232,000 GWh by 2020, equivalent to over six percent of 2011 electricity sales throughout the United States.[6]

The main reasons that public authorities in North America encourage energy efficiency resource acquisition programs are to ensure least-cost resource development by energy utilities, reduce environmental damage from energy use, enhance energy supply security, and reduce the bills of electricity customers. The relative priority of these objectives varies across jurisdictions and these varying priorities shape how energy efficiency programs are developed and implemented in each jurisdiction.[7]

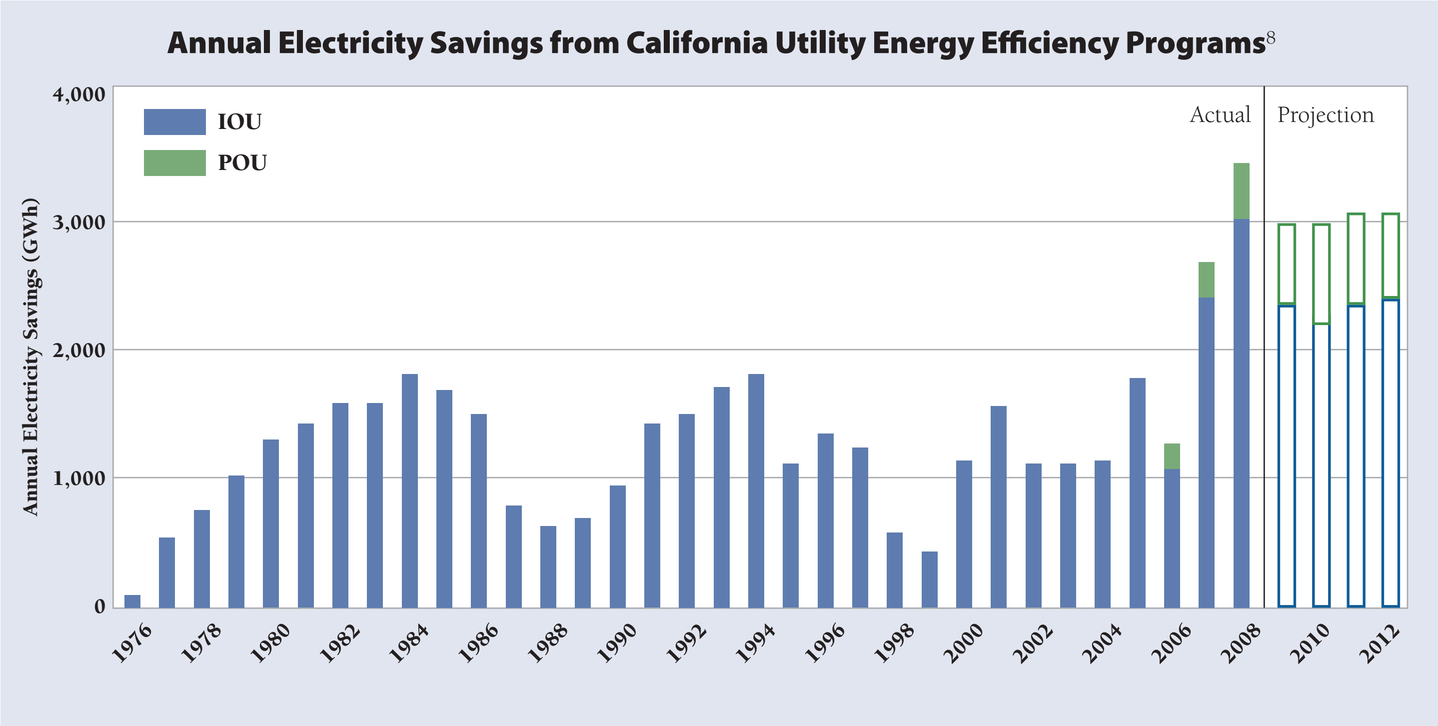
In the state of California, utility energy efficiency programs implemented by electricity utilities have been in operation since the mid 1970s. Figure 2 shows the annual electricity savings from energy efficiency programs implemented since 1976 in California by investor-owned utilities (IOUs) and publicly owned utilities (POUs).

5 American Council for an Energy-Efficient Economy (2014b).

6 American Council for an Energy-Efficient Economy (2014b).

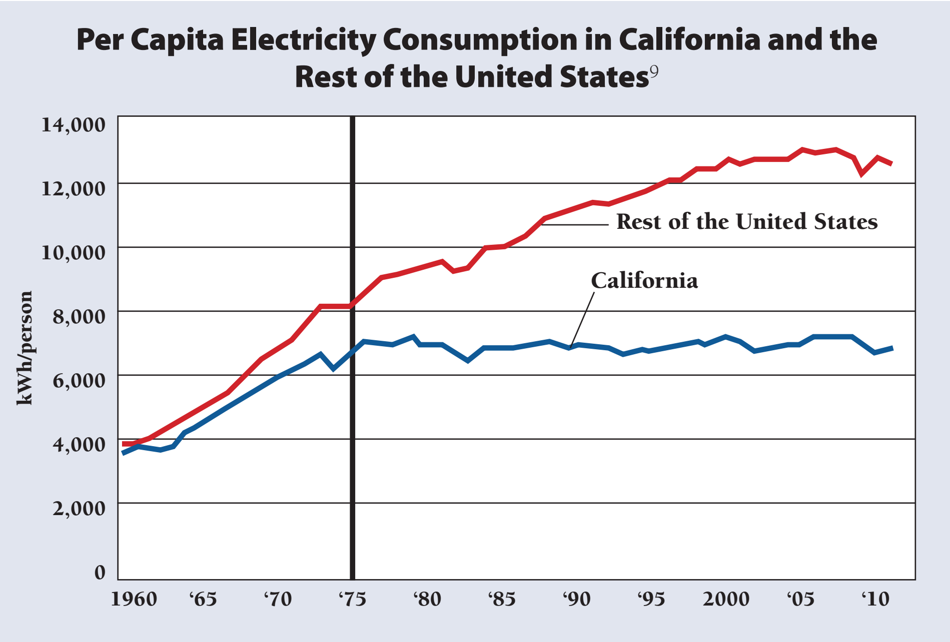
7 Taylor, Trombley, & Reinaud (2012).

Figure 2



During the nearly 40-year period since the mid 1970s, per capita electricity consumption in California remained nearly flat, while per capita consumption in the rest of the United States increased by over 50 percent (see Figure 3). Although some of the difference between the Californian and national per capita consumption may be explained by factors that are independent of energy policy, such as changes in industry composition and average household size, a major contribution has been made by utility-delivered energy efficiency programs.

Figure 3



8 Martinez, Wang, & Chou (2010).

9 Martinez (2013).

2. Multiple Benefits from Energy Efficiency

The primary result from enhancing the efficient use of electricity is a reduction in the quantity of energy required to meet customers' needs. Energy efficiency can also reduce loads at peak times on the power system and this leads to lower capacity requirements. In countries such as China, where there is a high growth rate in demand for electricity, the total quantities of energy and capacity required will increase over time, rather than reduce, following the implementation of energy efficiency, but the total energy and capacity requirements will still be less than in the business-as-usual case without energy efficiency.

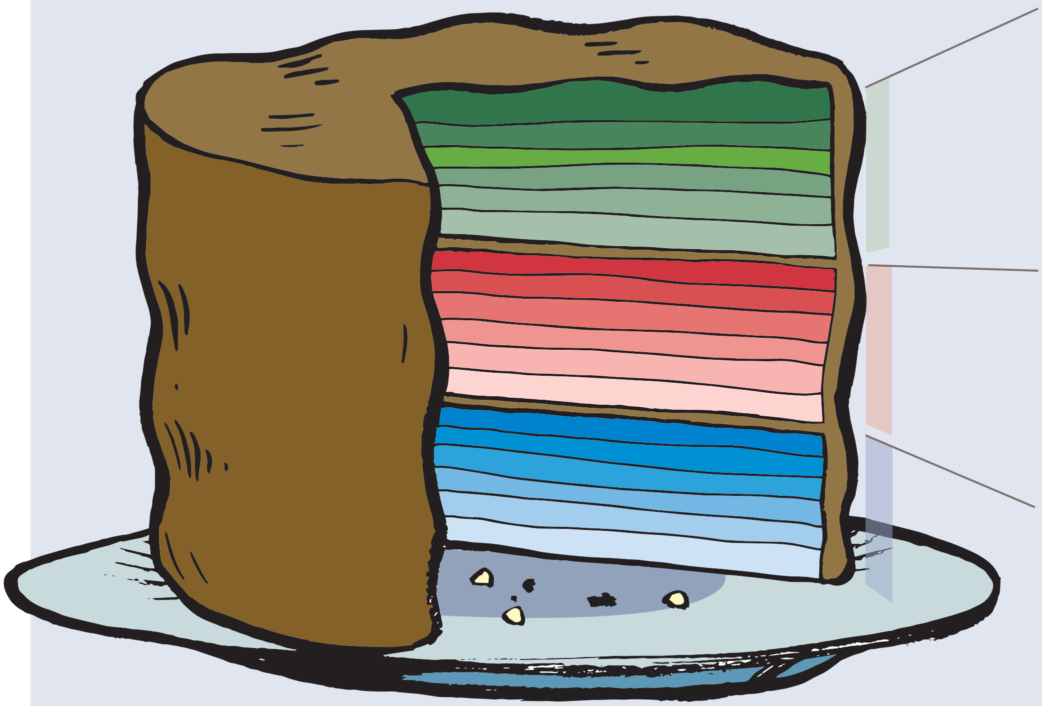
Through reducing energy and capacity requirements, energy efficiency provides a broad array of multiple benefits. Some of these benefits have direct impacts on the electric power system, whereas the impact of others occurs wholly outside the power sector. Some can be readily monetised; others are almost impossible to quantify in economic terms. Some accrue to customers who pay electricity bills; others accrue to broader segments of society.

A recent study in the United States[10] developed a comprehensive catalog of benefits that can be derived from implementing electric energy efficiency measures. The study classified these benefits into three general categories as shown in Figure 4:

- Power system benefits;
- Benefits for electricity customers; and
- Societal benefits.

Figure 4

Multiple Benefits from Electric Energy Efficiency[11]



Power System Benefits
- Least-cost resource development
- Avoided investments
- Avoided line losses
- Reduced GHG emissions
- Minimised reserve
- Decreased risk
- Reduced collection costs

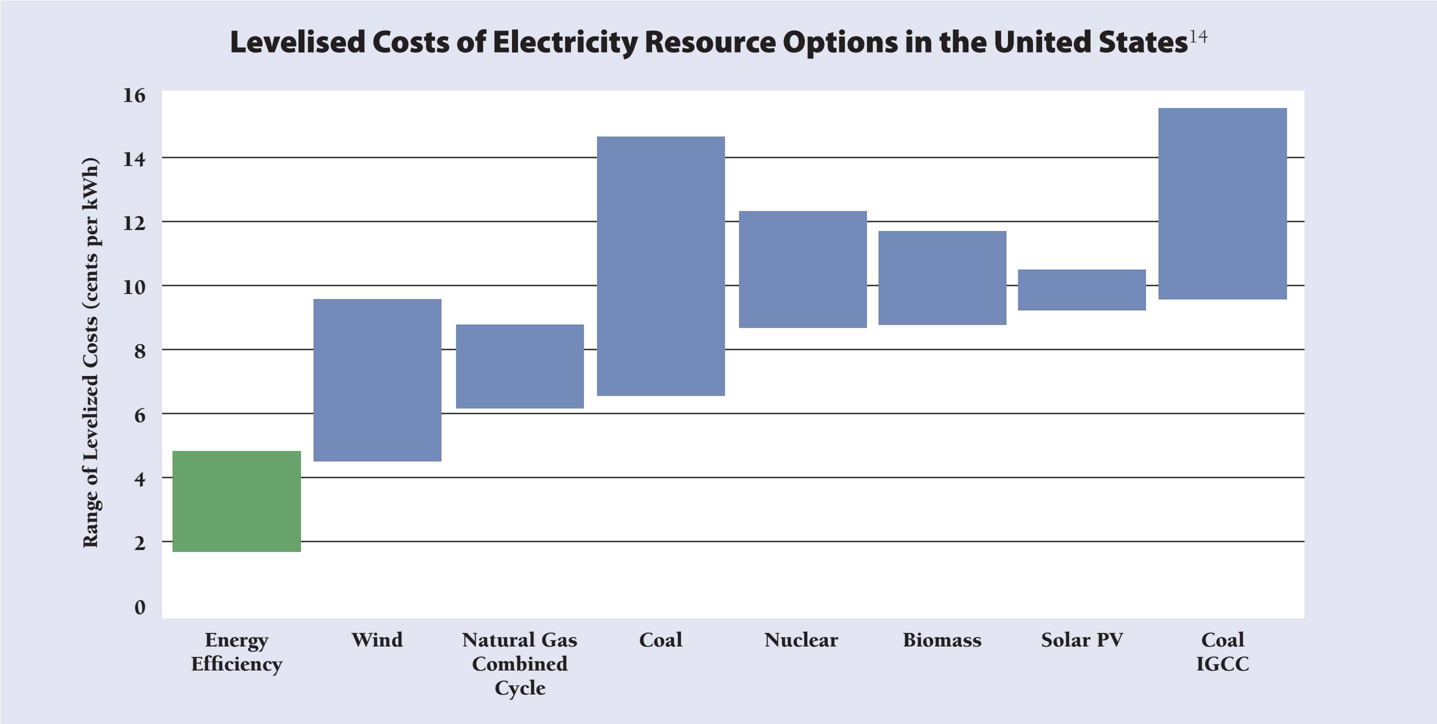
Electricity Customer Benefits
- Reduced electricity bills
- Other energy savings
- Operations & maintenance savings
- Increased employee productivity
- Health benefits
- Increased comfort

Societal Benefits
- Environmental benefits
- Improved air quality
- Improved water quality
- Increased employment
- Economic development benefits
- Increased energy security

10 Lazar & Colburn (2013).

11 Modified from Lazar & Colburn (2013).

Figure 5



2.1 Power System Benefits

Least-Cost Resource Development. Delivery of energy efficiency resources costs dramatically less than incremental electricity supply resources. In most electric power systems, the cost of delivering reliable energy efficiency resources to meet electrical energy demand (both kWh and kW) is considerably less than the costs of new power supply sources, such as a new power plant, even before factoring in environmental and other externalities. Figure 5 shows the unsubsidised levelised costs of electricity resource options in the United States; energy efficiency data are from a survey of utility energy efficiency program costs (range of four-year averages for 2009–2012)[12] and supply costs are from a standard electricity industry manual.[13] It is clear that energy efficiency is substantially cheaper than any other option, with the possible exception of wind.

Avoided Investments in Production, Transmission, and Distribution Capacity. Because less electrical energy must be supplied by the power system and peak capacity requirements are lower, fewer power stations are required to generate electricity, and fewer transmission and distribution lines are required to transport electricity to end-use customers, therefore requiring less investment in these assets.

Avoided Line Losses. Saving energy at customer premises reduces the quantity of electrical energy that must be transported through transmission and distribution lines from power stations to customers' premises. Because line losses increase exponentially as power lines become heavily loaded, energy efficiency can significantly reduce line losses. Reducing peak demand at customer premises through implementing energy efficiency measures translates into much larger savings at the generation level because of avoided marginal peak line losses. In the United States, marginal line losses at peak periods – losses avoided by energy efficiency – can be as much as 20 percent.[15]

Minimised Reserve Requirements. Power systems carry reserves in the form of generating capacity that can provide immediate backup service if a power plant suddenly goes off line. Typically, reserve requirements are calculated as a percentage of the demand at any point in time. For thermal systems in the United States, reserves are typically 13 to 15 percent of demand. Putting both line losses and reserves together, an energy efficiency measure with high

12 Molina (2014).

13 Lazard Ltd (2013).

14 Molina (2014).

15 Lazar and Colburn (2013).

on-peak savings can provide approximately 1.4 times the generation capacity benefits of the energy savings measured at customer premises.[16]

Reduced Greenhouse Gas Emissions. Implementing energy efficiency as an alternative to electricity generation reduces emissions in the power sector. The U.S. Environmental Protection Agency (EPA) is proposing emissions guidelines for states to follow in developing plans to address greenhouse gas emissions from existing fossil fuel-fired electric generating units.[17] Specifically, the EPA is proposing state-specific rate-based goals for carbon dioxide emissions from the power sector, as well as guidelines for states to follow in developing plans to achieve the state-specific goals. Under the EPA proposal, states will be able to use utility-delivered energy efficiency programs to achieve emissions reductions goals.

Decreased Risk. Power sector resource planning – particularly involving the construction and operation of supply resources – is an uncertain science that involves many risks. Energy efficiency measures decrease risk in many ways.

Energy efficiency programs are unique in that they consist of thousands of small discrete resources that cannot all fail at once, and are therefore inherently less risky in terms of failure than a power plant. In the United States, extensive analysis has shown that acquisition of a portfolio of resources consisting of a large number of discrete small units is inherently more reliable and predictable than a portfolio of a smaller number of larger units.[18]

Energy efficiency is a highly predictable and reliable resource that enables the power system and society as a whole to avoid the risk of surpluses, shortages, and periodic outages. Especially where delivered as a portfolio of measures with medium and/or long-term reliability, acquisition of energy efficiency resources can provide a valuable hedge against energy supply disruptions or shortages and energy price volatility, including price spikes.

Energy efficiency programs usually have shorter lead-times than supply-side infrastructure that usually takes many years to build. Energy efficiency resources are also readily scalable; if load rises more rapidly (or slowly) than expected, energy efficiency resources can be ramped up (or down) much faster than new supply resources can be built. Energy efficiency starts delivering benefits as soon as the first energy efficiency measures are installed; there is no waiting time until a large project is completed. Finally, because energy efficiency can be added in increments, it may be used to buy the time required to assess the need for large supply projects.

Reduced Credit and Collection Costs. Energy efficiency programs targeted to low-income households assist utilities with credit and collection costs. Energy efficiency measures reduce electricity use and lower electricity bills in low-income households. This leads to a reduction in non-payment of bills, thereby reducing the utility's need to provide for uncollectible accounts and decreasing collection costs. One recent study in the United States estimated these benefits at as much as ten percent of low-income weatherisation program costs.[19]

2.2 Benefits for Electricity Customers

Reduced Electricity Bills. Reduced electricity bills are the major benefit provided to electricity customers by increased levels of energy efficiency. Implementation of cost-effective energy efficiency measures reduces the bills of electricity customers, simply because they don't need to buy as much electricity. Also, by relying on least-cost energy efficiency resources, utilities are able to avoid more expensive supply resources. This eventually results in lower relative prices to customers because capital costs of avoided new generation are not included in these prices. How fast prices decline relative to the no energy efficiency scenario, and by how much, depends mainly on how fast the electricity load is growing and the differences between marginal costs for new supply and the marginal costs of energy efficiency resources.

Operations and Maintenance Savings. Replacing standard appliances and equipment with energy efficient ones often results in operations and maintenance savings. For example, replacing an incandescent lamp with an LED lamp saves approximately 80 percent of the lighting energy previously used. In addition to these energy savings, the LED lamp also has an average lifetime of 24,000 hours compared with approximately 1000 hours for an incandescent lamp or approximately 8000 hours for a compact fluorescent lamp.[20] Installing an LED lamp avoids multiple lamp replacements, saving money both on lamps and on the labor required to replace them.

16 Lazar and Colburn (2013).

17 United States Environmental Protection Agency (2014).

18 Lazar and Colburn (2013).

19 Kunkle and Schueler (2011).

20 Lazar and Colburn (2013).

Other Energy Savings. A variety of measures that primarily produce electricity savings also save other fuels, such as coal, natural gas, fuel oil, propane, and wood. Some energy efficiency programs also save water. In addition, some of the upstream and downstream savings in energy efficiency programs, for example, in water pumping or water treatment, may also displace fossil fuel consumption.

Increased Employee Productivity. Replacing an older air conditioning or lighting system with a newer, more efficient system can provide employee productivity improvements. Efficient air conditioning is one of the most important labor productivity investments an employer in a hot climate can make. One major employee complaint in the office environment is glare on computer screens from lighting; replacing such a lighting system with energy efficient indirect lighting can eliminate this problem and increase employee productivity.[21]

Health Benefits. When energy efficiency measures are installed in businesses and residences, improvements to indoor air quality, moisture control, and other environmental health elements often result. For example, when ceiling insulation is installed, proper roof ventilation is typically also addressed. In 2008, New Zealand initiated a program to improve the energy use of every low-income household in the country over a four-year period. The evaluation of the initial 40,000 homes treated in the first year showed the dramatic improvements, including[22]:

- 43-percent reduction in hospital admissions attributable to respiratory ailments;
- 39-percent reduction in days lost at work; and
- 23-percent reduction in days lost at school.

Increased Comfort. Many energy efficiency measures increase consumer comfort, such as air sealing in buildings (guided by blower-door tests) that reduces drafts, moisture, and mold and rot, and improves heat balance throughout the building. In the New Zealand example described above, entire heating systems, windows, and insulation were replaced, resulting in dramatically improved outcomes for occupants in relation to both health and comfort.

2.3 Societal Benefits

Environmental Benefits. Energy efficiency resources are arguably the cleanest energy resources from an environmental perspective. The unacceptable land footprint and ecological impacts, air and other local pollution impacts, and carbon emissions of many supply alternatives are avoided. In air quality improvement and carbon emission reduction plans, implementing energy efficiency measures usually ranks at or near the top of the list of cost-effective measures.

Improved Air Quality. Electric power plants typically control emissions of some pollutants to the atmosphere, but the balance goes up the stack. Some emissions are harmful to human health and welfare as they are emitted; others contribute to chemical reactions in the atmosphere, creating harmful contaminants while airborne. Where implementing energy efficiency measures facilitates retirement of the most polluting power plants with the severest health effects, this benefit can be many times the national average benefit from energy efficiency.

Improved Water Quality. Electric utilities use massive amounts of water for power plant operations. Although some discharge of pollutants is regulated, virtually all steam electric power plants (i.e., coal and natural gas plants) produce effluent that may adversely affect the biosphere. As with air quality, implementing energy efficiency measures that facilitate retirement of the most polluting power plants will greatly improve water quality.

Increased Employment. Electricity production is extremely capital-intensive, but not particularly labor-intensive, even in fuel production industries such as coalmining. In contrast, energy efficiency is labor-intensive, typically uses a higher proportion of skilled local labor, and generates more jobs per unit of energy savings delivered than the jobs per unit of energy supplied in fossil fuel-based electricity production, transmission, and distribution.

Implementing energy efficiency also creates jobs in other sectors. In the United States, a retrospective analysis of California's history of implementing energy efficiency programs since the mid 1970s concluded that energy efficiency measures have enabled California households to redirect their expenditure toward other goods and services, creating approximately 1.5 million full-time equivalent jobs with a total payroll of over USD 45 billion, driven by well-documented household energy savings of USD 56 billion from 1972 to 2006.[23]

21 Institute for Building Efficiency (2014).

22 Telfar-Barnard et al (2011).

23 Roland-Holst (2008).

Economic Development Benefits. Energy efficiency is typically much less expensive than the energy supply it displaces; over time electricity bills are reduced so consumers are left with additional disposable income that is mostly spent locally and circulates in the local economy with a multiplier effect. Studies in the United States indicate that the local economic benefit of energy efficiency can be two to four times the value of the energy saved.[24]

Increased Energy Security. Energy efficiency helps to avoid and minimise shortage or loss of electricity supply. The consequences arising from problems in electricity supply go far beyond the balance sheets of the electricity supply and distribution industries. Every business depends on a reliable and affordable supply of electricity. By minimising electricity demand through energy efficiency, risks to reliability are reduced.[25]

24 Geller, DeCicco, and Laitner (1992).

25 Lazar and Colburn (2013).

3. Integrating Energy Efficiency Into Resource Planning

To enable energy efficiency to be used as a power sector resource, it must be integrated into the sector's resource planning.

3.1 Resource Planning in the Power Sector

Power sector resource planners must decide how to meet future demand for electricity with limited information about future fuel prices, economic conditions, technology advancements, and government policies. Assessing the risk of not meeting demand is essential to the planning process.

In the United States, electric utilities and other power sector resource planners typically develop their plans for meeting future demand over the course of several years. This long-term planning process involves many stakeholders and can be computationally intensive. Many utilities are required to publicly release and defend their resource plans in front of regulators, consumer advocates, and/or other stakeholders.

Long-term resource planning in the United States power sector involves three basic steps[26]:

1. Developing a load forecast for the planning horizon;
2. Determining portfolios of existing and future resources for meeting that demand; and
3. Evaluating the cost and risk of candidate resource portfolios.

Load Forecast. Developing a load forecast is the critical first stage in the resource planning process. Sophisticated modelling techniques are used to project energy consumption and peak demand for a variety of customers over the planning horizon. Many factors affect future demand, including weather, population, consumer behaviour, technology adoption, and economic trends. Accurately forecasting any one of these variables is difficult. Load forecasters usually report projected aggregate consumer load in MWh of energy consumption and MW of coincident peak power demand prior to energy efficiency or demand response programs. Forecasts may include some allowance for "naturally occurring" energy efficiency, that is, load reductions that will occur anyway in the absence of utility energy efficiency programs. To be effective in supporting the use of energy efficiency as a resource, load forecasts should specifically identify the load reductions that will be achieved from utility energy efficiency programs separately from naturally occurring energy efficiency. Load reductions from utility programs are typically estimated from program planning data.

Resource Portfolios. Once load forecasting is completed, electric utilities construct candidate portfolios consisting of both supply-side and demand-side resources to meet the anticipated load. Demand-side resources typically include energy efficiency and demand response and are based on estimates of the likely energy savings and demand response load reductions from existing and new utility programs. Each utility first characterises potential resources using a broad set of criteria, including availability of existing resources and contract renewals; capital, fixed, and variable costs of new resources; access to fuel and transmission infrastructure; the possibility of future local-state-federal regulations; and financial return on investment. After constructing a number of candidate resource portfolios, the utility selects the portfolio that best satisfies its selection criteria (e.g., least-cost, lowest risk) as the preferred portfolio. Utilities often submit their preferred portfolios and their load forecasts to regulators and/or relevant government agencies for review and sometimes for approval.

Portfolio Risk and Uncertainty. There are many sources of risk in the power sector resource planning process, including uncertainty about future fuel prices, legislation, weather, construction timelines, and energy demand. An inaccurate prediction of one variable can have a significant impact on how a utility constructs its preferred resource portfolio. This can affect the utility's ability to meet

26 Wilkerson, Larsena, and Barbose (2014).

future demand, and the costs to the utility and ultimately to its customers. Utilities use several techniques to assess risk and uncertainty in their resource plans, including scenario analysis, sensitivity analysis, and probabilistic analysis.

3.2 Methods for Resource Planning with Energy Efficiency

In the United States, the National Action Plan for Energy Efficiency Leadership Group has produced a *Guide to Resource Planning with Energy Efficiency.* The guide outlines appropriate methods to use during the following resource planning stages[27]:

- Determining energy efficiency potential;
- Estimating energy efficiency avoided costs;
- Developing energy efficiency measures;
- Determining cost-effectiveness;
- Developing energy efficiency programs and portfolios;
- Estimating energy efficiency impacts;
- Procuring energy efficiency resources; and
- Evaluation, measurement, and verification.

3.2.1 Determining Energy Efficiency Potential

Potential studies are conducted to determine the potential for saving energy (kWh) and capacity (kW) through energy efficiency measures. Figure 6 illustrates the different types of energy efficiency potential.

The process begins with an estimate of the *technical potential,* the kWh and kW savings that would be achieved if all technically feasible efficiency measures were implemented for all customers. The technical potential is then adjusted by applying a series of screens of real-world constraints.

Economic potential is the result of reducing the technical potential by applying cost-effectiveness and program eligibility criteria. Section 3.2.4 outlines the various tests for evaluating cost-effectiveness, each reflecting the different interests of various stakeholders in energy efficiency.

Achievable potential is the result of estimating by how much market barriers and program uptake limits will reduce the economic potential.

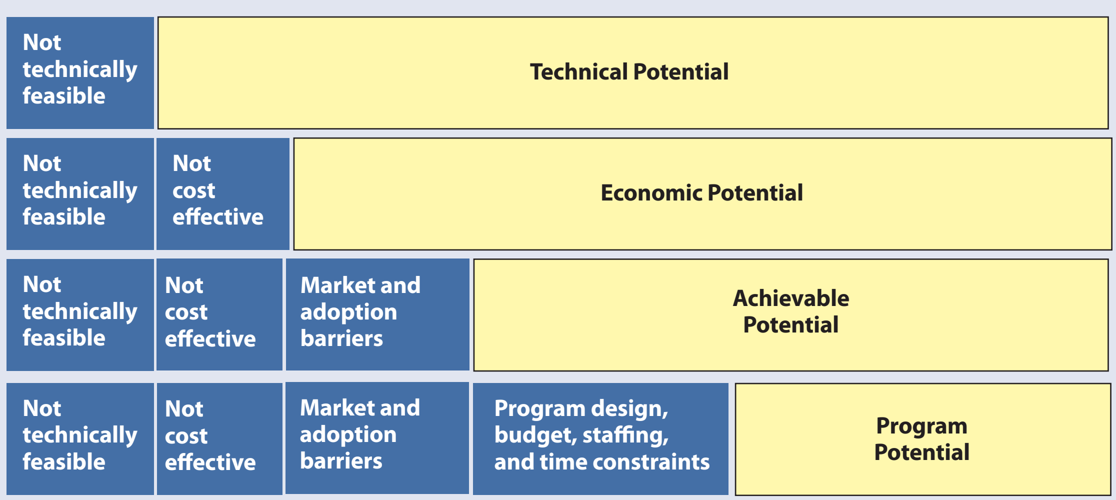
Finally, the *program potential* comprises the energy and capacity savings that can be realistically realised from the achievable potential, given budget, staffing, and time constraints. Program potential establishes the savings expected from a specific energy efficiency program.[28]

Energy efficiency potential studies differ in scope and methods as a function of their objectives and who is conducting them. They can be divided into three main types.[29]

Policy studies are typically high level and are primarily designed to develop a policy consensus for initiating new energy efficiency programs or to make changes to existing programs. A policy study might be commissioned by a regulator or legislative body that would like more information on the benefits of establishing a program, or by third-party energy efficiency advocates who want to bring energy efficiency benefits to the attention of regulators and policy-makers.

Figure 6

Different Types of Energy Efficiency Potential[30]



27 National Action Plan for Energy Efficiency (2007).

28 National Action Plan for Energy Efficiency (2007).

29 National Action Plan for Energy Efficiency (2007).

30 National Action Plan for Energy Efficiency (2007).

Planning studies are used by demand-side planners within utilities to incorporate energy efficiency into utility resource planning. The objective of a planning study is to identify energy efficiency opportunities that are cost-effective alternatives to supply-side resources in generation, transmission, or distribution.

Program design studies can be undertaken by utilities or third parties for the purpose of developing specific energy efficiency programs. They can also be used for developing customer program features, such as outreach and education, and rebates or other financial incentives for customer purchases of energy efficient equipment.

3.2.2 Estimating Energy Efficiency Avoided Costs

The usual method used to quantify the benefits of energy efficiency is to forecast long-term "avoided costs," defined as costs that would have been incurred if the energy efficiency had not been put in place. For example, if an electric distribution utility expects to purchase bulk electricity at a cost of USD 70/MWh on behalf of customers, then USD 70/MWh is the value of energy savings achieved by energy efficiency. In addition, the utility may not have to purchase as much system capacity, make as many upgrades to distribution or transmission systems, buy as many emissions offsets, or incur as many other costs. These additional cost savings may amount to, say, USD 30/MWh. All such cost-saving components attributable to energy efficiency are directly counted as avoided costs, in this theoretical example a total of USD 100/MWh.

Estimating avoided costs provides a quantitative value for the benefit of energy efficiency. In the example above, the utility avoids paying USD 100 for each MWh it saves by implementing energy efficiency. Energy efficiency can then be said to have a benefit or value of USD 100/MWh.

Table 1 shows typical components of avoided costs for power systems and the metrics that can be used to estimate the value of these components.

The easiest approach for a utility to estimate long-term avoided costs for energy efficiency may be to simply use the internal forecast of future electricity prices, or to benchmark avoided costs to the costs of building and operating the next power plant or other supply-side resource. Such a methodology is likely to be confidential, because utilities actively involved in procuring bulk electricity in a market will probably not want to publicly reveal their expectations of future prices. To develop a more open resource planning process, forecasts of avoided costs could be developed by appropriate public authorities such as government agencies or regulators.[32]

Table 1

Typical Components of Avoided Costs for Energy Efficiency in Power Systems[31]

Avoided Component	Metric
Electrical energy (with losses)	Reduction in bulk electricity purchases, or reduced operating cost of power plants Loss factors
Generation capacity (with losses)	Value of deferring power plant construction based on adjusted load forecast Loss factors
Ancillary services	Reduced costs of ancillary services associated with reduced energy and capacity
Transmission and distribution capacity	Value of deferring additional transmission and distribution capacity to meet customer peak demand growth Note that the value of deferring transmission and distribution capacity varies across different locations within a utility service area and may also vary depending on how coincident capacity savings are with the timing of the local area peak demand
Price effect of demand reduction	In jurisdictions where purchases of bulk electricity are made in a spot market, the reduction in total spot market purchase costs attributable to the reduction in the demand curve
Savings in water, fuel oil, and/or other inputs	Depending on the characteristics of the electricity system and the types of energy efficiency programs, additional avoided cost streams may be included.

31 Modified from National Action Plan for Energy Efficiency (2007).

32 National Action Plan for Energy Efficiency (2007).

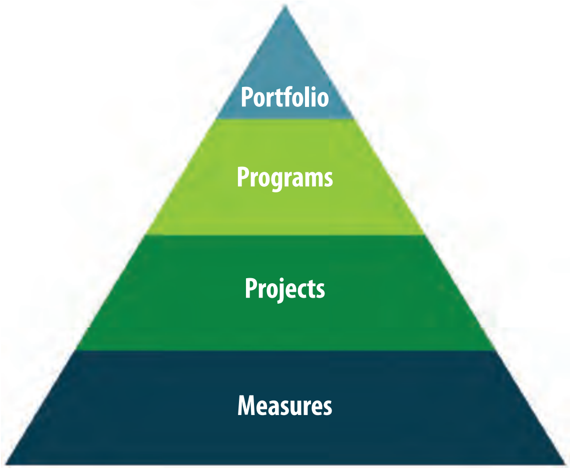
3.2.3 Developing Energy Efficiency Measures

Figure 7 illustrates the hierarchy of energy efficiency activities.

An energy efficiency *measure* is a particular action taken to reduce a specific type of load. For example, replacing incandescent lamps with compact fluorescent or LED lamps is a lighting efficiency measure. Measures are typically aggregated together into *projects* that are coordinated activities to install one or more measures at a single facility or site.

Figure 7

The Hierarchy of Energy Efficiency Activities[33]



Programs are collections of similar projects that are intended to motivate customers in a specific market segment to implement more energy efficiency. A lighting efficiency program typically consists of several different lighting measures implemented at many facilities or sites.

Programs are then aggregated into one or more *portfolios* at the utility or program administrator level. A portfolio is either (1) a collection of similar energy efficiency programs addressing the same market (e.g., a portfolio of programs targeted at the residential sector), technology (e.g., motor efficiency programs), or mechanisms (e.g., loan programs), or (2) the set of all energy efficiency programs administered by one program administrator.[34]

Developing energy efficiency measures involves identifying the loads on the system, determining the cost and impact of the different methods available for reducing specific loads, and then selecting particular methods to be implemented. From the planning standpoint, the key elements of each measure are its load impact and its incremental cost. There are two types of impact: energy and demand. Energy impact is the decrease in kWh attributable to the measure, and demand impact is the decrease in peak kW.[35]

3.2.4 Determining Cost-Effectiveness

There are several methods available for evaluating the cost-effectiveness of energy efficiency. The most commonly used method comprises the cost-effectiveness tests described in the Standard Practice Manual *Economic Analysis of Demand-Side Programs and Projects* published by the California Public Utilities Commission.[36]

The California Standard Practice Manual describes five main cost-effectiveness tests. Each test reflects a different stakeholder perspective on the impact of energy efficiency.

Participant Cost Test. This test measures the quantifiable benefits and costs to an electricity customer from participating in an energy efficiency program. Because many customers do not base their decision to participate in a program entirely on quantifiable variables, this test cannot be a complete measure of the benefits and costs of a program to a customer.

Ratepayer Impact Measure Test. This test measures what happens to customer electricity bills and prices because of changes in the program administrator's revenues and operating costs caused by an energy efficiency program. Prices will go down if revenues collected are greater than the total costs incurred by the program administrator in implementing the program. Conversely, prices will go up if revenues are less than the program administrator's costs. Even if prices go up, the electricity bills of individual customers participating in the energy efficiency program may go down if the program results in them purchasing less electricity.

Program Administrator Cost Test. Also known as the Utility Cost Test, this test measures the net costs of an energy efficiency program as a resource option based on the costs incurred by the program administrator and excluding any net costs incurred by customers who participate in the program.

Total Resource Cost Test. This test measures the net costs of an energy efficiency program as a resource option based on the total costs of the program, including both the participants' and the program administrator's costs. This test represents the combination of the effects of a program on both the participating customers and those not participating in the program but who bear a portion of the program costs through impacts on electricity prices.

33 State and Local Energy Efficiency Action Network (2012).

34 State and Local Energy Efficiency Action Network (2012).

35 National Action Plan for Energy Efficiency (2007).

36 California Public Utilities Commission (2001)

Societal Cost Test. This test is sometimes considered a variant on the Total Resource Cost Test. The Societal Cost Test differs in that it includes the effects of externalities and uses a different (societal) discount rate from the Total Resource Cost Test. The Societal Cost Test goes beyond the Total Resource Cost Test in that it attempts to quantify the change in the total resource costs to society as a whole rather than to only the program administrator and electricity customers.

A common misperception is that there is a single best perspective for evaluating energy efficiency cost-effectiveness. Each of the five tests described in the California Standard Practice Manual is useful and accurate, but the results of each test are intended to answer a different set of questions, as shown in Table 2.[37]

Either the Total Resource Cost Test or the Societal Cost Test may be the appropriate cost-effectiveness test from a regulatory perspective. The Total Resource Cost Test measures the net benefits to a community or region provided by an energy efficiency program. All energy efficiency that passes this test will reduce the total costs of electricity within the community or region. Thus, the Total Resource Cost Test is the primary test used to evaluate energy efficiency programs. The Total Resource Cost Test includes only direct costs and benefits, not externalities or non-monetised factors. Regulators who want to consider these factors in a cost-effectiveness test can use the Societal Cost Test, which does include externalities, such as emissions. The Total Resource Cost Test and the Societal Cost Test do not separately identify who pays for the energy efficiency and who receives the benefits. Therefore, the other cost effectiveness tests are used to evaluate costs and benefits to specific stakeholders.

3.2.5 Developing Energy Efficiency Programs and Portfolios

Just as there are several different methods to achieve increased energy efficiency, there are also several different types of energy efficiency programs; Table 3 outlines the main types.

Generally, energy efficiency programs are designed so that they meet some minimum level of aggregate cost-effectiveness at the portfolio level. However, other factors may be considered in designing a program, depending on what the program is intended to achieve in addition to energy and demand savings. These additional factors may include: making sure that there are programs targeted at hard-to-reach customers, that programs have continuity, and that programs provide for education and training. There may also be policy factors to consider in developing an energy efficiency program, such as a policy requirement to focus on the new construction market to minimise lost opportunities for energy efficiency in buildings at the initial construction stage.

Table 2

Questions Addressed by the Various Cost-Effectiveness Tests[38]

Participant Cost Test	Is it worth it to the customer to implement energy efficiency? Is the customer likely to want to participate in a utility program that promotes energy efficiency?
Ratepayer Impact Measure Test	What is the impact of the energy efficiency program on the utility's operating margin? Would the program require a change in electricity prices to achieve the same operating margin?
Program Administrator Cost Test	Do total utility costs increase or decrease? What is the change in total customer bills (i.e., revenue requirement) needed to maintain the utility's financial position?
Total Resource Cost Test	What are the net costs and benefits to the utility and its customers? Are all of the benefits greater than all of the costs (regardless of who pays the costs and who receives the benefits)? Is more or less money required by the community to pay for the energy delivered by the utility?
Societal Cost Test	What is the overall benefit to the community of the energy efficiency program, including indirect benefits? Are all of the benefits, including indirect benefits, greater than all of the costs (regardless of who pays the costs and who receives the benefits)?

37 National Action Plan for Energy Efficiency (2007).

38 Modified from National Action Plan for Energy Efficiency (2007).

Table 3

Types of Energy Efficiency Programs[39]	
Energy Audit	A survey or site visit to a customer facility is carried out by a knowledgeable contractor or utility representative. An energy audit is part review of customer equipment, part education of the customer, and part marketing of appropriate energy efficiency programs.
Rebate	**Cash rebate program:** Provides customers with a cash rebate toward the purchase of a high-efficiency appliance or device. **Upstream rebate program:** Provides a rebate to the manufacturer or wholesaler of high-efficiency appliances or devices so that they can discount the final price to the customer. Eliminates the need for the customer to apply for the rebate.
Direct Install	The program administrator or third-party contractors directly install energy efficiency measures for customers (e.g., a commercial lighting retrofit program may directly install new, energy-efficient lighting).
Education and Training	Educates and trains customers, retailers, architects, contractors, and building inspectors to identify energy efficiency opportunities, properly install energy savings measures, and maintain equipment so that it continues to operate as efficiently as possible.
Loans and On-Bill Financing or Grants	Provides funding that removes the disincentive caused by the high initial cost of energy efficiency measures. In on-bill financing, the cost of energy-efficient appliances or equipment is paid progressively in small installments added to the electricity bill.
Bidding/Standard Performance Contracts	Enables third-party contractors to develop programs and deliver energy and demand savings to the program administrator. The contractor can often leverage existing relationships with customers more effectively than a utility or program administrator.
Upstream and Midstream Incentives	Provides incentives or assistance to manufacturers, distributors, or dealers to promote energy-efficient products.
Failure Replacement	Encourages customers to purchase and install high-efficiency equipment or appliances at the time that they replace old energy using equipment (e.g., encouraging customers to purchase ENERGY STAR-certified equipment).
Early Replacement	Encourages customers to replace existing appliances or equipment that are currently in use with more efficient units. Generally more costly than failure replacement because it requires financial incentives closer to the entire cost of the efficient unit to attract customers.
New Construction	Targets new construction as the time to install energy efficiency measures that go above and beyond the building standard. Sometimes called "lost opportunity" programs because many energy efficiency upgrades are expensive or impossible to develop once a building is complete.
Commissioning	Confirms that a new building is operating properly (e.g., that the building shell is tight and ducts are not crushed or bent).

The detailed criteria that are used in developing energy efficiency programs and portfolios are essentially specific to each jurisdiction. As an example, the California Public Utilities Commission requires that an energy efficiency portfolio must adhere to available funding by utility service territory and have a total resources cost ratio greater than 1.0. The Commission also asks staff to compile a portfolio of programs that balances the following goals :

- Maximised energy savings;
- Strong cost effectiveness;
- Equitable geographic distribution;
- Diversity of target markets;
- Equity by customer class;
- Equity between gas and electric program offerings and energy savings;
- Diversity of program offerings; and
- Multiple languages offered to program participants.

3.2.6 Estimating Energy Efficiency Impacts

There are two main approaches for estimating the impact of energy efficiency programs for planning purposes: top-down and bottom-up.

39 Modified from National Action Plan for Energy Efficiency (2007).

40 National Action Plan for Energy Efficiency (2007).

The *top-down* approach is generally less time-consuming. To estimate energy savings, this approach commonly employs statistical comparisons of electricity billing data from before and after the installation of energy efficiency measures. Alternatively, billing data from customers who participated in energy efficiency programs can be compared with data from non participating customers. If billing data are not available for a particular energy efficiency program, data from other similar programs can also be used at aggregate levels to develop estimates of energy efficiency impacts. This type of analysis may be more applicable for jurisdictions that are just commencing to implement energy efficiency.

The *bottom-up* approach relies on detailed data by end-use. Bottom-up models construct estimates of the impact of energy efficiency programs based on energy savings from specific types of energy efficiency measures. Engineering models are often used in bottom-up analyses to estimate reductions in energy usage based on the performance characteristics of energy efficient versus standard appliances and equipment. The level of effort required to utilise engineering models varies widely. In some cases, the analysis can be based on single-line engineering formulas such as the difference in wattage between equivalent lumen incandescent lamps and energy efficient compact fluorescent or LED lamps. In other cases, the analysis may be based on complex building simulation models or detailed simulations of industrial processes.

Estimating capacity savings is carried out using the same methods as for energy savings. An additional consideration in estimating capacity savings is the time when the savings occur. Typically, capacity savings are estimated at the time of the system coincident peak, that is, the maximum MW demand at the utility level for a single hour in the year. This estimate is useful for many planning applications such as long-run generation planning, but it may not be appropriate for other applications. Maximum demand varies with the season and also may vary at different geographical locations within a utility service territory. For example, if it is intended to use energy efficiency to defer the replacement or augmentation of a particular grid element such as a substation or line, the relevant metric is the capacity savings achieved at the time of maximum demand on that grid element, which may occur at a different time from the system coincident peak.

To incorporate energy efficiency into resource planning, the estimation of capacity savings should use a definition that corresponds to how the resource planners value capacity. Care must be exercised to ensure that other groups within the utility do not use those same estimates if they do not match that group's application. It is common for numbers to become "set in stone" and misused in applications for which the numbers were not intended. For example, a value for demand reduction from energy efficiency may be developed for a transmission study that is based on the average reduction across the 12 monthly peaks, but then misused in a generation planning application that is concerned only with the single annual peak.[42]

There are also two adjustments that need to be considered when incorporating energy efficiency into resource planning[43]:

- Capacity savings associated with energy efficiency installations that occur after the peak period should not count for that year; and
- Energy and capacity savings from energy efficiency already included in the status quo load forecast should be explicitly identified to avoid double counting.

The first adjustment is straightforward and easy to incorporate into the planning process. The key is to manage forecasts of capacity savings from energy efficiency using a time period that ends prior to the peak period. For example, for a summer peaking utility, the second quarter of the year would be the ending period for counting capacity savings for peak reduction purposes.

The second adjustment requires the analyst to have a sound understanding of the data and methods used to develop the status quo load forecast. Double counting can be avoided by (1) removing energy efficiency impacts from the load forecast, or (2) removing the energy and capacity savings already included in the load forecast from the forecast of energy efficiency impacts.

3.2.7 Procuring Energy Efficiency Resources

Energy efficiency resources may be procured in several different ways by a number of different organisations. Frequently utilities themselves develop, design, and administer energy efficiency programs directly. Alternatively, or in addition, other organisations may be involved in

41 National Action Plan for Energy Efficiency (2007).

42 National Action Plan for Energy Efficiency (2007).

43 National Action Plan for Energy Efficiency (2007).

implementing energy efficiency, with the resulting energy and capacity savings integrated into electricity resource planning through a variety of mechanisms.

Irrespective of the specific stakeholders involved, a range of functions must be undertaken to effectively administer, manage, and deliver a portfolio of energy efficiency programs, as outlined in Table 4. These functions are typically carried out by one organisation that operates as the program administrator. The program administrator may be a utility, a government agency, or a third party specifically established to carry out the program administration functions. The program administrator must decide the most effective way to procure various types of energy efficiency resources, given the core competencies and capabilities of the program administrator and any third-party contractors engaged to deliver energy efficiency programs, and any policy direction from regulators and/or government. For example, the program administrator typically takes sole or primary responsibility for general administration/coordination and program development, planning, and budgeting functions.[44]

3.2.8 Evaluation, Measurement, and Verification

Evaluation, measurement, and verification (EM&V) is the process of determining the effectiveness and impacts of an energy efficiency program. The term "evaluation" refers to any real-time and/or retrospective assessment of the performance and implementation of a program. Measurement and verification (M&V) is a subset of evaluation that comprises the calculation of actual energy and capacity savings from individual sites or projects.

Table 4

Functional Overview of Energy Efficiency Program Management and Delivery[45]

General administration and coordination	**Financial/budget management:** develop/maintain financial accounting systems; propose and manage budget for portfolio of programs **Contract management:** maintain contracts with primary contractors (if any) **Reporting/information management systems:** prepare annual reports, highlight accomplishments, maintain information technology system for reporting to regulators and/or government
Program development, planning, and budgeting	Facilitate resource planning process Develop program designs; propose general program descriptions and budgets for regulatory and/or government approval Carry out program and measure screening, including initial screening for cost-effectiveness
Program administration and management	Manage and oversee individual programs Provide detailed program design and propose changes based on experience and market response Develop quality assurance standards and tracking mechanisms to ensure effective program delivery Establish dispute resolution processes
Program delivery and implementation	Design and implement program marketing/outreach; market individual programs Provide program delivery services: energy efficiency audits, technical/design assistance, financial assistance/incentives, commissioning of contractors (if any), contractor certification and training Manage evaluation, measurement, and verification of energy and capacity savings; develop EM&V procedures; focus on verification to determine payments to contractors (if any) Develop individual energy efficiency projects at customer facilities
Market assessment and program evaluation	Characterise specific energy efficiency markets and opportunities Assess program impacts Review program processes and administration with the aim of improving program effectiveness

44 National Action Plan for Energy Efficiency (2007).

45 Modified from National Action Plan for Energy Efficiency (2007).

M&V includes data collection, direct metering, computer modelling, and other techniques to verify savings. Utilities and third-party contractors use EM&V to calculate actual impacts after an energy efficiency program has been implemented. The lessons learned from EM&V results provide the information needed to improve estimates of energy efficiency impacts in resource planning prior to program implementation.[46]

Energy efficiency evaluation activities can be categorised in several different ways, one of which is to define evaluations as either formative or outcome. Formative evaluations are associated with helping energy efficiency programs be as effective as possible. Outcome evaluations are associated with documenting program results. However, the most common way to categorise energy efficiency evaluations is as impact, process, or market evaluations.[47]

Impact Evaluations. These are outcome evaluations of the changes attributable to an energy efficiency program. Whereas impact evaluations usually focus on determining the quantity of changes in energy use and demand associated with a program, the calculation of non-energy benefits (or co-benefits) such as avoided emissions and job creation that directly or indirectly result from a program can also be an output of impact evaluations. Impact evaluations often support cost-effectiveness analyses that document the relationship between the value of program results (i.e., energy, capacity, and emission savings) and the costs incurred to achieve those benefits.

Process Evaluations. These are systematic assessments of an energy efficiency program. Their purpose is to document program operations and identify and recommend improvements to increase the program's efficiency or effectiveness in acquiring energy efficiency resources while maintaining high levels of participant satisfaction. For example, process evaluations can include an assessment of program delivery, from design to implementation, to identify bottlenecks, successes, failures, constraints, and potential improvements. Timeliness in identifying opportunities for improvement is essential to making corrections along the way. Process evaluations also provide a backdrop for interpreting the results of impact evaluations.

Market Evaluations. This is a very broad category of EM&V activities that document aspects of the marketplace with respect to energy efficiency. One particular type is a market-effects evaluation, which characterises changes in the structure or functioning of a market or the behaviour of market participants that resulted from the implementation of one or more energy efficiency programs. Market effects evaluations can include assessments of the influences that a market could exert on future energy efficiency programs. If the evaluation's goal is to assess cost-effectiveness for stakeholders or regulators, excluding the measurement of market effects could result in underestimating (or possibly overestimating) a program's overall benefits or cost-effectiveness.

A rough rule of thumb for spending on EM&V is two to five percent of total energy efficiency program expenditures, although some jurisdictions spend more than this. Overall, evaluators recommend that EM&V efforts should aim to achieve the highest degree of rigor that is consistent with the program or project budget and objectives. Experience with EM&V suggests that there are diminishing returns beyond some level of rigor, and it is best to follow a rule of thumb like, "10 percent of the EM&V effort to achieve verification within 90 percent accuracy." Thus, one strategy for doing impact assessment is to reduce the propagation of estimation errors by verifying the important but uncertain drivers of the impact. For example, consider a lighting program in which the impact is equal to the number of hours the lighting is in operation multiplied by the change in watts attributable to more efficient lamps. If the hours of operation are already well established, one would focus the EM&V effort on measuring the change in watts.[48]

46 National Action Plan for Energy Efficiency (2007).

47 State and Local Energy Efficiency Action Network (2012).

48 National Action Plan for Energy Efficiency (2007).

4. Using Energy Efficiency as a Resource

This section describes three comprehensive policy, regulatory, and organisational systems that enable energy efficiency to be used as a power system resource:

- Integrated resource planning;
- Regional resource planning; and
- The efficiency power plant concept

The section also includes three case studies, two from the United States and one from China.

4.1 Integrated Resource Planning

Integrated resource planning (IRP) is a planning process used mainly in the United States and also in some other countries. Some theoretical studies of integrated resource planning have been carried out in China.[49] IRP examines the forecasted growth in future demand for electricity and evaluates alternative methods of meeting the resulting load on the system, including using demand-side resources. The goal is to identify the least-cost resource mix for electric utilities and their end-use customers.[50] Figure 8 presents an outline of the IRP process.

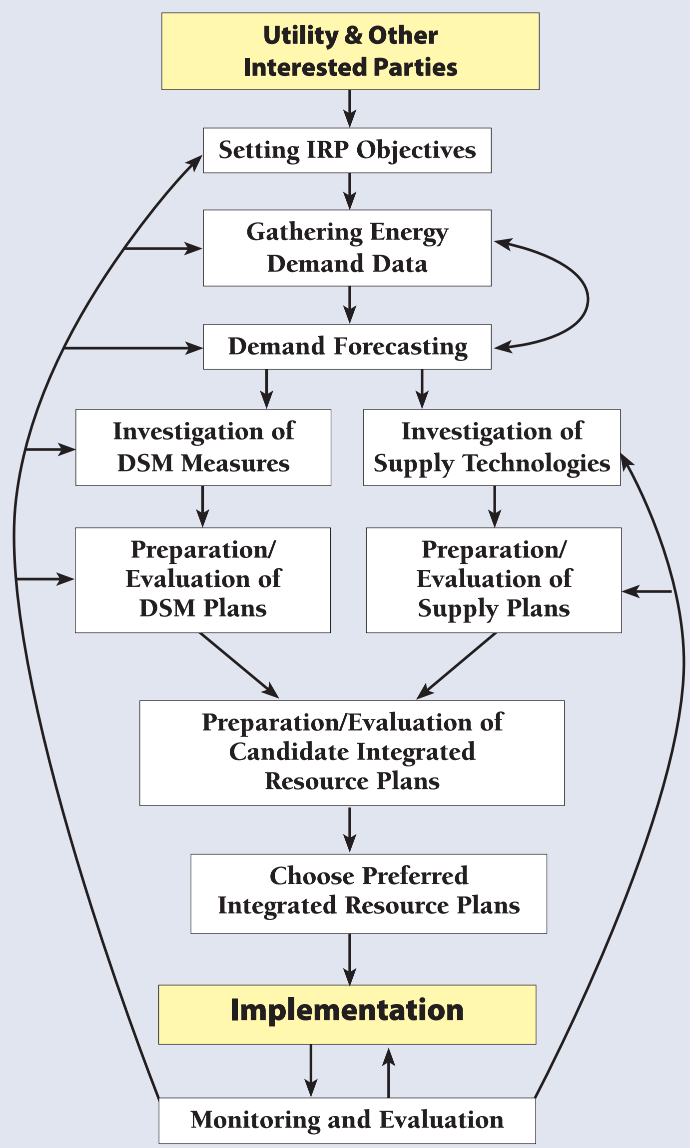
The IRP process offers advantages over traditional resource planning because it incorporates demand-side management (DSM), including energy efficiency and demand response, as a resource. Successful integrated resource plans achieve the reliable production and delivery of electricity at the lowest practicable cost.

4.1.1 The Integrated Resource Planning Approach

The innovation incorporated in the IRP approach is the broadening of the range of options beyond those typically considered in traditional power sector resource planning, especially by including demand-side resources. When done well, IRP essentially identifies the size, location, cost, and value of demand-side resources to the electricity sector and the least-cost mix of generation and demand-side resources needed to meet customer energy service needs.[52]

Figure 8

The Integrated Resource Planning Process[51]



49 Zhou and Hu (2010).

50 Crossley (2013).

51 The Tellus Institute (undated).

52 Lazar (2011).

Ideally, the IRP process should look at a wide range of options to meet future needs and include consideration of all social and environmental costs when evaluating the options. Supply-side options for evaluation should include: continued operation of existing power plants, building new power plants, buying power from other generators, and encouraging customer-owned distributed generation. Demand-side options should include: non-generation alternatives, such as investing in DSM programs, promoting construction or refurbishment of energy efficient buildings, reducing transmission and distribution system line losses, and any other available, reliable, and cost-effective means of meeting future demand for electricity.[53]

The IRP process may also consider future requirements for local and regional transmission and distribution grid infrastructure and establish a plan for future upgrades to existing lines, and/or construction of new lines, and/or the deployment of demand-side resources to relieve network constraints.

Such a broad-ranging planning process provides an opportunity for demand-side resources to be evaluated on their merits (particularly their cost-effectiveness) as methods for meeting forecasted future electricity demand and future requirements for grid infrastructure.

Many aspects of the implementation of IRP are technical and straightforward, and follow established electricity planning methodologies. Others aspects add new methodologies and slightly more complexity to the analysis. For example, most demand-side resources are very different from supply-side resources. Demand-side resources are usually smaller in scale, and may be intermittent or otherwise not as predictable or as "firm" as supply-side resources. These perceived disadvantages may be reduced by technology that enables targeting of some demand-side measures to particular time periods and/or geographic locations. Such targeting is much more difficult to achieve with supply-side resources. Targeting enables demand-side measures to be used effectively to provide demand response during peak periods or at times of high prices in wholesale electricity markets and in locations where there are grid constraints.[54]

4.1.2 Integrated Resource Planning Implementation

IRP was first implemented in the United States during the 1980s and early 1990s when regulators in several U.S. states placed IRP obligations on large, vertically integrated, investor-owned monopoly utilities. The boundary within which the planning process applied was primarily the utility's geographic service territory. All resources owned by the utility, wherever located, were included. Resources not owned by the utility and located outside the service territory could be included if they were likely to be cost-effective and compliant with resource security and reliability standards.

In 1992, the federal *Energy Policy Act* formally defined the term "integrated resource planning" for the U.S. Federal Government and required utilities that purchased electricity from federal power authorities (e.g., Bonneville Power Administration) to create an integrated resource plan. The *Energy Policy Act* provides some basic guidelines, but rules and requirements governing long-term electric utility planning activities are mandated by state or local governments. State-level planning requirements are carried out through legislation, codes, agency requirements, or IRP regulations.[55]

Figure 9 shows the U.S. states that require utilities to prepare and file (submit) formal integrated resource plans, and other states that have adopted the Long-Term Procurement Plan framework as an alternative to IRP. Long-Term Procurement Plans include much of the same information as an integrated resource plan, but typically have shorter planning horizons.[56]

Although IRP was originally applied to individual monopoly utilities in the United States, this planning process has also been applied in other jurisdictions.

Under Denmark's 1994 *Electricity Act,* electricity distribution/retail supply companies were required to prepare DSM plans. Generation and transmission companies and the independent system operator (ISO) drew up scenarios for generation and transmission. The Danish Energy Agency developed guidelines and coordinated an overall 20-year plan for the whole country.[57]

In South Africa, the Department of Energy developed an integrated resource plan for electricity for the whole country covering the period 2010 to 2030. The integrated resource plan was promulgated in March 2011 and it was indicated at the time that the integrated resource plan should be a "living plan" that would be revised by the Department of Energy every two years. An updated integrated resource plan

53 Lazar (2011).

54 Crossley (2013).

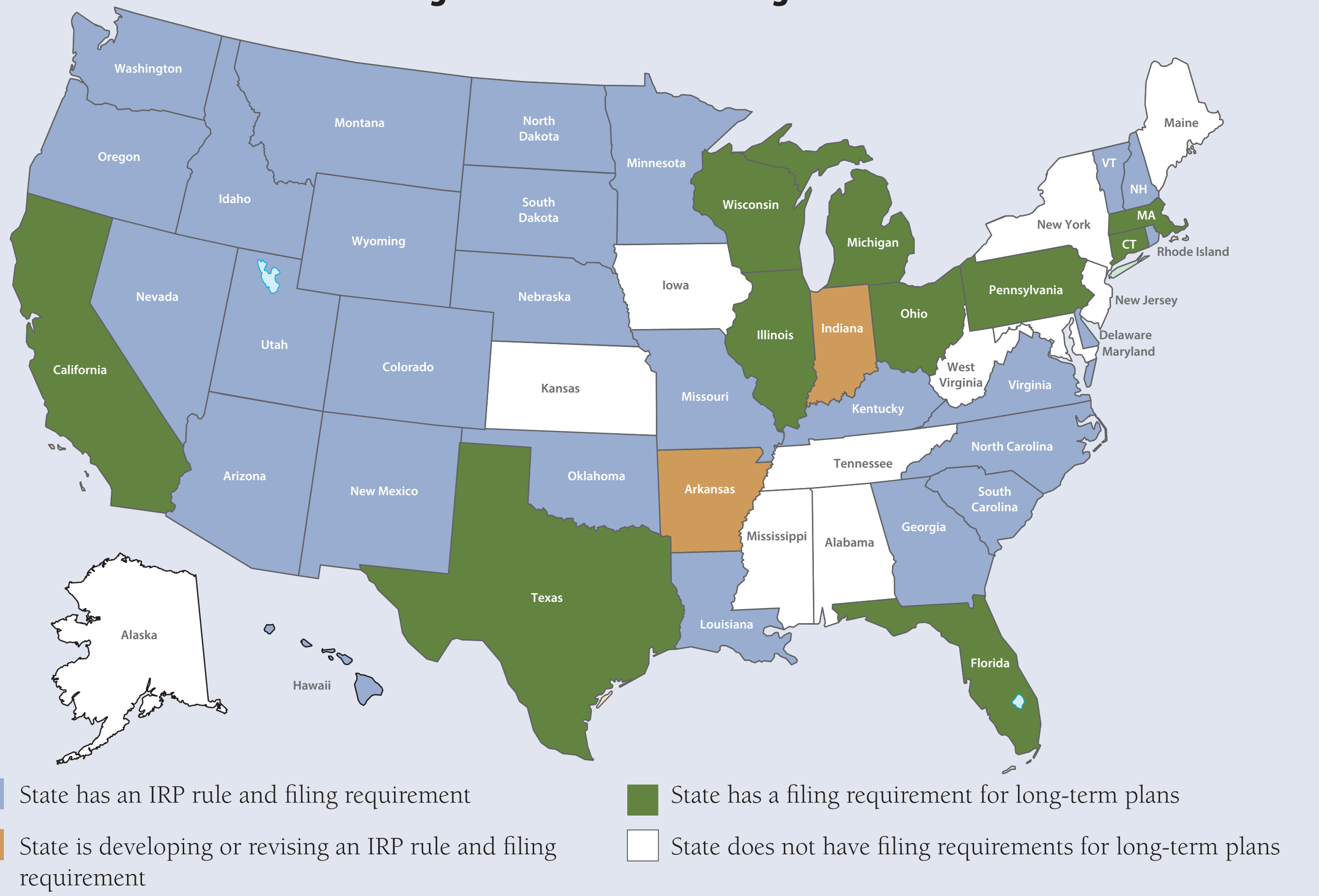
55 Wilkerson et al (2014).

56 Wilkerson et al (2014).

57 D'Sa (2005).

Figure 9

U.S. States With Integrated Resource Planning or Similar Processes[58]



was produced in 2013.[59] The original integrated resource plan assumed a set level of energy efficiency and identified the preferred generation technology, including renewable generation, required to meet expected demand growth up to 2030. The updated integrated resource plan produced in 2013 incorporated a number of government objectives, including affordable electricity, carbon mitigation, reduced water consumption, localisation, and regional development, and produced a balanced strategy toward diversified electricity generation sources and gradual decarbonisation of the electricity sector in South Africa.

In the United Kingdom, the electricity market reform process implemented during 2012 and 2013 was driven by IRP-type studies that identified the mix of generation and demand-side resources needed to meet long-term climate goals.[60]

4.1.3 Integrated Resource Planning Case Study

The following case study briefly describes the IRP process carried out by the vertically integrated utility PacifiCorp in the United States. PacifiCorp serves more than 1.7 million customers across 136,000 square miles in six states. The company comprises three business units: Pacific Power serves customers in Oregon, Washington, and California; Rocky Mountain Power serves customers in Utah, Wyoming, and Idaho; and PacifiCorp Energy operates a broad portfolio of power-generating assets.

PacifiCorp prepares its integrated resource plan on a biennial schedule, filing its plan with state utility commissions during each odd-numbered year. For five of

58 Wilson and Biewald (2013).

59 South Africa Department of Energy (2013).

60 United Kingdom Secretary of State for Energy and Climate Change (2011).

its six state jurisdictions, the company receives a formal notification as to whether the IRP meets the commissions' IRP standards and guidelines, referred to as IRP acknowledgement. For even-numbered years, the company updates its preferred resource portfolio and action plan by considering the most recent resource cost, load forecast, regulatory, and market information.[61]

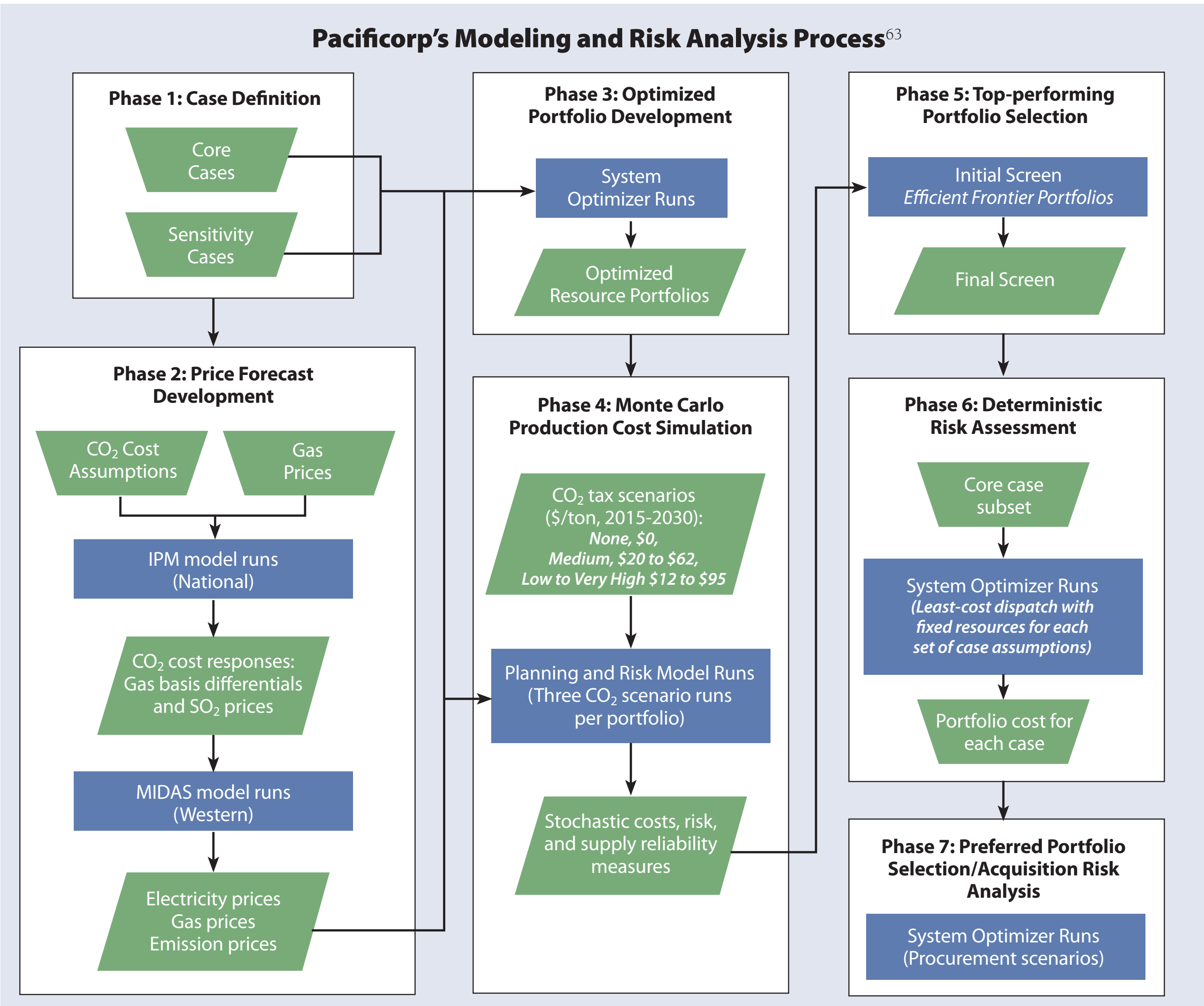
PacifiCorp's IRP process uses system modelling tools as part of its analytical framework to determine the long-run economic and operational performance of alternative resource portfolios. These models simulate the integration of new resource alternatives with the companies' existing assets, thereby informing the selection of a preferred portfolio judged to be the most cost-effective resource mix after considering risk, supply reliability, uncertainty, and government energy resource policies.

PacifiCorp filed its 11th Integrated Resource Plan[62] with state regulatory commissions on March 31, 2011. The filing initiated the state processes for acknowledgment in Idaho, Oregon, Utah, Washington, and Wyoming.

The key elements of the plan included:

- The resource portfolio modelling process and assumptions;

Figure 10



61 PacifiCorp (2011b).

62 PacifiCorp (2011a).

63 PacifiCorp (2011a).

- A finding of resource need, focussing on the first 10 years of a 20-year planning period;
- The preferred portfolio of supply-side and demand-side resources to meet this need; and
- An action plan that identified the steps to be taken during the next two to four years to implement the plan.

PacifiCorp employs a comprehensive portfolio modelling process. It uses a model called System Optimizer, which has the capability to determine capacity expansion plans, to run a production cost simulation of each optimised portfolio, and to perform a risk assessment on these portfolios.[64] Figure 10 shows PacifiCorp's schematic of its modelling process.

PacifiCorp is unusual in that it models energy efficiency as supply-side resources, rather than as load modifiers. The model is provided with specific quantities of energy efficiency at given costs, and those efficiency resources are allowed to compete against the other resources from which the model is able to select. Data for the energy efficiency resources included in the modelling for PacifiCorp's 11th Integrated Resource Plan are derived from a 2010 energy efficiency potential study that provided estimates of the size, type, timing, location, and cost of more than 18,000 energy efficiency measures in PacifiCorp's service territory.[65]

In the PacifiCorp modelling, energy efficiency measures are called Class 2 DSM, whereas capacity-based measures are separated into two categories: Class 1 DSM includes dispatchable demand response programs, and Class 3 DSM includes pricing programs. Focussing on Class 2 DSM measures, PacifiCorp consolidated them into nine cost bundles grouped by levelised cost for inclusion in the modelling, and 1400 supply curves were modeled for the IRP.

Energy efficiency measures performed well in the modelling, representing the largest resource added through 2030 across all portfolios modelled, with cumulative capacity additions from energy efficiency exceeding 2500 MW in PacifiCorp's preferred portfolio. The inclusion of such large quantities of energy efficiency achieves large cost savings for PacifiCorp's customers. If energy efficiency were not included in PacifiCorp's resource portfolio, the utility would have to meet the forecasted load by adding 2500 MW of supply-side resources at much greater cost.[66]

For PacifiCorp, the 2011 Plan is part of an evolving process that incorporates current information and reflects continuous improvements in system modelling capability required to address new issues and an expanding analytical scope. PacifiCorp's preferred portfolio and action plans are not seen as static products reflecting resource acquisition commitments, but rather represent a flexible framework for considering resource acquisition paths that may vary as market and regulatory conditions change.[67] The preferred portfolio and action plans are augmented by a resource acquisition path analysis informed by extensive portfolio scenario modelling. Specific resource acquisition decisions stem from PacifiCorp's procurement process as supported by the IRP and business planning processes, as well as compliance with then-current laws and regulatory rules and orders.

4.2 Regional Resource Planning

In the United States, in addition to resource planning by individual electric utilities, power sector planning is also handled at the state and regional level.

4.2.1 The Regional Planning Approach

There are various organisations involved in regional power sector resource planning in the United States. Historically, the dominant model for the power sector comprised vertically integrated utilities that carried out all four functions of electricity generation, transmission, distribution, and retailing within defined geographical service territories. Within this model, most resource planning was carried out relatively independently by the individual electric utilities.

During the 1990s, the *Energy Policy Act* of 1992, and particularly rulings by the Federal Energy Regulatory Commission (FERC), mandated increasingly open access to transmission lines. In April 1996, FERC issued two final rules on open access. Order 888[68] addressed equal access to the transmission network for all wholesale buyers and sellers, transmission pricing, and the recovery of stranded costs. Order 889[69] required jurisdictional utilities that own or operate transmission facilities to establish electronic systems to post information about their available transmission capacities. Consequently, transmission planning was required to be carried out across and between regions rather than within individual utility service territories.

64 Wilson and Biewald (2013).

65 Wilson and Biewald (2013).

66 Wilson and Biewald (2013).

67 PacifiCorp (2011a).

68 Federal Energy Regulatory Commission (1996a).

69 Federal Energy Regulatory Commission (1996b).

ISOs and regional transmission operators (RTOs) were established in some regions, and now in many parts of the United States, an ISO or RTO manages the day to day operation of the transmission system, the efficient administration of a wholesale electricity market, and long-term reliability planning (see Figure 11).

4.2.2 Regional Planning Implementation

Partly as a result of the increasing focus on regional transmission planning, in some areas of the United States, dedicated organisations were established to carry out broader power sector resource planning across defined regional geographical areas. These organisations often use forms of IRP that incorporate energy efficiency as a resource.

4.2.3 Regional Planning Case Study

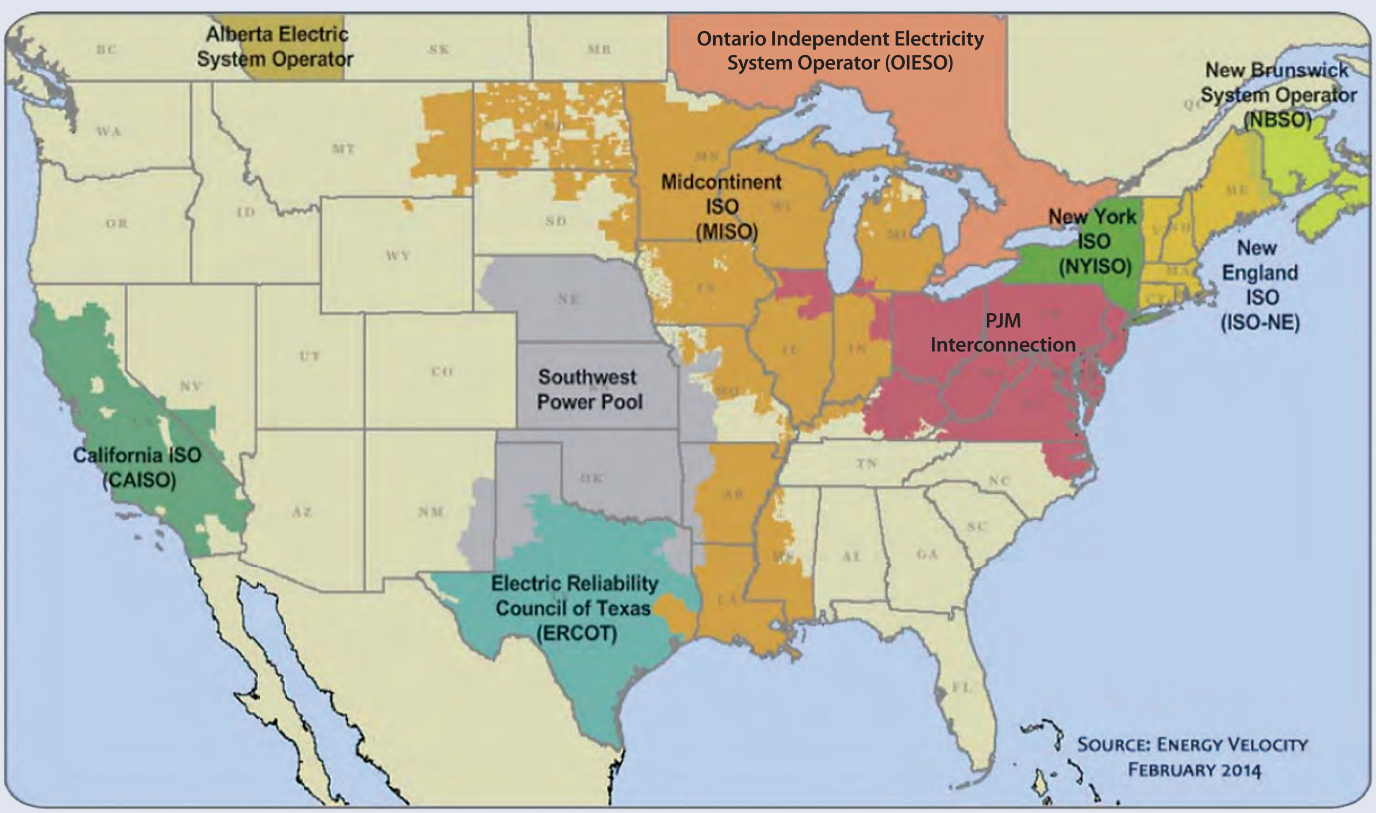
In the northwest of the United States, the Northwest Power and Conservation Council was created in 1980 under the federal *Northwest Power and Conservation Act* to lead the power sector resource planning efforts across four states: Washington, Oregon, Idaho, and Montana. Under the Act, the Council is required to develop a least-cost plan for meeting the region's future electricity needs. This power plan identifies a targeted mix of resources; state governments then use competitive mechanisms to acquire the resources.

The essential characteristics of the Council's power planning methods were established in the Act and implemented in the first power plan, which was adopted in 1983. The Council established the basic principles and methods for IRP in that first power plan. Since then, the methods and tools have been refined each time a new plan is prepared. The Council adopted its Sixth Power Plan in March 2010.[71]

The Act prescribed the basic scope and stance of the Council's planning. The power plan is required to be a long-term, 20-year strategy for meeting the region's electricity needs. Its objective is to describe a resource strategy that ensures an "adequate, efficient, economical and reliable power supply" at the lowest cost. The plan

Figure 11

Independent System Operators and Regional Transmission Organisations in the United States and Canada[70]



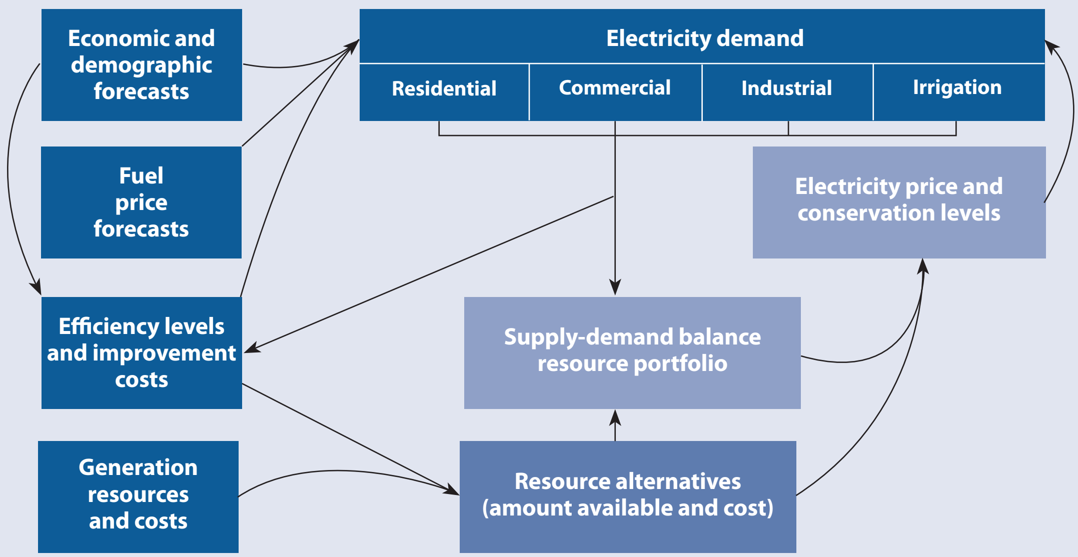
70 Federal Energy Regulatory Commission (2014).

71 Northwest Power and Conservation Council (2011).

has a long-term focus to minimise the cost of the entire regional power system. Resources included in the plan are to be cost-effective, that is, they should result in a resource strategy "to meet or reduce the electric power demand … of the customers at an estimated incremental system cost no greater than that of the least-cost similarly reliable and available alternative measure or resource." System cost is defined to include all costs of a resource over its useful life, including quantifiable environmental costs.[72]

Figure 12

Northwest Power and Conservation Council Modelling and Planning Process[75]



A major innovation in the Act is the inclusion of "conservation" (energy efficiency) as a resource. Energy efficiency is specified as the first priority resource, and it is given a 10 percent cost advantage for planning purposes. The Act also specifies additional resource priorities after energy efficiency: the second priority is generation from renewable resources, followed by high-efficiency generation such as combined heat and power applications, and finally other generation resources.[73]

Including energy efficiency in the power plan as the first priority resource has widespread implications for the Council's planning methods. The Council's least-cost objective under the Act relates not to the cost of electricity itself, but rather to the cost of the services that electricity provides to consumers, such as cooked food or rooms maintained at a comfortable temperature. Minimising the cost of electricity services is quite a different proposition from minimising the cost of electricity itself. The focus is on reducing consumers' electricity bills, rather than decreasing electricity prices or generation costs.[74]

Prior to the *Northwest Power and Conservation Act,* the typical planning process was fairly straightforward: forecast the demand for electricity and then stack up a set of resources to meet that demand. Including energy efficiency as a resource changes the process significantly, particularly by creating the need for a feedback loop, turning the Council's planning into an iterative process.

Figure 12 provides an overview of the Council's modelling and planning process. The Council first uses economic and demographic forecasts and a preliminary forecast of electricity price to develop an initial electricity demand forecast. This demand forecast serves as a baseline; it is called the "frozen efficiency" forecast because it assumes that no new end-use efficiency improvements will be made over the planning period. A least-cost resource strategy, which does include energy efficiency improvements, is then developed to meet the demand in the frozen efficiency forecast. This resource strategy changes electricity prices because both the cost of generation resources and also the quantity of electricity sales through which the costs are recovered change. The change in electricity prices causes changes in demand and the process starts again. This iterative modelling and planning process continues until the beginning and ending electricity prices are close enough to make little difference.[76]

72 Northwest Power and Conservation Council (2011).

73 Northwest Power and Conservation Council (2011).

74 Northwest Power and Conservation Council (2011).

75 Northwest Power and Conservation Council (2011).

76 Northwest Power and Conservation Council (2011).

During the development of each power plan, estimates of the potential for improved energy efficiency in the northwest regional power system are built from technical assessments of hundreds of individual efficiency improvements in many electricity uses and sectors. For the Sixth Power Plan, 1400 different efficiency measures were evaluated.

Two types of energy efficiency improvements are recognised. The first type is cost-effective when a new building is constructed or new equipment purchased. Such efficiency improvements are categorised as "lost-opportunity" investments. Their timing is linked to economic growth and building and equipment replacement cycles. A second type of efficiency improvements is cost-effective when retrofits to existing buildings or equipment are carried out. These improvements can be developed at any time and are referred to as "discretionary" efficiency investments.[77]

Before estimated energy savings can be added to a power plan, individual energy efficiency measures are screened for cost-effectiveness, limits to the share of the cost-effective potential that can be acquired, and constraints on the rate of development over time. Estimates of the energy savings from each of the measures are aggregated into supply curves, one for discretionary efficiency and another for lost-opportunity efficiency. Supply curves summarise the quantities of energy savings available at various costs and at various times in the future.

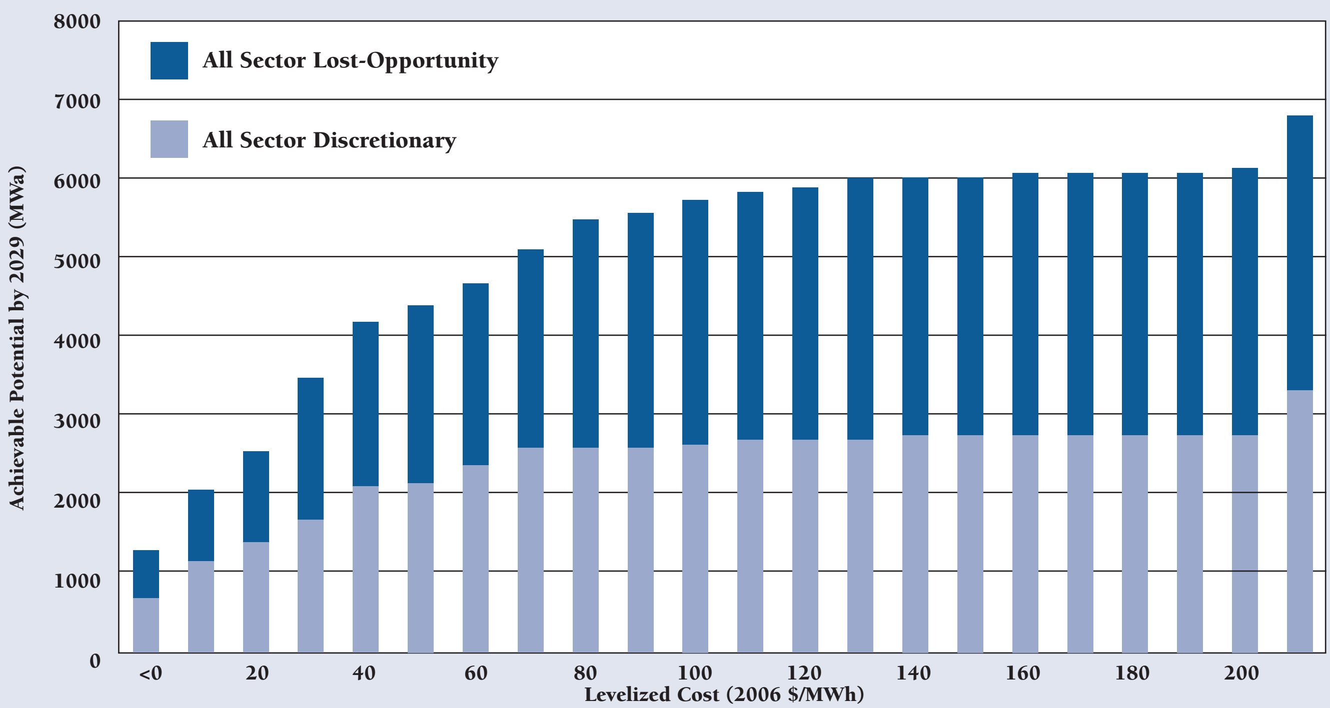
Figure 13 shows supply curves for the two types of energy efficiency. Typically, the Council has not put much effort into identifying measures that cost more than USD 100 per MWh. Consequently, the supply curves do not increase greatly as costs increase above that level.

4.3 The Efficiency Power Plant Concept

The efficiency power plant (EPP) concept was first developed in China by the Regulatory Assistance Project in 2004, in recognition of the fact that conventional power plants (CPPs) have well defined planning and investment frameworks whereas energy efficiency does not – and as a challenge to institutions that fund conventional electricity generation in China.

Figure 13

Typical Energy Efficiency Supply Curves Prepared by the Northwest Power and Conservation Council[78]



77 Northwest Power and Conservation Council (2011).

78 Northwest Power and Conservation Council (2011).

An EPP is a carefully selected portfolio of energy efficiency projects that provides a specified quantity of load reduction over a particular time period, with a level of reliability similar to the output from a CPP.

Compared to CPPs, EPPs are inexpensive, clean, and easy to plan. Moreover, they can be "constructed" and financed in much the same way as a con ventional unit. The portfolio approach enables the cost of an EPP to be compared with the cost of conventional electricity generation. On the basis of this cost comparison, energy efficiency resources can be integrated into power sector resource planning. However, in order for this to happen, a number of policy and financial arrangements must first be in place.

Since the EPP concept was developed, the EPP term has become quite widespread in China[79], for example, the central government's DSM Pilot Cities program is framed in terms of EPPs. However, the implementation of EPPs in China has not closely followed the original concept and particularly the link with resource planning and using energy efficiency as a resource is generally nonexistent or weak.

Table 5

Characteristics of a Conventional Power Plant (CPP) and an Efficiency Power Plant (EPP)[80]

	CPP	EPP
Capacity	300 MW	300 MW
Annual MWh produced/saved	1.5 million	1.5 million
Fuel use/kWh	340 grams coal	0 grams
SO_2 emissions/kWh	4 grams	0 grams
Estimated average cost/kWh	CNY0.35 to CNY0.40	CNY0.15

4.3.1 The Efficiency Power Plant Approach

The EPP concept combines many of the best features of international energy efficiency experience. An EPP can be partly explained by contrasting it with a CPP. Table 5 reveals several differences between a typical CPP and an EPP for each kWh of electricity or energy savings delivered. In Table 5, a typical CPP in China is assumed to be a 300-MW coal-fired power plant that operates for approximately 6000 hours a year. Table 6 (next page) shows that, like a CPP, an EPP must be planned, financed, built, and operated, and its performance must be measured and verified.

With the right policies and actions by the government, an EPP can be financed and paid for in the same way as a CPP. With a CPP, the capital and operating costs are paid over time as the power plant produces electricity. Similarly, the cost of an EPP can be paid over time as the EPP saves energy. The need for, and approach to, cost recovery can be simplified by amortising the cost of the EPP's aggregation of energy efficiency activities in a similar way to the amortisation of the cost of constructing a CPP.

The Regulatory Assistance Project sponsored the development of a software application, the *EPP Calculator*,[81] in English and Chinese that helps planners assess and plan for the "construction" of an efficiency power plant.

4.3.2 Efficiency Power Plant Implementation

The Regulatory Assistance Project identified four general models for implementing EPPs.[82] All of the models share certain common features:

- Energy efficiency opportunities are identified and evaluated. Cost-effective energy efficiency measures are selected and aggregated into a single EPP of substantial size (on the order of 300 MW). Aggregation makes large-scale, low-cost external financing possible and reduces financial risk and administration and transaction costs.
- Investment capital to fund the energy efficiency measures is identified, and loans or other capital resources are obtained by a responsible, competent, and creditworthy program administrator who can oversee the design and delivery of energy efficiency programs and manage the loan repayment process.
- Energy efficiency programs are delivered by a mix of energy services companies (ESCOs), customers, contractors, and others under the supervision of the program administrator.
- Actual energy savings performance is measured and verified by one or more responsible government agencies or independent third parties.
- The loan is repaid over the life of the energy efficiency investment.
- The entire process is subject to government oversight and approval.

79 Zhou and Hu (2010).

80 Moskovitz et al (2007).

81 Energy and Environmental Economics Inc (2011).

82 Moskovitz et al (2007).

Table 6

Comparison Between Conventional Power Plants and Efficiency Power Plants[83]

	Conventional Power Plants	Efficiency Power Plants
Planning	China's planning process is not transparent. Proposed power plants are screened for compliance with government policies and regulations.	Integrated resource planning would identify best types, size, and location of EPPs' energy efficiency programs.
Financing	Capital construction cost financed using debt, equity, or other sources of capital.	Capital cost including cost of rebates and other incentives can be financed using debt, equity, or other sources of capital.
Building	CPPs must be designed and engineered. Major components must be ordered. Skilled contractors of all types must be hired and deployed.	EPPs' energy efficiency programs must be designed to deliver the desired savings at a reasonable cost. Efficient products must be ordered for some programs. Skilled contractors of all types must be hired and deployed.
Operation	Operating cost depends on type of power plant. Some, such as coal and natural gas, have high operating costs. Others, such as hydroelectric and wind, have low operating costs.	EPPs' energy efficiency programs have no significant operating cost.
Performance	Power plant performance (and operating cost) is an ongoing risk. Actual power plant output is metered.	Energy saving performance is reasonably predictable and risk-free. Actual kWh savings are determined by well-established M&V protocols.
Cost Recovery	CPPs recover capital and operating costs through kWh prices paid over the life of the plants.	EPPs are designed to recover costs through payments for energy savings over the life of the energy efficiency investments. The sources of funds vary depending on the EPP model selected.

The main differences between the four models relate to the source of funding, the grid company role, and the degree of integration with power sector reform. All of the models are practical and effective but most of the models require central level policy reforms. Even those that do not require central level reform would benefit from the reforms to produce substantial results.[84]

***Model 1:* Comprehensive Integration of EPPs with Power Sector Reform.** Model 1 is the most comprehensive and powerful model. It places high priority on energy efficiency and treats energy efficiency as a full alternative to electricity generation. It also harmonises national goals and grid company profitability. Under this model, grid companies have an obligation to meet customer needs by planning and acquiring a resource portfolio from the least-cost mix of CPPs and EPPs. Because EPPs are much less expensive than CPPs, this model results in substantially increased use of EPPs. Implementing this model in China would require significant changes to the way the electricity industry is currently regulated, including ensuring that the costs of CPPs and EPPs are treated equally.

Currently in China, grid companies' costs of purchasing electricity from CPPs are included in prices. There is the potential for the cost of acquiring energy savings from EPPs also to be included in prices. Under the *Guidance on Electricity Demand-side Management Regulations No. 2643* 关于印发《电力需求侧管理办法》的通知 (发改运行 [2010] 2643) issued in November 2010,[85] grid companies in China are required to carry out DSM activities, including both energy efficiency and load management, to achieve specified targets for reductions in electricity sales (GWh) and peak demand (MW). The guidance document states that the cost of reasonable DSM expenses incurred by

83 Moskovitz et al (2007).

84 Moskovitz et al (2007).

85 China National Development and Reform Commission (2010).

grid companies can be recovered as part of power supply costs. So far, grid companies have not used this funding mechanism because detailed rules to enable them to do so have not yet been promulgated. Once these rules are promulgated, grid companies could use this mechanism to fund EPPs.

***Model 2:* EPP Funded by a Small Uniform Charge on All Electricity Sales.** Model 2 differs from Model 1 in two significant ways. First, the grid company role is substantially reduced and is limited to collecting the funds needed to repay the EPP financing. Second, EPP costs are included in electricity prices in a different way. Under Model 1, electricity prices are adjusted to both collect EPP-related costs and give consumers increased incentives to invest in energy efficiency. Under Model 2, EPP costs are recovered as a separate small uniform surcharge on electricity prices or electricity generators (this is known in the United States as a "system benefit charge"). Integrated resource planning can be used with Model 2 to identify the size and cost of EPP potential. This approach of funding energy efficiency with a system benefit charge has been taken internationally in many countries and regions. The U.S. state of Vermont is one of the best examples of this approach.

***Model 3:* Government Funding.** The main difference between Model 3 and Model 2 is the source of funding. Under Model 3, funds to repay the cost of the EPP are provided directly by the government. Government funding can come from existing revenue sources or from new taxes designed to encourage energy efficiency such as energy or pollution taxes.

***Model 4:* Direct Funding by Participating Consumers.** Model 4 combines the EPP's aggregation approach with traditional loan or ESCO approaches in which consumers who choose to invest in energy efficiency pay for the investment over time. Individual participating consumers or ESCOs propose energy efficiency projects. The projects are reviewed for technical, economic, and financial viability. The projects that pass the tests are aggregated into an EPP and loans for individual projects are approved. Each of these loans is made to a particular participant but, for purposes of risk management and repayment, all the participants are treated as a group. Loan repayment is structured as an "Energy Saving Fee" (ESF) equal to the average cost per kWh saved across the whole EPP. Each participant pays the same ESF for the kWh savings estimated for its particular project.

There are several useful versions of this option. Under the best versions, the ESF is included on the power bills of the participating customers; however, it is a separate charge and is not part of the electricity price. The grid company merely collects the ESF payments and forwards the funds to the actual borrower (a government-designated entity), which will then repay the loan. The loan may also be structured as a revolving fund in which the money collected from the ESF is used to fund more energy efficiency projects.

Table 7 (next page) summarises the four models for implementing an EPP and the major distinguishing features of each model. Table 7 also summarises the major policy reforms needed to implement each model and the best international example of the model.

4.3.3 Efficiency Power Plant Case Study

In 2008, the Asian Development Bank (ADB) funded a project to establish an EPP in the Chinese province of Guangdong.[86] The original framework financing agreement between the ADB and the Chinese central government called for the establishment of a 107-MW EPP with an investment of USD 142 million, of which USD 100 million was to be financed by a 15-year loan from the ADB.[87] The remainder was to be self-financed by the implementing firms (also known as sub borrowers). In the event, sub-borrowers contributed significantly more and the total investment was actually USD 269 million to establish a 154-MW EPP. The Guangdong EPP is an example of Model 3, involving external funding of energy efficiency projects, in this case by the ADB with a small amount of funding from the Guangdong provincial government.

The Chinese government approved the project in early 2008, followed by the ADB Board in June of that year. The loan agreement was signed in September 2008 and the project went into effect in January 2009. The implementation stage finally began in February 2009 with the launch of the first batch of sub-project agreements. The second batch of sub-project loans became effective in May 2010, and a third and final batch became effective in February 2012.

When completed, the EPP will be the equivalent of a 154-MW CPP, saving 810 GWh annually. In the context

86 Yi and Wen (2013).

87 Asian Development Bank (2008).

Table 7

Distinguishing Characteristics of EPP Models[88]

	Model 1 Costs Recovered in Electricity Prices	*Model 2* Funded by a System Benefit Charge	*Model 3* Government Funded	*Model 4* Funded by Participating Consumers
Planning and investment	Energy efficiency is treated as a resource in power sector planning and investment process. Amount of energy efficiency is determined by studies identifying all cost-effective energy efficiency.	Energy efficiency may or may not be analyzed as part of the planning process. Level of energy efficiency funding is determined by government and collected by grid company through a system benefit charge.	Energy efficiency may or may not be analyzed as part of the planning process. Level of energy efficiency funding is determined by government.	Energy efficiency opportunities are identified by participants. Level of energy efficiency funding determines the number and size of energy efficiency opportunities consumers are willing to implement.
Grid company role	Grid company is fully involved in assessing potential for energy efficiency and suggesting program design and funding level.	Grid company collects system benefit charge and forwards funds to administrator of energy efficiency programs.	Grid company has no significant role.	Grid company may collect energy saving fee (loan repayment) from participants.
Source of funds for repayment	Electricity prices, preferably through pricing policies that reinforce consumer incentives to invest in energy efficiency, such as inclined block prices and differential new construction hookup fees.	Small uniform system benefit charge added to electricity prices of all consumers.	Government energy efficiency funding, possibly through increased taxes or fees on energy or pollution.	Energy saving fee added to electric bills of participating customers, based on kWh saved and original loan amount.
Major policy reforms needed in China	Requires reform of planning, investment, market, and electricity pricing policies and pricing methods.	Requires adoption of system benefit charge policies and identification of administrator for energy efficiency programs. Planning reforms would improve results.	Requires government decision to fund energy efficiency and identification of administrator for energy efficiency programs.	Requires identification of administrator for energy efficiency programs.
Best international example	California	Vermont	South Korea	Loan programs in several U.S. states

of Guangdong this is a relatively small project, roughly equal to approximately 0.2 percent of total 2008 electricity consumption in the province. Despite its fairly small size, the EPP is intended as an experiment and offers potentially valuable lessons for future EPP projects around China and in other countries.[89]

The organisational structure of the Guangdong EPP features a Project Management Office (PMO) that administers and coordinates the EPP. The PMO includes representatives from the Guangdong Development and Reform Commission, the Guangdong Financial Bureau, and the Guangdong Energy Conservation and Monitoring Center, among other provincial bodies. The PMO answers to an EPP Steering Committee of senior provincial officials.

88 Moskovitz et al (2007).

89 Dupuy and Weston (2010).

The PMO decided to employ an external financial firm, Guangdong Yuecai Financial Trust, to handle management of the sub-project loans – including facilitation of financial disbursements and collections. This firm also takes the lead with evaluation of sub-projects.

The framework financing agreement states that the sub-projects in the Guangdong EPP may include retrofits of[90]:

- Motors and motor-drive systems;
- Transformers and reactive power compensators;
- Lighting;
- Air conditioning, ventilation, refrigeration, and heating;
- Air compressors and pumping systems;
- Recovery of waste energy from industry;
- Industrial boilers and industrial cogeneration; and
- Other related energy efficiency improvement projects.

Implementing firms (sub-borrowers) can be electricity end-users or ESCOs and must self-finance part of the cost of sub-projects. The framework financing agreement states that sub-borrowers must contribute a minimum of 20 percent of a sub-project total investment cost as counterpart financing. The total economic benefits of a sub-project must exceed the total economic costs, the internal rate of return must be greater than the discount rate of 12 percent, and the simple payback period (total investment cost divided by annual savings in electricity bills) must be less than five years. Firms that have any history of tax problems, credit problems, or documented history of failure to punctually meet payroll are excluded from consideration. Applicant firms must also have a debt to equity ratio lower than 75 percent.[91]

The Guangdong EPP's processes for sub-project application, review, approval, and evaluation are as follows[92]:

- An application prepared by a prospective sub-borrower must include a project brief, including a description of technologies, implementation methods, projected energy savings, estimated investment costs, and a plan for partial self-financing.
- After receipt of the application, the PMO prepares an initial technical review while the financial intermediary (Yuecai Financial Trust) assesses the sub-project from a financial perspective (including borrower creditworthiness).
- Once this preliminary review is completed, the prospective sub-project implementer hires an engineering agency to prepare a feasibility study.
- The Guangdong Development and Reform Commission reviews the sub-project.
- The central government's National Development and Reform Commission and Ministry of Finance then review the sub-project before the contract can finally be signed.
- During the implementation of the project, the intermediate financial agency (Yuecai) monitors disbursements and repayments, with regular reports to the PMO and provincial Development and Reform Commission.
- Equipment acquisition by sub-project borrowers must comply with strict ADB procurement guidelines.[93] For each batch of equipment purchase, the sub-borrower must obtain a no-objection letter from the PMO (stating that the acquisition methods are acceptable) in order to draw down funds from Yuecai.
- Evaluation of the sub-project must be done by a third-party organisation.

In August 2013, the ADB prepared a completion report evaluating the results of the first tranche of the Guangdong EPP project. Originally, nine sub-projects were identified and assessed for Tranche 1. The processing of sub-project applications was relatively lengthy, because this was the first tranche of the investment program and the first ADB pilot energy efficiency project in Guangdong Province. During the application processing period, four of the original candidate sub-borrowers decided to implement sub-projects with their own and other resources or were no longer able to implement the sub-projects owing to market changes and other considerations. Three new sub-borrowers were selected and loan reallocations were made to utilise the entire loan amount of USD 35 million.

The Tranche 1 ADB loan was fully disbursed and closed on February 3, 2012. The Tranche 1 project was originally expected to develop EPP capacity of 38 MW and produce annual energy savings of 188 GWh by the time all sub-projects were completed. The completion report concluded that the Tranche 1 project had delivered EPP capacity of 130 MW and annual energy savings of 651 GWh, which actually exceeded the original targets for all three tranches of the Guangdong EPP project and the total ADB loan of

90 Asian Development Bank (2008).

91 Asian Development Bank (2008).

92 Dupuy and Weston (2010).

93 Asian Development Bank (2013b).

Table 8

Annual Energy Savings and Emissions Reductions Achieved in Tranche 1 of the Guangdong EPP Project[94]

Sub-borrower	Electricity Saved (kWh)	Standard Coal Converted (tce/yr)	CO_2 Emissions Reduced (t/y)	SO_2 Emissions Reduced (t/y)	NO_x Emissions Reduced (t/y)	TSP Emissions Reduced (t/y)
Guangzhou Zhiguang Electric Company	393,969,690	130,010	307,296	3,546	788	1,379
Guangzhou Jinguan (G.K.) Company	75,895,968	25,046	59,199	683	152	266
Zhuhai Secopower Transformer Company	1,305,393	431	1,018	12	2.6	5
Zhuhai Charlie Energy-Saving Company	6,205,784	2,048	4,841	56	12	22
Guangdong Zhongyu Technology Company	77,639,467	25,621	60,559	699	155	272
Guangdong SGIS Songshan Company	82,467,240	27,214	64,324	742	165	289
Kaiping Fulai Electric Company	519,697	172	405	5	1	2
Guangdong Haihong Transformer Company	12,895,134	4,255	10,058	116	26	45
Total	**650,898,373**	**214,797**	**507,701**	**5,858**	**1,302**	**2,278**

CO_2 = carbon dioxide, kWh = kilowatt hour, NO_x = nitrogen oxide, SO_2 = sulfur dioxide, t = ton, t/y = tons per year, tce/y = tons of coal equivalent per year, TSP = total suspended particulates.

USD 100.0 million.[95] Table 8 shows the annual energy savings and emissions reductions achieved in Tranche 1.

Following are details of the sub-projects implemented in Tranche 1, as shown in Table 8. Guangzhou Zhiguang Electric Company implemented energy efficiency retrofits with 168 variable-speed and variable-frequency industrial motor drive systems for large electricity end users. Guangzhou Jinguan (G.K.) Company implemented energy efficiency retrofits of heating, ventilation, and air conditioning systems for commercial buildings, as well as upgrading 88 sets of industrial motor drive systems. Zhuhai Secopower Transformer Company replaced 88 sets of transformers with high efficiency models for direct end users. Zhuhai Charlie Energy-saving Company carried out one steam waste heat recovery sub-project and three industrial boiler retrofits. Guangdong Zhongyu Technology Company installed 13,631 sets of distribution transformer station monitoring terminals for power grid utilities and other end users. Guangdong SGIS Songshan Company conducted a technical retrofit for waste heat recovery and utilisation from the circular cooler in its sinter factory. Kaiping Fulai Electric Company installed 144 sets of reactive power compensators for large direct end users to save energy. Guangdong Haihong Transformer Company

94 Asian Development Bank (2013a).

95 Asian Development Bank (2013a).

replaced inefficient transformers with 1318 sets of high efficiency models for electricity end users.[96]

Tranche 1 successfully promoted ESCO sector development in Guangdong province. Two of the Tranche 1 sub-borrowers were ESCOs – Guangzhou Jinguan (G.K.) Company and Zhuhai Charlie Energy-saving Company. Two other sub-borrowers – Guangzhou Zhiguang Electric Company and Guangdong Zhongyu Technology Company – established their own ESCO subsidiaries in 2011.

The majority of Tranche 1 sub-projects were implemented in the industrial sector. This is not the case for the other two tranches. For example, the second tranche comprises substantial nonindustrial sub-projects, including an LED street lighting project and a solar project.

The Tranche 1 loan has a 15-year term with a grace period of 12 years and also allows the relending of repaid loan funds to new sub-projects. The longer than usual grace period was considered essential to maximise the benefits by making the full amount of the loan available for rotation and relending to a greater number of sub-borrowers, thereby generating maximum energy savings and emissions reductions. To maximise the benefit from the revolving of the funds, the term of each sub-loan is no longer than three to five years, including a grace period of one to two years. The recovered sub-loan funds will be revolved and relent to more sub-borrowers during the 15-year term of the overall Tranche 1 loan.

In conclusion, the Guangdong EPP is a pioneering effort that is achieving real energy savings and emission reductions and lays the groundwork for future EPPs. It is perhaps best viewed as a test case and capacity building exercise. The Guangdong authorities successfully organised a project management office (PMO) that is operating well as an administrative center. The PMO and other responsible provincial authorities are successfully demonstrating the ability to manage economic, technical, and financial aspects of delivering energy efficiency.

Today, the Guangdong EPP is less of an EPP as originally conceived (a set of programs whose savings resemble the output of a typical coal-fired generator) than it is a system of accounting for the energy savings produced by discrete and unrelated energy efficiency projects. These savings can be identified and catalogued, but they have not been acquired as part of an integrated resource strategy to meet the province's overall energy needs.[97]

The Regulatory Assistance Project (RAP) recommends that future EPPs should:

1. Involve grid companies in the development and implementation of EPPs;
2. Move away from commercial loans and toward energy efficiency projects that are directly funded by grid companies with resource acquisition funds that are recovered by including the cost of acquiring energy savings in electricity prices; and
3. Establish EPP models that reach beyond implementing energy efficiency retrofit projects in large facilities.

96 Asian Development Bank (2013a).

97 Dupuy and Weston (2010).

5. Conclusion: Using Energy Efficiency As A Resource In China

This paper has shown that, in several jurisdictions around the world, electricity utilities employ end-use energy efficiency as a resource in meeting their customers' needs for energy services. Energy efficiency is seen as a cost-effective alternative to investing in supply-side resources, such as building power plants and expanding the electricity grid. Used in this way, energy efficiency provides multiple benefits to the power system, to electricity customers, and to society as a whole.

Methods for integrating energy efficiency into power system resource planning are readily available and are in active use in many jurisdictions. Some jurisdictions have established comprehensive policy, regulatory, and organisational systems that enable energy efficiency to be used as a power system resource. The paper presents three case studies, including one from China. The Chinese case study, of the Guangdong EPP, demonstrates that energy and capacity savings can be successfully acquired at a lower cost than conventional electricity generation, with all the additional benefits that energy efficiency provides.

Using energy efficiency as a power system resource is particularly important in China, where air pollution from coal-fired power plants is a large and growing problem. Energy efficiency can meet a portion of China's needs for energy services while also contributing to reducing air pollution and could make an important contribution to China's current Clean Air Action Plan.

China has a long history of establishing government policies that require extensive energy efficiency programs, particularly in the industrial sector. More recently, the central government has established a Rule that requires grid companies to implement energy efficiency. What is needed now is for government to strengthen policy and regulatory mechanisms to both expand the energy efficiency programs delivered by grid companies and to enable energy and capacity savings achieved by all energy efficiency programs implemented in China to be used as power system resources. This will reduce the number of new power stations and augmentations of grid infrastructure that must be built in the future.

Grid companies are the key to using energy efficiency as a power system resource in China. In common with many electricity utilities in other countries, Chinese grid companies may be initially reluctant to consider energy efficiency as a resource; they may have questions about whether energy efficiency is as predictable or as "firm" as supply-side resources. The practical experience with utility energy efficiency programs described in this paper should alleviate these concerns.

Grid companies are also concerned about the reduction of revenue that results from encouraging customers to use electricity more efficiently. As long as the State-Owned Assets Supervision and Administration Commission evaluates grid company performance primarily on the revenue they earn and the profit they make, revenue reduction will be a major barrier to grid company implementation of energy efficiency. This barrier could be removed by changing the metrics for evaluating grid company performance, particularly by developing a metric that measures grid company performance in delivering energy efficiency. The multiple benefits that using energy efficiency as a power system resource will bring to China provide ample justification for changing the evaluation of grid company performance in this way.

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