Best Practices Guide:

Integrated Resource Planning For Electricity

Prepared for:

Energy and Environment Training Program
Office of Energy, Environment and Technology
Global Bureau, Center for the Environment
United State Agency for International Development

Implemented by:

The Energy Group
Institute of International Education
Washington, DC

Prepared by:

The Tellus Institute
Boston, Massachusetts

Contents

Acronyms

CC	Combined Cycle
CT	Combustion Turbine
CO_2	Carbon Dioxide
DSM	Demand Side Management
IIEC	International Institute of Energy Conservation
IRP	Integrated Resource Planning
KWh	Kilo-watt Hour
LCC	Life-Cycle Costs
MW	Megawatt
NO_x	Nitrogen Oxide
NPV	Net Present Value
O&M	Operations and Maintenance
PV	Photovoltaic
SO_x	Sulfur Oxide
T&D	Transmission and Distribution
US	United States

Acknowledgements

USAID's Office of Energy, Environment, and Technology (EET) would like to thank the team of individuals who wrote, reviewed, and produced this *Best Practices Guide: Integrated Resource Planning for Electricity*. EET would also like to recognize the Energy and Environment Training Program Team Leader, Mark Murray, and Deputy Team Leader, Nohemi Zerbi, for their guidance in the Energy Training Program under which this Guide is produced.

The material found in this Guide is adapted from a four week long training course presented to a multinational audience. The course was taught in Boston and Cambridge, Massachusetts, USA, by Tellus Institute. EET would like to acknowledge the authors of this Guide for synthesizing the key training materials in the chapters that follow. Dr. David Nichols of Tellus served as lead instructor for the training course. He and Dr. David Von Hippel are the lead authors for this Guide.

USAID's Office of Energy, Environment, and Technology would also like to thank the Institute of International Education for administering the training course and for its assistance in bringing this Guide to completion.

Introduction

The Global Center for Environment of the United States Agency for International Development (USAID) has developed the Best Practices Guide series to provide technical information on the topics of energy efficiency and the environment to support international initiatives and promote the use of clean and innovative technologies. This series of guides is adapted from course work that was designed to help develop technical leadership capacity to pursue energy development and greenhouse gas emission reduction through practices that are both friendly to the environment and beneficial to economic growth.

This guide is for resource planners at national and sectoral levels; for businesses or agencies providing electricity services through generation, transmission, or distribution; for regulators of electricity markets; and others interested in the structuring of policies, markets, and regulations affecting electricity. It provides the analytical framework and assessment methodologies needed to promote integrated resource planning in different economic, political, and geographic settings. Through a contract with the Energy Group of the Institute of International Education, USAID's contractor for the Technical Leadership Training Program, the Tellus Institute has prepared this *Best Practices Guide: Integrated Resource Planning for Electricity*.

The Institute of International Education's Energy Group provides assistance and training to government and business leaders to develop the skills and knowledge they will need to successfully meet their energy resource challenges in the context of their national development goals.

Tellus Institute conducts a diverse program of research, consulting, and communication. Founded in 1976 as a nonprofit corporation, the Institute has conducted over 3,000 studies and assignments throughout the world. The name Tellus comes from the ancient Roman goddess who attended to the earth's well-being and productivity. Tellus projects address policy and planning issues in such areas as energy, water, waste, pollution prevention, and environmental accounting. Using state-of-the-art methods, Tellus staff analyze evolving problems and evaluates options for technological and institutional change. The Institute disseminates decision-support tools to strengthen capacity to develop effective resource and environmental strategies. The Institute's sponsors—international, national, state/province, and local government agencies, multilateral organizations, non-governmental organizations, foundations, utilities, and businesses—reflect the diversity of its research. Tellus is committed to bringing insight, vision, and guidance to all participants in the transition to a sustainable society.

Contact Information

US Agency for International Development
Global Center for Environment
Office of Energy, Environment, and Technology
1300 Pennsylvania Ave., NW
Washington, DC 20523-3800 USA

Tel: (202) 712-1750
Fax: (202) 216-3230
http://www.info.usaid.gov

Institute of International Education
The Energy Group
1400 K Street, NW
Washington, DC 20005-2403 USA

Tel: (202) 326-7720
Fax: (202) 326-7694
http://www.iie.org

Tellus Institute
11 Arlington Street
Boston, MA 02116-3411 USA

Tel: (617) 266-5400
Fax: (617) 266-8303
http://www.tellus.org
www.seib.org

Chapter 1

Introduction to Integrated Resource Planning

Integrated Resource Planning, or IRP, can be thought of as a process of planning to meet users' needs for electricity services in a way that satisfies multiple objectives for resource use. Broad objectives can include:

- Conform to national, regional, and local development objectives.
- Ensure that all households and businesses have access to electricity services.
- Maintain reliability of supply.
- Minimize the short term or long term economic cost of delivering electricity services or their equivalent.
- Minimize the environmental impacts of electricity supply and use.
- Enhance energy security by minimizing the use of external resources.
- Provide local economic benefits.
- Minimize foreign exchange costs.

Each country, or other planning region, establishes its own objectives to guide planning for electricity services. Objectives such as those listed above are often among those selected to guide IRP. Such objectives as the above conflict with one another to varying degrees. Therefore, preparing, deciding upon, and implementing a preferred resource plan requires both a series of objective *analyses* and the use of *processes* by which the values and judgements of stakeholders are applied in developing plans.

Developed Countries

In many developed countries, IRP has been pursued by privately owned integrated utilities under regulatory oversight, or by governmentally owned utilities. IRP approaches were originally applied to *vertically integrated* power systems, that is, systems in which one utility or agency has the responsibility and authority to build, maintain, and operate facilities for the generation, transmission, and distribution of electricity to end-users. Integrated resource plans could therefore govern the selection of power plants as well as investment in other aspects of electricity supply and in demand-side efficiency measures as well.

A number of developed countries privatized electricity generation and reduced the amount of price regulation in the late 1990s, a process known as electric industry restructuring or as power sector reform. As a result, the selection, construction, and operation, of generation facilities was left largely to private investors responding to their perceptions of the markets for power output.

Of course, each generating facility must still comply with government regulations that apply to all power facilities. But restructuring or power reform often leaves the *selection of* and *investment in* generating facilities to the unregulated market. When generation investment, and with it pricing, is no longer subject to governmental or regulatory direction, IRP must be adapted to the changed market structure. If competitive generation markets are introduced at the retail level, so that energy users purchase power supply services directly from the market, then IRP must be reinvented. It must move to the jurisdictional level, where national or state/province level IRP processes can develop benchmark plans. National benchmark IRPs can help in monitoring the performance of the electricity sector on critical policy variables like costs to consumers and environmental protection. Such national or state IRP processes can inform policy development to structure and regulate the competitive electric generation market.

However, if competitive generation markets operate only at the wholesale level, while electricity users must still purchase power at retail from distribution utilities, then IRP can still be applied at the utility system level in much the same manner as it is when there is a vertically integrated utility system. IRP can sill function framework and process for the selection of investments in:

- transmission and distribution systems;
- end-use efficiency options; and
- that mix of power available at wholesale which best satisfies IRP objectives.

With or without electric industry restructuring, IRP processes are useful for very large electric generation projects with extensive environmental impacts. For example, large dams for hydropower are usually either public projects or highly regulated private projects, and it will always be appropriate to apply IRP in assessing them at the project level through a comprehensive analysis of the dam option versus likely or feasible alternative options.

Developing Countries

Many developing countries confront basic needs for reliable electricity supply and the provision of electric service to all households. Many are experiencing rapid growth in the demand for power. Just as in more developed countries, there is a need to minimize generation costs while meeting development and environmental objectives. IRP can help countries with varying market structures, whether it functions as a blueprint for a governmentally owned utility system or as a benchmark utilized in the process of regulating the private power market. Developing countries need to stay abreast of new technologies for generation and transmission as well as for electricity end-use, and to consider all available technologies, including end-use efficiency and electricity generation using local renewable resources, on a consistent basis. IRP can assist in developing responses to the restricted availability of capital for electricity supply investments as well as the growing private-sector involvement in financing and operating generation facilities.

Summary

Integrated resource planning is built on principles of comprehensive and holistic analysis. Traditional methods of electric resource planning focussed on “supply-side” projects only, i.e., construction of generation, transmission, and distribution facilities. Demand-side options, which can increase the productivity with which electricity is used by consumers, were not considered. Too often, even the assessment of supply-side options was limited to a few major technologies, and cost-benefit analysis of the alternatives was rudimentary. By contrast, IRP considers a full range of feasible supply-side and demand-side options and assesses them against a common set of planning objectives and criteria.

IRP, as we intend the approach, is also a transparent and participatory planning process. It contrasts with traditional planning that is typically top-down, with public consultation occurring only as a last step, when plans are virtually complete. IRP can make planning more open to relevant governmental agencies, consumer groups, and others, thus considering the needs and ideas of all parties with a stake in the future of the electric system.

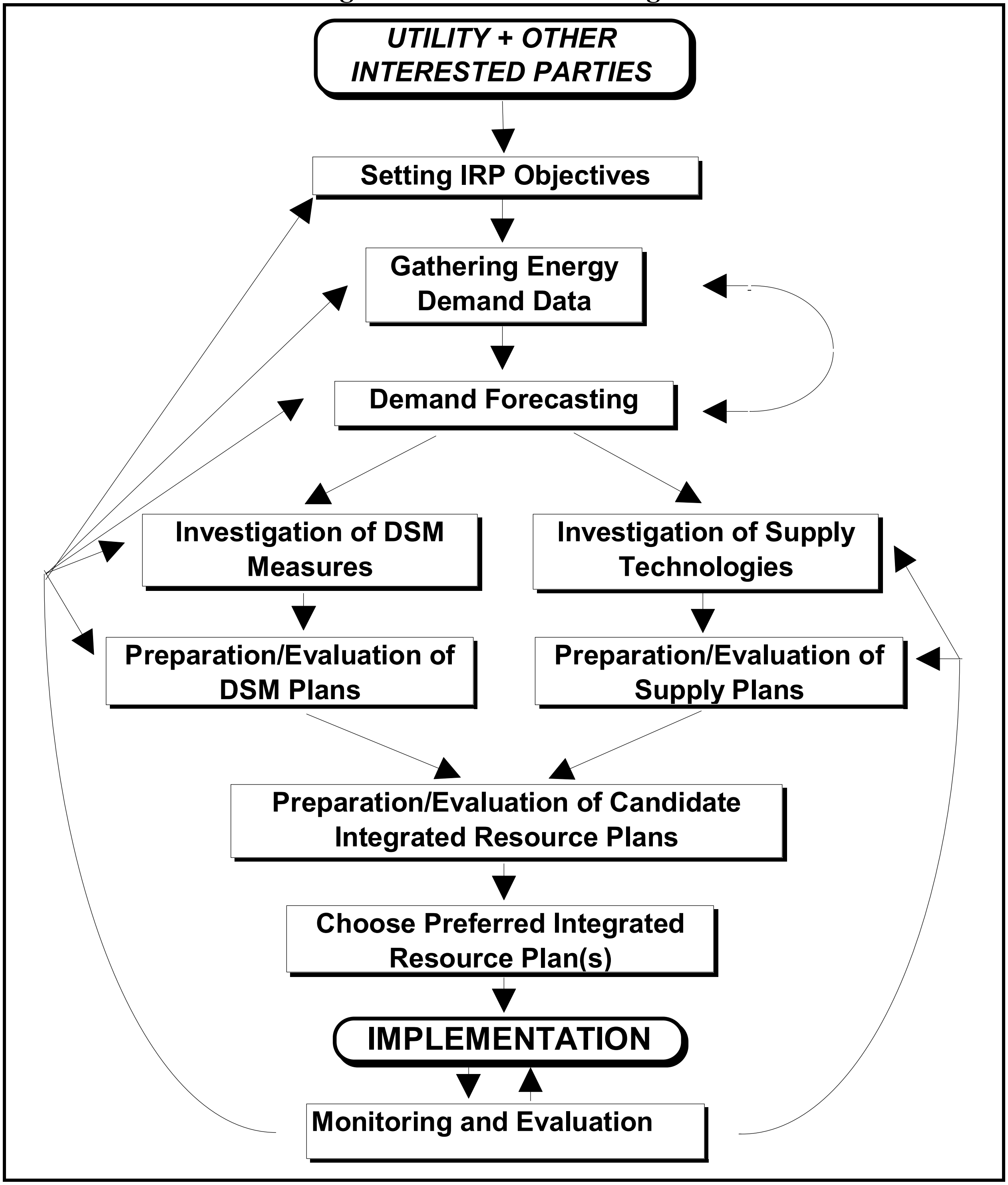
In summary, IRP provides an opportunity for electric system planners to address complex issues in a structured, inclusive, and transparent manner. At the same time, it provides a chance for interested parties both inside and outside the planning region to review, understand, and provide input to planning decisions.

The remainder of this Guide sets out the elements of integrated resource planning for electricity. The steps in this process generally are to:

- establish objectives;
- survey energy use patterns and develop demand forecasts;
- investigate electricity supply options;
- investigate demand-side management measures;
- prepare and evaluate supply plans;
- prepare and evaluate demand-side management plans;
- integrate supply- and demand-side plans into candidate integrated resource plans;
- select the preferred plan; and
- during implementation of the plan, monitor, evaluate, and iterate (plan revision and modification).

The figure below depicts the various elements involved in integrated resource planning for electric systems as well as the major linkages amongst elements.

The Integrated Resource Planning Process



Chapter 2

The Planning Process: Scope and Objectives

The Scope of Planning

The policies of national and sub-national governments frame the structure of ownership, operation, and regulation of electric facilities and systems. Policy also establishes the rights and responsibilities of all sectors of society as they relate to electric system planning and operation.

The operation of the electric system necessarily affects a wide range of legitimate societal interests. In structuring the IRP process itself, it is desirable to include not only members from various departments of a utility system (for example, engineering, finance, law, and customer service), but also representatives of (other) government agencies (ministries or departments of economic planning, environmental protection, and energy), energy consuming sectors, community groups, etc. Incorporating the views of a broad spectrum of those that will be affected by planning decisions can foster consensus and avoid polarization as those plans are implemented.

The logical geographic boundaries for power system planning may or may not coincide with the nation-state boundary. The existing power system may be operated on a national basis, for example. In such cases there may be a neat fit between national plans, policies, or regulations and the boundaries for ongoing application of more detailed planning processes for the power sector. In other cases, however, there are reasons for a planning boundary that does not correspond to the nation.

In countries with federal governmental structures, socio-economic, political, and technical logic may have led to applied power system planning being carried out at the state or provincial level (or across groupings of states or provinces). Within large or energy-intensive states or provinces the logical bases for applied power system planning may be even "lower:" Planning at the level of individual electricity service areas within one state or province has been practiced extensively in the U.S., for example.

On the other hand, there are also numerous cases in which there are some good reasons for power system planning that transcends national boundaries. The demand for power may be on one side of a national boundary, and resources on the other. Consider, for example, the hydropower resources of a Quebec versus demand across the border with the U.S., or those of a Nepal versus demand across the border with India. Such situations create a case for cross-national planning. Political and practical difficulties currently limit cross-national power planning. However, it may be to the mutual benefit of nations to establish integrated resource planning regions that cross national boundaries. Establishment of a regional working group or a regional electric power pool might provide a foundation for developing more through-going regional IRP over time.

Whatever the geographic level at which planning for power systems is applied, there will usually be planning issues that cross the boundary — at the very least, questions of transmission interconnections and the creation of power grids that interconnect power systems that may once have been "islands." In principle the IRP methods described here can be used at the inter-utility-system level. The degree to which inter-system IRP is applied — for example, in transmission planning — will depend on whether the parties involved can expand the boundaries for integrated planning, at least for purposes of considering inter-system project alternatives.

Similarly, IRP can be applied to a localized problem within a power system. For example, there may be a local region within a utility service area that is capacity-constrained. "Local" IRP can be focussed in the particular area to determine the mix of feasible transmission, distribution, and load-management options, and develop a preferred plan to address the localized problem.

In describing electric IRP in this guide, we simply refer to the "utility system" to indicate the geographic boundaries of the planning process, whatever they might be.

Setting Objectives

Explicit objectives for the planning process are formulated in qualitative terms. They generally do not quantify the level of outputs or service to be provided. However, *criteria* by which the achievement of each objective may be measured must be established.

National policy and planning affect the objectives addressed in planning. Country-level economic development and environmental protection policies, supplemented by provincial/state-level policies in federated countries, influence the structuring of IRP. In particular, national development objectives and management strategies for energy resources should be reflected as objectives in electric resource planning processes.

The stakeholder concerns that inform the planning process are a critical source of planning objectives, possibly more specific in character than those derived from government policy. Specific planning objectives may be preliminary and subject to modification as initial informational and assessment activities convey a clearer picture of current and expected conditions to stakeholders. Several objectives are established at this stage of the planning process. The table below presents possible objectives that utility planners and others might choose to guide the formulation and evaluation of integrated resource plans.

Once planning objectives have been agreed on, *measures must be ascribed to each objective*. Cost objectives lend themselves well to quantitative measures of performance, while social objectives may require a qualitative approach to measurement. Measurement of environmental performance may entail a mix of quantitative measures (for example, estimates of air pollutant emissions) and qualitative measures (for example, aesthetic impacts).

Possible Objectives for Integrated Resource Planning

Objective	Nature of the Objective
Reliable electric service	Serving consumers with minimal disruptions in electric service
Electrification	Providing electric service to those without convenient access to electricity is a common objective in developing countries
Minimize environmental impacts	Reducing the impacts of electricity generation (and energy use in general) is a goal that has received increasing attention in recent years. Environmental impacts on the global, regional, and local scales can be considered
Energy security	Reducing the vulnerability of electricity generation (and the energy sector in general) to disruptions in supply caused by events outside the country
Use of local resources	Using more local resources to provide electricity services — including both domestic fuels and domestically manufactured technologies — is of interest in many countries. This objective may overlap with energy security objectives
Diversify supply	Diversification may entail using several types of generation facilities, different types of fuels and resources, or using fuels from different suppliers
Increase efficiency	Increasing the efficiency of electricity generation, transmission, distribution and use may be an objective in and of itself
Minimize costs	Cost minimization is key impetus for pursuing IRP, and a key objective in planning. The costs to be minimized can be costs to the utility, costs to society as a whole (which may include environmental costs), costs to customers, capital costs, foreign exchange costs, or other costs
Provide social benefits	Providing the social benefits of electrification to more people (for example, refrigeration and light for rural health clinics and schools, or light, radio, and television for domestic use). Conversely, social harms, as from relocation of households impacted by power project development, are to be prevented or minimized
Provide local employment	Resource choices have different effects upon local employment. IRP objectives can include increasing local employment related to the electricity sector, and increasing employment in the economy at large
Acquire technology and expertise	A utility (or country) may wish to use certain types of supply project development in order to acquire expertise in building and using the technologies involved
Retain flexibility	Developing plans that are flexible enough to be modified when costs, political situations, economic outlook, or other conditions change

Chapter 3

Demand Forecasting

Demand forecasts estimate the amount of electricity needed in the geographic area served by a power system. Forecasts may project the amount of energy (Watt-hours) and power (Watts) that will be needed over the course of a day, a week, or a year.

In the context of integrated resource planning, forecasts typically look at energy and power requirements from five to 30 years into the future. A demand forecast is basic to analyzing how much new generation capacity may be needed, which generation resources are applicable, how transmission and distribution systems should be expanded, and in which customer groups or geographic areas these requirements will be concentrated.

Data Needs for Demand Forecasting

Demand forecasts require data describing how electricity and alternative fuels are currently used in the utility system's service area. Some of the types of information needed for forecasting are:

- Sales records: Records of electricity sales for as many historical years as are available. Sales records by geographical area and by customer class (for example, household, commercial and industrial classes) are needed, along with the number of customers by class and by area.
- Demand records: Data on power demand that chart the MW requirements on the utility over days, weeks, months, and years are needed to determine the relationship between electricity sales and the amount of generation capacity required. Disaggregated data are useful. The shape of the load curve (the variation of peak loads over time, or the "load profile") helps to determine what types of generating capacity are needed.
- Economic and demographic data: Forecasting uses historical data on economic performance, and population or the number of households.
- Economic and demographic projections: A utility company may make its own economic and demographic projections for its service territory, or these projections may be obtained from an economic planning ministry or from some other entity.
- Energy end-use data: Types of end-use data include the number/fraction of households using specific electric appliances, the number/fraction of commercial, institutional, or industrial consumers using different types of electric equipment, and the amount of electricity used per customer per end use. These data are referred to as penetration or saturation data (for example, the percentage of households with electric lighting) and energy intensity data (for example, the kWh of electricity used per household per year). Ideally, historical data of these types would be available for each customer class and each major end use. In practice, even a single year's worth of such data may be hard to obtain. In some cases, partial data on

appliance ownership or use, most frequently for the household sector, can be found in national census documents. In some developing countries, government agencies or non-governmental organizations have studied energy end-use, or have been participated in data collection activities funded by bilateral or multilateral aid. These studies are rarely as complete as needed. New end-use surveys are often needed to obtain the data required for end-use forecasts.

Types of Forecasting Models

Methods used to forecast demand include trending, econometric analysis, end-use simulation, and combinations thereof. *Trend forecasting* assumes that past rates of change in electricity use, or in electricity use per customer, will continue into the future. A growth rate calculated from historical data (sales or peak demand data) may be applied to estimate future consumption and demand. Separate trending forecasts can be compiled for each customer class or geographic division. Trending requires only access to basic sales and peak statistics, and the use of simple statistical methods. Trending forecasts assume that the future will be like the past, which often turns out to be untrue. Changes in technology, structural shifts in the economy or in demography, and changes in regulations are difficult to capture with a trending forecast. Trending is most useful for short-term forecasting (one to two years), for which the assumption that the future will be like the past is more robust.

Econometric forecasting assumes that past relationships between electricity use or peak demand and various economic or demographic variables continue to hold into the future, but econometric forecasts are generally more detailed than trending forecasts. In econometrics, the first step is to look for statistically significant historical relationships between economic variables and electricity sales or peak demand. Variables used to develop econometric relationships may include household income, electricity prices (by consumer group), prices for other household necessities, employment (by sector and sub-sector), labor productivity, tourism, industrial or agricultural output (measured in physical quantities or monetary terms), commercial-sector output (by sub-sector), use of other fuels, and the prices of other fuels.

Different statistical procedures can be used to test how well changes in one or more driving variables (such as those above) predict the value of the quantity to be forecast. In addition to testing the statistical significance of these relationships, econometric tools allow calculation of the mathematical relationships among parameters. Once statistically significant historical relationships between economic or demographic variables that affect electricity use or demand are identified and specified, projections for the driving variables must be developed. Such projections can often be obtained from ministries of economics or finance, or sources such as national banks. These projections are used to “drive” the econometric forecasts of electricity use or peak demand. As the factors that influence household electricity use are generally different from those that affect commercial, institutional, or industrial electricity needs, econometric forecasts, at least of electric energy use (as opposed to peak demand), are typically done separately for each major customer group, then aggregated to estimate system-wide sales.

End-use forecasting differs from trending and econometric forecasting in that it builds up estimates of electricity needs starting with an analysis of what electricity is used for. An end-use model of household electricity use might include separate estimates of electricity used for lighting, water heating, space heating, air conditioning, fans, cooking, entertainment, and other appliances. Using the example of air conditioning, one can specify a relationship between end-use variables:

> Electric energy use for air conditioning = number of households * fraction of households with air conditioners * amount of cooling required per household * energy intensity (kWh per unit cooling delivered) of average air conditioner model in use.

In this example, one can forecast energy usage by projecting each of the four parameters on which air conditioning electricity usage depends. End-use forecasts can be prepared using spreadsheet software, or using customized forecasting software packages, of which several are available.

End-use approaches have several advantages. They can be quite detailed, providing more information for planners. They can provide integrated forecasts of both energy and peak power demands. The assumptions used in forecasting are usually easy to follow, check, and revise as new data become available. End-use forecasts provide an excellent framework for estimating the impacts of energy-efficiency options and demand-side management by making changes to parameters used in the baseline forecast. In the example used above, for instance, the analyst can change the assumed energy intensity of air conditioners to reflect introduction of more efficient units. On the other hand, end-use forecasts are data-intensive. Surveys of different types of buildings are usually needed to collect good data on energy end-uses.

Since the future is inherently uncertain, most forecasters prepare a "base case" and several alternative forecasts of electricity use and peak demand. The base case might be the forecasters' best estimate of how the parameters that influence electricity use will evolve over time, while alternative forecasts might include projections that assume "high" or "low" economic growth, higher or lower fuel prices, higher or lower population growth, or other combinations of key parameters. Alternative scenarios give planners an idea of the sensitivity of forecast results to changes in the assumed value of key parameters. *Forecast scenarios* can be used to assess whether a candidate IRP includes sufficient flexibility that it can be cost-effectively modified even if demand is higher (or lower) than anticipated.

Chapter 4

Investigation of Supply-Side Options

An electricity supply system consists of power generating technologies, transmission and distribution (T&D) technologies, fuel supply systems, and environmental controls and waste disposal processes. A review of supply options begins with identification of all applicable options and related infrastructure, review of the attributes of the options, and selection of promising options for further study and analysis. There are hundreds of different supply options and configurations of options that could be used in a power supply system.

Options for Generating Electricity

The many types and sizes of power plants can be broadly grouped into central-station, local, or dispersed applications. In countries where electrification is a priority, it may be necessary to choose among these applications, or make different choices for different areas within the country. Central power stations are often large generators designed to feed electricity into a central power grid serving an extensive region. The generating capacity of central power stations can range from tens to thousands of megawatts. The following table provides a sampling of types of generators suitable for use in central power stations.

Generation Options for Central Power Stations

Gaseous and Liquid Fuels (natural gas, oil products)
- Steam Cycle
- Combustion Turbines
- Combined-Cycle
- Repowering and Refurbishment of Existing Power Plants
- Large Internal Combustion Engines (Diesels)
- Fuel Cells (large arrays — still under development)

Solid Fuels (coal, biomass)
- Steam Cycle (many boiler configurations available)
- Gasification/Combined Cycle
- Nuclear Generators

Renewable Fuels
- Larger Hydroelectric (including pumped-storage)
- Wind “Farms” (arrays of many turbines)
- Large-array Solar Photovoltaic and Solar Thermal
- Geothermal
- Hybrids

Local power plants are designed primarily to meet electricity needs of an isolated electric grid in a particular locale (a larger village or town, for example) or for a large institutional or industrial facility. They tend to range in size from tens of kilowatts to tens of megawatts. In some cases combinations of technologies may be most appropriate. The following table lists some of the types of generators that can be used in local applications.

Generation Options for Local Power Generation

Gaseous and Liquid Fuels (natural gas, oil products)
- Combustion Turbines
- Combined-Cycle (small units)
- Internal Combustion Engines (Diesels)
- Fuel Cells (still under development)

Solid Fuels (coal, biomass)
- Small Steam Cycle
- Gasification/Internal Combustion Engines
- Biogas/Internal Combustion Engines

Renewable and Other Fuels
- Small and Medium Hydroelectric (including pumped storage)
- Wind "Farms" (one to several turbines)
- Solar PV and Solar Thermal, Small and Medium-sized arrays

Dispersed generation provides power to residences (or small groups of residences) and businesses. Where great distances separate potential electricity users and/or the existing electricity grid is far away, dispersed generation can be a cost-effective alternative to grid extension. The following table describes some of the technologies suitable for dispersed generation.

Generation Options for Dispersed Generation

Gaseous and Liquid Fuels (natural gas, oil products)
- Very Small Combustion Turbines
- Internal Combustion Engines (Diesels, gasoline generators)
- Small Fuel Cells (still under development)

Solid Fuels (coal, biomass)
- Gasification/Internal Combustion Engines
- Biogas/Internal Combustion Engines

Renewable and Other Fuels
- Mini and Micro-Hydroelectric
- Wind Power (turbines in a range of sizes, with battery storage)
- Solar PV, Small arrays (in a range of sizes, with battery storage)

The types of generating plants that are added to electricity grids must be matched to the varying loads encountered during each day, week, or year. Electric systems must consider needs for baseload, intermediate load, and peaking capacity. These types of capacity can be characterized as follows.

- Baseload capacity is designed to operate for most hours of the year — perhaps 50 to 80 or more percent of the time (50-80+% "capacity factor"). Coal-fired steam-cycle power plants, nuclear plants, and hydroelectric plants are examples of baseload generation capacity. Baseload plants may have high capital costs, but typically their fuel costs are low. The output of baseload-type plants cannot be rapidly decreased or increased to "follow load," i.e., adjusted to changes in the amount of power needed. (Sometimes hydro plants follow load, in which case they are not "baseload" units.)

- Intermediate-load plants provide power during periods when demand is higher than minimal levels, such as during the day and evening (capacity factors about 15-50%). Technologies for intermediate-load plants include oil or gas-fired steam cycle plants, combined-cycle plants, some hydroelectric plants, and internal-combustion-engine generators. (geothermal)

- Peak-load plants provide power when demand is highest, and may operate only a few percent of the hours in the year. Types of peak-load power plants include combustion turbines (sometimes also used as intermediate load plants), internal combustion engine plants, and pumped-storage hydroelectric facilities. (wind and photovoltaic systems)

Different types of power plants require different fuels or resources. It is necessary to consider what fuels and resources are available from domestic sources or imports, and the fuel delivery infrastructure (such as gas pipelines, liquefied natural gas terminals, coal mines, coal transport trains, and oil distribution networks). Depending on the fuel used, fuel treatment (coal cleaning or gas processing, for example) may also be necessary.

Transmission and Distribution Infrastructure

Transmission and distribution plans (T&D) form an essential part of an overall electricity supply plan. T&D infrastructure delivers electricity from power plants to consumers. Transmission lines carry power from power plants to the main electric grid, and along its major branches. Power from transmission lines is "stepped down," or reduced in voltage, for distribution to electricity users. There may be several sets of transformers to step down transmission voltage to the voltage level used by consumers. The distribution system carries power from transmission lines via substations and transformers, delivering electricity to its final points of use, and metering amounts used. Numerous technical choices for T&D systems and components must be costed and assessed.

Emissions Treatment and Waste Disposal

Generation options often produce pollutant emissions or wastes. Obvious examples include emissions of the air pollutants nitrogen and sulfur oxides (NO_x and SO_x) from coal, oil, and gas-fired power plants, and the ashes from coal combustion. The quantity of emissions and wastes per unit of electrical output varies by type of generating technology and with the fuel used, as do emissions control and waste disposal costs. Emissions of carbon dioxide (CO_2), which as a greenhouse gas contributes to climate change, can be reduced by choosing low- or no-carbon generating options and fuels. Technologies to “scrub” CO_2 from exhaust gases are under development.

Attributes of Supply Options

A major part of the process of reviewing the supply options is the collection of the quantitative and qualitative information needed to sift among alternatives. The table below describes the most important types of information required for each generation option.

Resources for reviewing supply options are available from international agencies (International Energy Agency, the World Bank), national or sub-national governments, trade organizations or institutes, private sources, and non-governmental organizations. Two sources for data on electricity supply options are Projected Costs of Generating Electricity, prepared by the Nuclear Energy Agency and the International Energy Agency (Update 1998), and Developing Countries & Global Climate Change: Electric Power Options for Growth, 1999, prepared for the Pew Center on Global Climate Change. Data from these sources are being put into a “Technology & Environment Data Base” that will be available through the Stockholm Environment Institute-Boston (www.leap2000.org).

Attributes of Supply Options

Attribute	Information About the Attribute
Plant capacity	In what sizes is the supply option available from vendors (or via local construction)?
Maximum and optimal capacity factors	For what fraction of the year is the full capacity of a generation option likely to be available to generate electricity?
Fuel type	What quantities and qualities of fuel are required by a generation option?
Efficiency	What is the efficiency of the supply-side technology? For a generation technology, efficiency is the net amount of electricity produced per unit of fuel input. For T&D technologies, efficiency is expressed in terms of the percentage of power or energy lost during transmission or distribution.
Fuel costs	How much do the fuels used for power generation cost? How much are they expected to cost over the planning period time horizon?
Reliability	How reliable is the technology under consideration? What has been its operating history, either domestically or in other countries?
Capital and operating costs	How much does it cost to acquire, operate, and maintain the technology (in addition to fuel costs)?
Lifetime	How long will the supply-side technology be operable?
Decommissioning costs	What is the expected net value of the plant at the end of its useful life, including the costs of decommissioning? Decommissioning should be considered for all options, even dams that may last longer than other options.
Foreign exchange requirements	What fraction of the capital, operating, and maintenance costs of the power plant will be spent in-country, and what fraction must be spent on imported goods?
Environmental impacts	What quantities of air pollutants, liquid wastes, and solid wastes are produced by a generation option per unit of electricity produced? How much land is required for the option? Is cooling water is needed? For a hydroelectric facility, how much area will be submerged when a dam is complete, and how many households and farmers affected? What are the environmental impacts of plant construction and decommissioning?

A source covering all energy forms is *International Energy Outlook 1999* from the U.S. Department of Energy's Energy Information Administration. Other databases of generic technologies include the *Energy Technology Status Report* compiled by the California Energy Commission in the U.S., and the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), sponsored in part by the International Energy Agency. (See "Resources for Further Information" at the end of this Guide.)

Vendors are an important source for information on technologies — trade publications can be used to identify and locate vendors of specific products — although getting information from more than one vendor for more than one brand of a given option is prudent. The Internet and the World-wide Web are becoming increasingly convenient tools to access this type of information.

Other utility systems may well have experience with technologies that are applicable for a particular review of supply technologies. Planning documents prepared by other utilities may be available for use as references.

Preliminary Assessment of Options

Once assembled, data on supply options must be evaluated to select attractive options to include in candidate supply plans. This evaluation and preliminary selection can be done in several ways, including preparation of a matrix to rank each option according to its "score" (for example cost per MW, fuel cost per kWh, or carbon emissions per kWh) on key attributes. Often, particularly for larger power plants, advanced review of supply options involves identifying candidate sites where the power plants or dams could be located. Quantitative and qualitative considerations enter into the options evaluation. The goal is to screen out options that are clearly inappropriate based on cost, resource, technical, or other grounds. Options passing preliminary screening are assessed more fully later on.

For example, screening calculations may be in order to establish whether a supply option is clearly ruled out on economic grounds. Some of the types of cost calculations often used in economic screening analyses include:

- Life-cycle costs of generating options can be computed to compare very different generating options. Capital, operating, fuel, waste treatment, and decommissioning costs (or salvage value) enter into calculation of overall plant net present value (NPV) and NPV per kW or kWh. Sensitivity analysis can be used to evaluate the impact of changes in key parameters (such as discount rate and capacity factors) on plant economics. (Life cycle cost analysis can also be used in screening demand-side options, as discussed below.)

- Leveled busbar cost. This analysis estimates the life-cycle cost (revenue requirement) of power from a supply option at the "busbar," the point at which electricity leaves the plant. Busbar revenue requirements, calculated in cost per kWh, may be used as indicators of overall costs when sifting among supply options (see Box at right of page).

- Leveled annual cost versus capacity factor. Calculation of the variation of annual costs (including capital, fuel, and O&M costs) at a range of capacity factors provides an indicator for how plant economics will change depending on how the plant is used.

Cost Levelization

Economic screening requires comparing power plants with very different capital costs, operating costs, size, output, and lifetimes. One tool for preliminary economic comparison is to convert the life-cycle costs (LCC) of each power plant option into a uniform (levelized) amount in each year. LCC costs are all the costs to produce electricity over the life of a plant: capital costs, including return on investment; taxes; depreciation; fuel costs; maintenance costs; cost of expected repairs, and decommissioning. The plant's real levelized value, A, is obtained as follows:

$$A = \frac{S*(1-R)}{1-(R^n)}$$ where:

S=Present value sum of all lifecycle costs
R=1/(1+real discount rate)
n=the number of values summed (in S)

Dividing A by kWh output provides the real levelized cost/kWh produced. Since price inflation is removed in calculating the real discount rate, cost streams with different start and end dates can be compared.

- Simplified production cost analysis is another method of estimating the cost of power from a supply option.

Chapter 5

Investigation of Demand-Side Options

Demand-side management, or DSM, refers to programs or projects undertaken to manage the demand for electricity: reducing electric energy use, changing the timing of electricity use (and thereby the profile of peak power demand), or both. By reducing the demand for electric energy and power, DSM options can reduce the use of existing electric supply facilities (or, equivalently, serve more users with given facilities), and defer the addition of new capacity. Review of DSM options begins with identification of all applicable options and their cost and performance characteristics. The more promising DSM options are selected for further study and incorporation in draft DSM programs and plans.

DSM Options

The list of potential DSM options for utility systems is longer than the list of supply options. DSM options can be roughly divided into four categories, as follows.

1. Information and/or Incentives to Encourage Efficiency in Electricity Use

   One class of options is to provide information to electricity consumers on how to use energy wisely and efficiently, and to provide pricing structures that help spur customers to change the amount and timing of energy use. Although there is uncertainty in the estimates of electricity or peak power savings from all types of DSM measures, the savings from information/price incentive measures are perhaps hardest to quantify.

2. Higher-efficiency Technologies

   Another class of options are "energy-efficiency" measures. These are technologies that reduce energy use (usually with some reduction in peak loads) by substituting more efficient appliances and equipment for less-efficient units or systems. Energy efficiency measures are available for virtually every end-use application. A small sample of generic measures, organized by sector (customer group), is presented in the following table.

Selected End-Use Electric Energy Efficiency Measures

Residential Sector

- Higher-efficiency appliances (air conditioners, refrigerators, stoves, water heaters, electronic devices)
- Devices that save hot water (efficient washing machines, plumbing fixtures)
- Compact fluorescent lamps
- Automatic lighting controls
- Building envelope improvements (insulation, window improvements) to reduce cooling, heating, and sometimes lighting needs.

Commercial/Institutional Sectors

- Higher-efficiency air conditioning, refrigeration equipment
- High-efficiency fluorescent bulbs, lamp ballasts, and lighting fixtures
- Lighting, cooling, space heating, and water heating controls
- High-efficiency office equipment
- Building envelope improvements
- High-efficiency electric motors, drives, and controls

Industrial Sector

- Process improvements
- High-efficiency electric motors, drives, and controls
- Applicable commercial/institutional sector measures

Other Sectors

- High-efficiency cooling and refrigeration equipment for the agricultural sector
- High-efficiency electric motors, drives, and controls for mining and transport applications
- High-efficiency lighting products for street lighting

3. Fuel-Switching Technologies

In electric IRP, the most common types of fuel-switching options are those that save electricity and reduce electric peak loads by substituting another fuel for electricity. Fuel switching to electricity is also considered. Illustrative fuel choice alternatives:

- Use of natural gas or solar energy (instead of electricity) to provide space heat, water heat, or industrial process heat;
- Use of natural gas or solar-thermal absorption chillers or natural gas engine-driven chillers (instead of electricity) for air conditioning or refrigeration; and
- Use of electric appliances for cooking, instead of wood stoves or coal stoves.

4. Load Management

Load management measures reduce peak demand by shifting power use from times of high power demand (for example, during the day or early evening) to times of lower demand (during the night). Examples include:

- Water heater controllers for household applications. These can be simple timers that turn off appliances during peak times, or electronic controls (“load control”) activated by the utility system operator. With centrally activated load control systems, different groups of end-use equipment can be cycled off for a few minutes during each peak load hour.

- Ice-storage systems for air conditioning. Ice is made at night by refrigeration, and stored until air conditioning is needed (for example, in an office building or hospital) during the day. The ice is then melted in a heat exchanger and used to cool the building.
- Special "interruptible" rates. Large volume electricity users may be offered price discounts in exchange for allowing the utility to disconnect all or a portion of their electrical equipment when the utility system is short of generating capacity.

Attributes of DSM Options

It is necessary to collect data on DSM options so that they can be compared with each other and with supply-side options. Attributes of DSM options that need to be considered are described in the following table.

Attributes of DSM Options

Attribute	**Information about the Attribute**
Applicability	To what sectors and end-uses can the DSM measure be applied? What is the size of the market for which the measure is applicable?
Fuel type	For fuel-switching measures, what fuel is used?
Reliability and lifetime	How has the measure performed in previous applications? What is its typical lifetime?
Efficiency	How much energy and power does the measure save, relative to standard equipment?
Capital and operating costs	What does it cost to own, operate, and maintain the technology?
Environmental impacts	What are the impacts of the technology, relative to standard equipment?
Foreign exchange requirements and local input	What fraction of the materials and technology for the DSM measure can be provided locally?

Data on the cost and performance characteristics of DSM options are available from a variety of groups, generic and specific databases of technologies, equipment and appliance vendors, and other utilities. Information sources include most of the multilateral agencies, government institutions in many countries, private groups, and non-governmental organizations including E-Source (Boulder, CO, USA) the International Institute for Energy Conservation (IIEC), and many others. The US trade journal *Energy User News* is a good source for information about DSM measures and technologies. The U.S. California Energy Commission has published compendia on end-use DSM options. The "Technology & Environment Data Base" cited in the previous chapter has data on demand-side as well as supply-side options (www.leap2000.org).

Another source of ideas and information is utility system customers themselves. Commercial and industrial consumers in particular are likely to be aware of DSM options that fit their needs. Representatives of these groups can be consulted when preparing a list of DSM options.

Preliminary Assessment of DSM Options

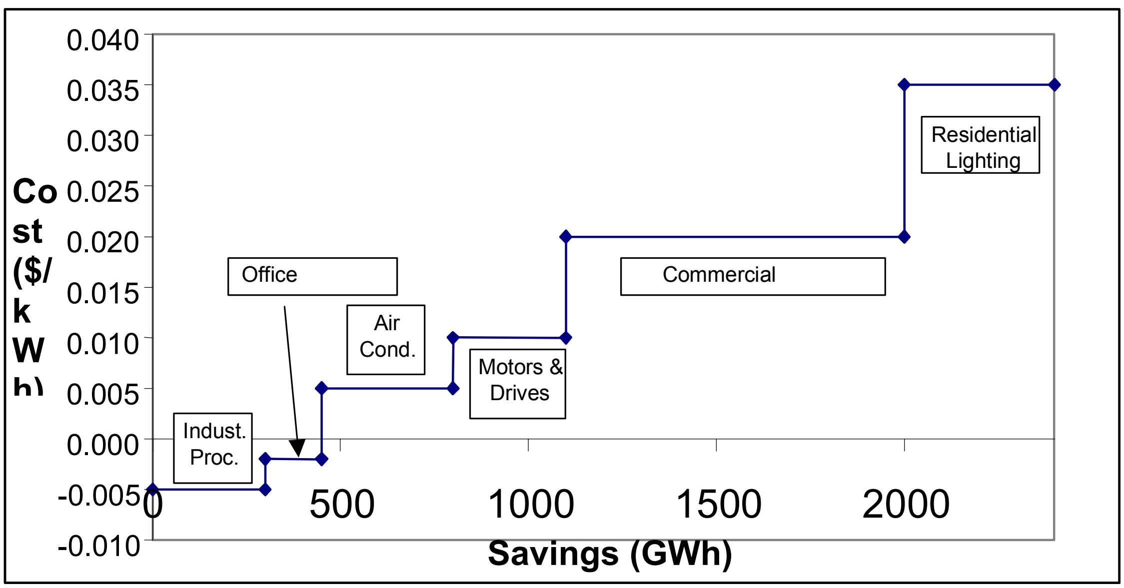
Once information on the key characteristics of DSM options has been assembled, the list of options is narrowed to those to be included in candidate DSM plans. As with the preliminary assessment of supply options as was discussed earlier, narrowing the list of DSM options involves applying quantitative and qualitative screening criteria (see the Box on the right).

> **DSM Measure Assessment — Typical Outputs**
> - Life-cycle cost of energy-efficiency measure, vs. standard alternative
> - Benefit/Cost (B/C) ratio expressing cost-effectiveness of measure: Measures with B/C ratio much greater than 1:1 likely to be cost-effective, less than 1:1 not cost-effective, near 1:1 questionable
> - Cost per unit energy saved (expressed as net capital/O&M costs per unit electricity saved)
> - Cost per unit carbon emissions avoided
> - Qualitative assessment of customer acceptance

One measure often used in preliminary screening is the overall lifetime cost of a DSM measure per unit of energy saved (for example, in cents per kWh of electricity saved), which is then compared to the overall cost to generate and deliver the electricity that would otherwise be required. This measure, the cost of saved energy or "CSE," is defined in the "Commonly Used Formulae" section at the end of this Guide, following the Glossary. (A cost of saved capacity measure can be developed by applying DSM measure costs to capacity savings rather than energy savings.)

Information about the cost of saved energy from specific DSM measures can be combined with estimates of the amount of total energy that could be saved by implementing each measure to construct a cost of saved energy curve.

Cost of Saved Energy Curve



The example shows how much electricity might be saved beginning with the lowest-cost measure — improved energy-efficiency in industrial processes, which has a negative cost because the efficiency measures actually cost less to install and operate than standard measures. The measures — efficient office machines, efficient air conditioning, efficient electric motors and drives, efficient non-residential lighting, and efficient residential lighting — are arranged in order of increasing cost. If the objective is to minimize the total cost of energy services, one would plan to implement DSM measures until their cost of saved energy reached the cost of supplying and delivering electricity. (The values shown are illustrative example figures only.)

Chapter 6

Preparation and Assessment of Supply Plans and DSM Plans

Once data on the possible supply-side and DSM options have been assembled, and a list of the most attractive options in each category has been decided upon, the next step in the planning cycle is to compile the options into candidate supply and DSM plans that help to meet forecasted electricity demand.

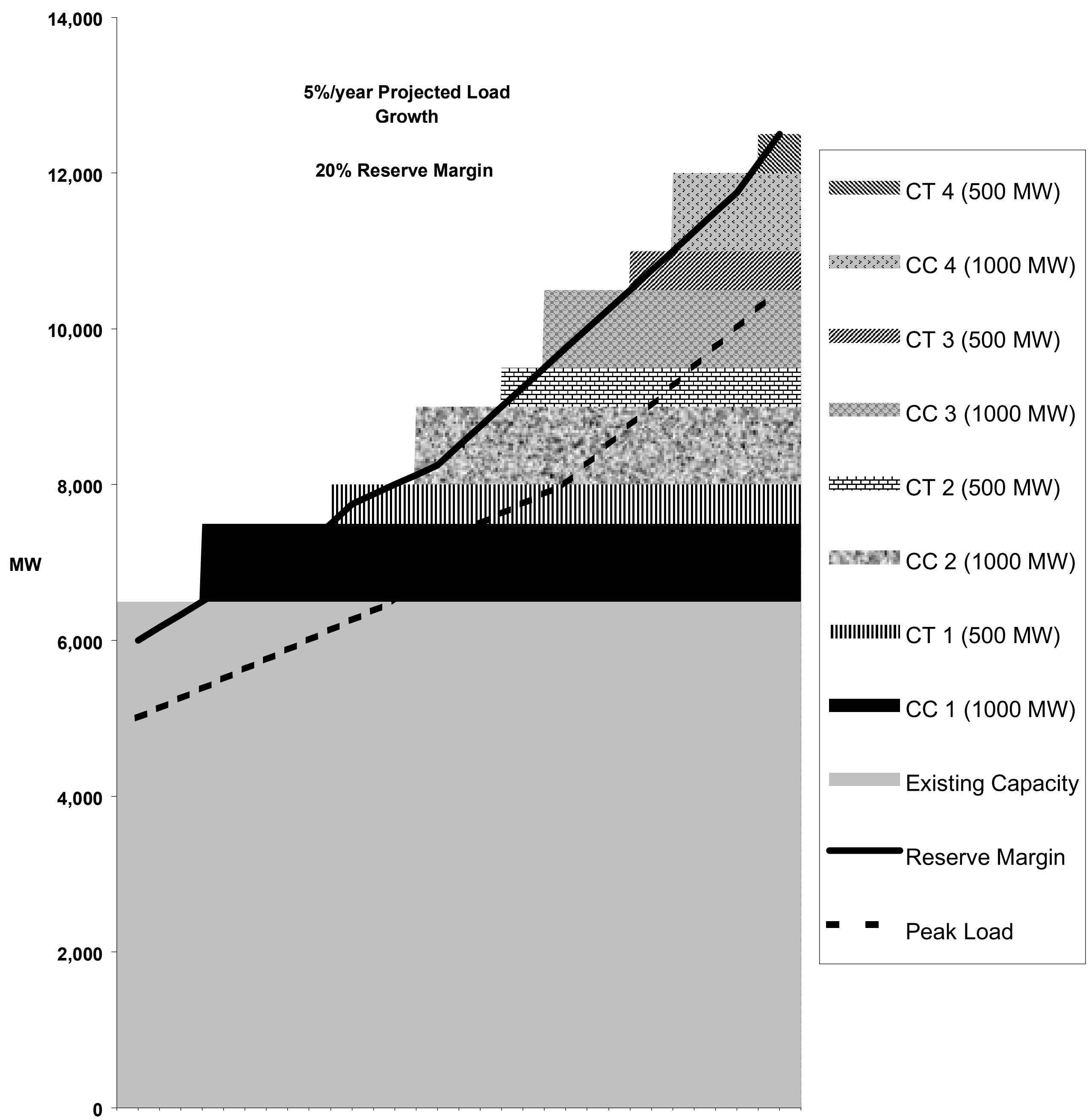
Supply Plans

A *supply plan* is one that meets the electricity needs indicated in the demand forecast in a practical manner using supply-side resources. Many different candidate supply plans can be assembled from a list of candidate supply resources. Reducing the list of supply plans to a manageable few is an exercise in judgement, although there are software tools available to assist in the process. Some of the elements that must be considered in preparing and evaluating supply plans are:

- Location of power plant or other supply resources: What sites are suitable for hosting power plants? Access to fuels or resources, access to transmission facilities, population density, and political and environmental considerations all play a role in determining where facilities can be sited. This issue is especially critical for medium and large hydroelectric facilities.
- Timing relative to need: When will electricity supply resources be needed? For power plants that require a long “lead time” to construct, planning must start well in advance of when power will be needed. This is a critical issue for large baseload power plants, as well as, again, large hydroelectric facilities.
- Costs and financing: How much money will be needed? How do financing needs compare with the availability of capital? Are the facilities included in a plan suitable for private, as well as public, financing?
- System integrity and reliability: A supply plan should meet forecasted peak power demand with sufficient capacity to spare for emergencies.

A simplified preliminary supply plan for an imaginary electric utility is contained in the following figure. It consists of existing resources, and new resources added to meet load. The new resources are a mix of combustion turbines (CTs) and combined cycle units (CCs). CTs are usually the least-cost choice for meeting peak demand (and providing a reserve margin). Modern CTs are often the economical choice for serving up to about the 2000 highest demand hours a year. CCs are often the economical choice for serving loads

Wattco Load Growth and Expansion Plan, 2000-2015



CT = Combustion Turbine

CC = Combined Cycle Unit

Total New Capacity = 6000 MW

from 2000 hours/year and up. The figure is simplified to show how new resources may be planned to meet forecasted demand. In an actual system, some existing resources may be retired, other resources than CTs and CCs may be planned, and the size of the capacity additions will vary from the largish generic capacity additions shown. In developing candidate supply plans, many alternative resource configurations are prepared and assessed.

Assessing Supply Plans

Each candidate plan must be assessed using such criteria as cost (capital cost, total cost, and rate of return on investment), technical reliability (often measured as “loss-of-load probability” or “reserve margin”), environmental impacts (air pollutants, solid waste created, land area lost), and other quantitative and qualitative criteria. Standard evaluation approaches and software tools are available to aid in the evaluation of candidate plans. Systems planning software tools are used to determine whether the grid configuration included in a supply plan will be adequate to meet energy and power demand, and to simulate the way that the power plants in a supply system are dispatched.

Dispatching is the process by which utility personnel decide which power plants will be used to provide energy to an electric grid at which times. The “SUPER” power system generation and interconnection planning model, developed by the Latin American Energy Organization and the Inter-American Development Bank, is an example of a tool that can aid in modelling system dispatching. Other software tools allow users to mathematically evaluate the costs and other attributes of many different alternative supply plans, or to optimise supply plans based on specific objectives.

DSM Plans

Once DSM measures have been screened roughly to identify the most attractive options, candidate measures are bundled into prototypical DSM programs that could be implemented to secure the reliability, cost, environmental, and other benefits of the DSM technologies. The delivery of DSM programs in the marketplace will be the means by which utility systems can “procure” DSM resources or attempt to transform end-use energy markets in ways that lead to ongoing end-use efficiency improvements. The delivery of programs requires administration, advertising and marketing, and monitoring and evaluation of results, the anticipated costs for which must be included in screening candidate programs.

Prototypical DSM programs (and, ultimately, those actually delivered) combine one or more DSM measures with a set of services or inducements to encourage energy users to adopt the program measures. Programs may include information, technical assistance, certification of vendors, financing, or other services. Program inducements may be include rate designs, incentives and rebates to consumers or suppliers, subsidized financing, or other incentives.

DSM programs may be organized around a specific set of technologies, such as technologies for lighting. Alternatively, programs may offer a suite of products and services aimed at decreasing energy use (or reducing peak loads) among a segment of energy users such as household, commercial/institutional, agricultural, or industrial customers.

A utility system DSM *plan* is a set of one or more DSM *programs* to encourage the adoption of DSM measures, yielding electricity and/or cost savings to electricity consumers, the utility system, and society. A DSM plan describes the actions that a utility system or other program administrator will take over some period of years.

Assembling candidate DSM plans from candidate DSM programs (and assembling programs from candidate measures) involves weighing a number of considerations. Some of these are similar to the criteria for evaluating supply plans, but some are unique to DSM.

- Technology availability: Are the technologies to be promoted commercially available in the country? If not, what would need to be done to increase their availability?
- Program effectiveness: Common technical measures of DSM program and plan effectiveness are the annual and cumulative energy savings, and annual peak power savings, that can be expected from implementing the programs.
- The timing and persistence of savings: How long will the savings achieved under the program last? When will savings be available, and how does the timing of savings correspond to the timing of electricity needs?
- Financing: Are sufficient funds available to finance the DSM programs at an appropriate level? Can financing be obtained from the same sources as financing for supply resources?
- Social and institutional issues: What are the impacts of candidate programs and plans on customers, the suppliers and installers of appliances and equipment, and others? Will particular DSM programs result in greater local employment than others?
- Environmental issues: What are the environmental impacts of alternative plans?

Assessing DSM Plans

Assessment criteria for DSM plans overlap those for supply plans, and include energy and peak power savings, costs, practicality and applicability, net environmental impacts, and other criteria as described above. The basic measure of the cost-effectiveness of a DSM program or plan is how its costs compare with those of the supply-side resources that it displaces. If its "total resource cost" exceeds the total resource cost of the supply-side resources displaced, a DSM measure is prospective cost-effective. In addition to this total resource cost ("TRC") perspective, DSM cost-effectiveness may be assessed from the subsidiary perspectives of the utility (the utility cost perspective) and those of participating and non-participating customers. (For more on DSM cost-effectiveness assessment, see the *Standard Practice Manual* cited in the "Resources for Further Information" section at the end of this Guide.)

The most accurate way to calculate the "avoided cost" of the energy saved via a DSM plan is to compare the costs of energy from integrated resource plans that 1) include, and 2) exclude the DSM programs to be evaluated. In practice, estimates of avoided costs are often based on the costs of a supply-side plan, and streams of avoided energy and capacity costs by year are used to evaluate the benefits of DSM savings (Rosen, 1995).

There exists a variety of software tools that can be used to evaluate DSM plans, including spreadsheet software and programs written especially for the purpose. Examples of software written specifically for the evaluation of DSM programs and plans include COMPASS™, developed by Synergic Resources Corp., and ECO™, developed by Tellus Institute. Similar tools are available from other sources as well.

Assumptions as to how markets will react to DSM offerings must be made. The experience of earlier DSM programs and initiatives can provide guidance as to the market impacts to expect from particular programs. Until the utility system or other program administrator gains first-hand experience with DSM, informed judgement must be used to establish the initial estimates of program impacts to use in developing the IRP.

Chapter 7

Alternative Integrated Resource Plans: Construction and Assessment

The culminating steps in IRP assemble candidate supply- and demand-side plans into a set of candidate integrated resource plans, evaluate these IRPs, and select a preferred IRP for the coming years. Candidate IRPs combine plans for supply- and demand-side resources into a *resource portfolio* that meets forecasted electricity requirements. There are two strategies for constructing candidate IRPs from supply-side and DSM plans.

- IRPs can be constructed “by hand,” incorporating the energy and peak power savings from a DSM plan into a supply-side plan, then reducing the amount (or delaying the dates of plant construction) of generating capacity added in the supply-side plan so that the electricity supply meets forecasted demand less DSM savings.

- Alternatively, software tools are available that can generate and evaluate many different supply/demand combinations. One example of this type of software is the PROVIEW II™ system developed by Resource Management Associates.

With either strategy, candidate IRPs must be reviewed carefully to ensure that the candidate plans are fully practical. Deciding among the candidate IRPs is then a matter of setting the evaluation criteria to be applied, evaluating and ranking the candidate plans according to the criteria, and then using the results of the evaluation to decide on one or more “preferred” or “optimal” plans to adopt for implementation (or further study).

Assessment Criteria

The criteria used for assessing candidate IRPs will typically include many of the same criteria that were used in evaluating supply- and demand-side plans, and should overlap substantially with the list of basic objectives generated by stakeholders at the beginning of the planning process. Though it is necessary to include objective measures of plan performance — those that can easily be quantified — it is equally important to consider subjective criteria. The table below presents both objective and subjective criteria that can be used to rate candidate IRPs.

Assessment and Selection

Selecting a preferred integrated resource plan (or a few top options) from a wide range of choices is a complex process, and should be decided systematically if the result of the planning process is to be credible. There are several methods, with many variations, for deciding which plan or plans is or are most desirable. These range from simply listing each attribute of each plan in a large matrix (for example, on a board in a conference room) and methodically eliminating candidate plans (noting why each is eliminated), to quantitative approaches involving "Multi Criteria Analysis" or "Multiple Attribute Analysis."

Whatever tool or technique is used to aid in deciding among plans, it is ultimately the people involved in the planning process who will decide which plan is to be adopted and implemented. The initial ground rules for the planning process as a whole will have identified the locus of ultimate responsibility for arriving at a decision on the preferred IRP. One of the critical process principles of IRP is to conduct the decision process in a transparent, clear, and complete manner, so that others may review the decisions made along the way.

"Preferred" and "Contingency" IRPs

The planning process usually aims to select a single preferred integrated resource plan to guide utility system activities in the coming years. Though long-term planning is a hallmark of IRP, the plans themselves function as *guides for shorter-term decisions*. A description of the preferred plan is typically accompanied by an implementation schedule that details when and how key plan activities — such as building a power plant, or starting a DSM program — will be undertaken.

Alternative IRPs identified in the planning process may become more attractive if expected conditions change. The IRP itself may include "contingency" plans for use if electricity demand grows faster or slower than expected, fuel prices trend differently from what was assumed, national environmental laws (or global agreements) create restrictions on certain resources, or technological changes offer new opportunities.

IRPs are a mix of supply-side and demand-side resources. While the supply-side resources generally dominate, DSM resources can significantly reduce required supply-side additions over a planning period. This is illustrated in the simplified supply plan for an imaginary electric utility is contained in the figure following the table of criteria. The figure represents the simplified supply-only plan that was presented in chapter 6, modified to incorporate the effects of a suite of DSM programs. The amount of new generating capacity that is required is reduced 25%, from 6000 MW to 4500 MW, due to the reduction in forecasted load. The load reduction results from summing the impacts of the DSM programs in the plan, though the mix of programs is not shown in the figure.

Sample Criteria for Assessment of Integrated Resource Plans

Financial Criteria

- Overall plan cost (including capital, fuel, and other costs, usually expressed in "present value" terms)
- Plan capital cost
- Plan fuel costs
- Plan foreign exchange cost
- Interest coverage ratio
- Return on equity
- Utility net income
- Internal generation of funds

Performance Criteria

- Customers served
- Loss of load probability
- Reserve margin
- Efficiency of energy use (on supply- and/or demand-side)

"Energy Security" Criteria

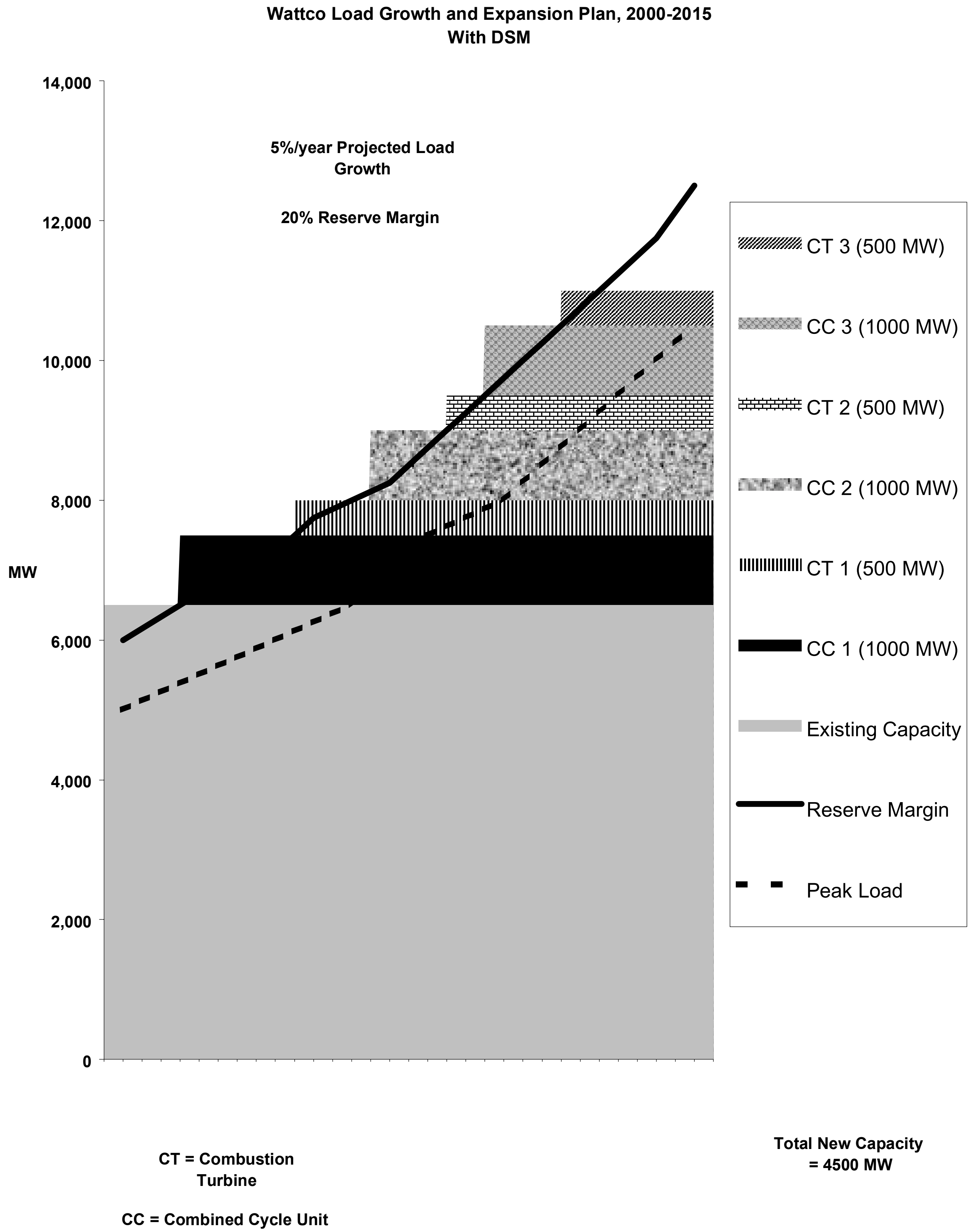
- Diversity of supply (fraction of each fuel used)
- Use of domestic resources
- Use of renewable resources

Environmental Criteria

- Amount of carbon dioxide produced over the life of the plan
- Amounts of other air pollutants (acid gases, particulate matter, hydrocarbons) produced over the life of the plan
- Amount of land used for energy facilities
- Liquid waste production
- Solid waste production (accounting for differences between hazardous and non-hazardous wastes)
- Plan impact on wildlife, biodiversity

Other Criteria

- Aesthetic issues (impact of plan on recreation, tourism)
- Employment impacts of plan
- Impacts of plan on other economic sectors (both positive and negative impacts)
- Political acceptability/feasibility of plan
- Social implications of plan (including impacts on local and indigenous populations)
- Cultural impacts of plans (impacts on culturally important resources)



Wattco Load Growth and Expansion Plan, 2000-2015
With DSM
5%/year Projected Load Growth
20% Reserve Margin
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
MW
CT 3 (500 MW)
CC 3 (1000 MW)
CT 2 (500 MW)
CC 2 (1000 MW)
CT 1 (500 MW)
CC 1 (1000 MW)
Existing Capacity
Reserve Margin
Peak Load
CT = Combustion Turbine
CC = Combined Cycle Unit
Total New Capacity = 4500 MW

The Resource Plan Report

When a final integrated resource plan has been completed, it is usually described in a fair amount of detail in a report. An outline for an IRP report is contained in the box below. Technical appendices may include supporting studies that were done to develop particular kinds of data inputs needed for the IRP, as well as detailed input assumptions and model outputs.

IRP Report — Typical Contents

Introduction
Goals and objectives of the planning process; responsibilities of the entity organizing the process; participants in the process.

Summary
Components of preferred resource plan; its costs and impacts; near-term implementation actions to be taken.

Electricity Requirements
Historic usage patterns; methods used to forecast future electricity requirements; key exogenous assumptions; forecasts of energy requirements and demand by usage group (household, commercial, industrial, irrigation, others); forecast scenarios for resource planning.

Supply-side Resources
Existing electricity supply and T&D system; characteristics of feasible supply additions; assessment and screening of options; candidate plans to meet demand forecast scenarios.

Demand-side Resources
Identification of DSM measures by usage group; use of avoided costs to screen options; development of candidate DSM programs and plans.

External Costs and Benefits
Identification of environmental and other externalities to be considered; methods for measuring external impacts of alternative options (physical impacts and, where used, monetized impacts).

Development of Candidate Plans
Approach used to integrate supply and demand options; range of candidate plans considered; criteria used to select short list of candidate plans with different mixes of supply and demand options; sensitivity analysis of results of major plans under alternative assumptions.

Selection of Preferred Plan
Differences among key plans: generation options; T&D upgrades; costs of plans; financial feasibility; environmental impacts (air, water, land); socio-economic impacts; other differences; criteria and process used to select preferred plan.

Preferred and Contingency Plans
Preferred plan (DSM elements; supply elements; detailed costs, benefits, and other impacts; adaptability and resilience of plan in face of risks); contingency plans.

Implementation and Monitoring
Near-term action plan; DSM plan; procedures for interim and full updates to the selected IRP.

Appendices
Supporting studies and data

Chapter 8

Implementation, Evaluation, Monitoring, and Iteration

The adoption of an IRP is a decisional milestone in the planning process, but not its end. Implementation of the IRP still lies ahead. The IRP serves as a benchmark against which actual utility system performance is measured. More profoundly, the IRP should be a living document, to be revised as conditions change and as new information becomes available.

During implementation of the last adopted IRP, ongoing evaluation of the effectiveness of the resource plan is useful. Implementation of the supply-side components of an IRP involves execution of contracts for the purchase of power or the construction of utility-owned facilities. Often competitive requests for proposals are used to implement the several supply-side elements of an IRP. During the process of soliciting and evaluating bids to provide supply-side resources, the utility may gain information about the cost and availability of options in the preferred plan varies significantly from the assumptions in the preferred plan. This may require revisiting and revising the plan.

Once resources added pursuant to a procurement process are in service, their performance may be better or worse than had been expected. Monitoring the performance of the electric system, and in particular the new elements added in implementing a resource plan, provides critical information for the next iteration of the resource planning process. In the case of performance at lower levels than expected, if a common type of power plant or other plant is involved, performance in a specific utility system can be compared with data on performance in other jurisdictions to help determine whether the problem is localized or is common to the technology.

In the case of DSM programs and plans, the utility or other program administrator typically will monitor the number and types of customers participating in programs, the electric energy and peak savings experienced, and the costs of implementing the programs. Monitoring data facilitate subsequent evaluation of the effectiveness of the DSM programs, and the comparison of program impacts with original estimates. DSM Program evaluation assesses the impacts of programs on energy consumption, the process by which they being delivered, and their effectiveness in causing market development.

"Process" evaluation aims to assess the implementation of programs. This includes management, marketing, field delivery of programs, quality control procedures, and the response of target groups, such as customers and dealers, to the program. Process evaluations provide critical feedback as to both tactical issues of program delivery and strategic issues of program design. They inform program sponsors, managers, and stakeholder parties both about mid-stream corrections that may be feasible and desirable, and about how to build on the lessons of the program in promoting replication.

Process evaluations employ several methods. These include in-depth surveys with program managers, site visits, survey techniques, focus groups, and documents review. Process evaluations must be thoroughly coordinated with impact evaluations. Though their methods are mostly distinct, there are some cases in which survey instruments are administered to participants and non-participants to serve both impact and process evaluation needs.

Assessing the performance of DSM programs is relatively more difficult than evaluation of the performance of supply-side resources and programs. One cannot directly observe the impact from DSM in the way that one can measure the production and costs of production from a supply resource. Rather, one must infer results through "impact" evaluation activities.

A variety of impact evaluation methods have been developed, applied, and refined. The major methods used in impact evaluation are indicated in the table. Several of these have been gathered together into an International Performance Measurement & Verification Protocol ("IPMVP") in which several countries participate. (See the "Resources" section at the end of this Guide for information on how to obtain the IPMVP.)

Major DSM Impact Evaluation Methods

Approach	**Characteristics of Approach**
Site inspection	Inspection of a larger facilities or a sample of smaller ones to verify installation of DSM measures. Does not directly measure energy consumption. Does not address "free rider" issue.
End use metering	Measures specific circuits in larger facilities or a sample of smaller ones to quantify energy consumption. Does not measure energy savings measurement applies to period before and after installation of DSM measures. Does not address "free rider issue."
Analysis of billed consumption	If billed consumption data are available, statistical analysis of consumption before and after DSM measure installation can estimate impact from DSM. If a comparison group of "non-participants" is included, can begin to address "free rider" issue and estimate net impact of DSM.
Surveys of customers	Surveys of customers, both "participants" and non-participants, can be used to strengthen conclusions drawn from any of above approaches.
Market transformation	Examines broader market trends such as the mix of equipment sold and installed in order to infer the sustainability of DSM impacts after specific DSM programs have been concluded.

Since planning is a continuous process, the development of IRPs is repeated periodically. Major planning cycles may vary from two to five years. Interim updates may be scheduled, or mid-course corrections may made as necessary to respond to changing conditions. Flexibility is important. When a development occurs that was not adequately foreseen or considered, it is important to revisit the plan, rather than rigidly abiding by it, or, in the alternative, bypassing it.

When done properly, IRP provides a structure and an opportunity for utility systems and stakeholders to learn and to develop plans in a co-operative atmosphere. Although the IRP ultimately adopted is considered the blueprint for utility activities, conditions do change. Changes in an IRP over time are inevitable, necessary, and desirable, when made in a transparent and well-documented fashion.

Resources for Further Information

Organization	Resources	Notes
Regional Economic Research, Inc. (RER) 20 Park Plaza, Suite 440 Boston, Massachusetts 01116, USA Tel. +617-423-7660 www.rer.com	Demand forecasting	Forecasting tools include REEPS, COMMEND, and INFORM end-use models
Electric Power Research Institute (EPRI) Palo Alto, CA, USA Tel. +650-855-2300 (publications); +858-259-3442 (software) www.epri.com	Demand-side and supply-side technologies; planning models	Technology Assessment Guides (TAGs) for technologies. Software tools include DSMANAGER, a DSM screening model
Stockholm Environment Institute-Boston, 11 Arlington St., Boston, MA 02116, USA. Tel. 617-266-8090 www.seib.org	Demand-supply planning; technologies and their emissions coefficients	LEAP planning model. Technology and Environment Data Base.
Centre for the Analysis and Dissemination of Demonstrated Energy Technologies PO Box 17 6130 AA SITARD The Netherlands Tel. +31-46-4202224 www.caddet-ee.org	Demand-side and renewable energy technologies	Known as "CADDET"
Energy Efficiency and Renewable Energy Network U.S. Department of Energy P.O. Box 3048 Merrifield, VA 22116, USA Tel. +703-363-3732 www.eren.doe	Demand-side and renewable energy technologies	Known as EREN
International Institute for Energy Conservation 750 First Street, NE, Suite 940 Washington, DC 20002, USA Tel. +202-842-3388 www.iiec.org	Demand-side technology information	Known as IIEC
International Energy Agency 9, rue de la Fédération 75739 Paris Cedex 15 France Tel: +33-1 40 57 65 54 Www.iea.org	Supply-side technologies; energy statistics & studies	*Projected Costs of Generating Electricity*, prepared by the Nuclear Energy Agency and the International Energy Agency (Update 1998)

Environmental Defense Fund 5655 College Ave, Suite 304 Rockridge Market Hall Oakland, CA 94618 USA Tel. +510-658-8008 www.edf.org/elfin	Electric utility resource planning and financial analysis software	"Elfin" model
Argonne National Laboratory 9700 South Cass Avenue, DIS-900 Argonne, IL 60439, USA Tel. +630-252-4962; +630-252-7173 www.anl.gov	Supply planning software	"ENPEP" electric resource planning model, which includes "WASP" optimization model; "GTMax" utility optimization model
Oak Ridge National Laboratory P. O. Box 2008, MS 6070 Oak Ridge, TN 37831-6070 Tel. +423-576-1768 www.ornl.gov	Supply planning software	Known as ORNL
UNEP Collaborating Centre on Energy and Environment Risoe National Laboratory, Bldg. 142 Frederiksborgvej 399 P.O. Box 49 DK 4000 Roskilde Denmark tel: +45 46 32 22 88 www.uccee.org	Textbook on IRP	*Tools and Methods for Integrated Resource Planning*, prepared for UNEP, 1998.
Tellus Institute 11 Arlington Street, Boston, MA 02116, USA Tel. +617-266-5400 www.tellus.org	DSM screening software	"ECO" model

Additional Resources

Supply-side Technologies

Developing Countries & Global Climate Change: Electric Power Options for Growth, 1999, prepared for the Pew Center on Global Climate Change.

International Energy Outlook 1999, from the U.S. Department of Energy's Energy Information Administration.

Incorporating Environmental Impacts

Lazarus, M., D.F. Von Hippel et al. 1995. *A Guide to Environmental Analysis for Energy Planners*. Stockholm Environment Institute—Boston, MA, USA. www.tellus.org

Developing Avoided Costs

Rosen, Richard. 1995. Costing Energy Resource Options: An Avoided Cost Handbook For Electric Utilities. Tellus Institute, Boston, MA, USA. www.tellus.org

DSM Cost-Effectiveness Perspectives

Standard Practice Manual: Economic Analysis of Demand-Side Management Programs. 1987. California Public Utilities Commission and California Energy Commission, USA.

DSM Impact Evaluation

International Performance Measurement and Verification Protocol. US Department of Energy, Washington, DC, USA. Report DOE/EE-0157. Downloadable at www.ipmvp.org

All website addresses are preceded by http://

Glossary of IRP Related Terms

Achievable potential. The fraction of economic potential that could be achieved through cost-effective DSM programs over the planning period. See also market potential.

Administrative costs. With regard to DSM, costs incurred by a utility or other program administrator for program planning, design, marketing, implementation, and evaluation. They exclude costs of purchases of equipment for specific programs, and rebates or other incentives.

Air conditioning. The process of treating air so as to control its temperature, humidity, cleanliness, while distributing it to cool building space.

Avoided cost. The total economic costs (consisting of the capital and operating costs to provide generation capacity and fuel, transmission, storage, distribution, and customer service) to serve end-use energy requirements using a given set of resources. These costs are referred to as "avoided" when an alternative set of resources is used to serve requirements. A better term for these costs would be "avoidable cost." Avoided cost must be determined to assess the cost-effectiveness of potential supply-side and demand-side resources. (See: differential total resource cost method.)

Base load. The minimum average electric load over a given period of time.

Base load unit/station. An electric generating facility designed for nearly continuous operation at or near full capacity to serve base load. Base load generating stations are operated to meet all, or part, of the minimum load demand of an electric system.

Baseline market characterization. The mix of end-use fuels and end-use technologies, including their associated costs, energy efficiencies and load factors expected to occur in each year of the planning period in the absence of expenditures on DSM programs.

Benefit-cost ratio. The ratio of the value of a DSM measure's energy savings to its installed cost. The energy savings value is based on the utility's avoided cost.

British Thermal Unit (Btu). A commonly used unit of energy, especially for fuels or heat. A kilowatthour is equal to approximately 3412 Btu.

Building envelope. The roof, floor, walls, doors, and windows that separate the inside of a building from the outside. Also known as building shell.

Capacity. The maximum quantity of electrical output for which a supply system or component is rated.

Capacity expansion plan. The schedule of power supply investments that is planned in order to meet forecasted future electricity demand.

Capacity factor. The ratio of the average output of an electric power generating unit for a period of time to the capacity rating of the unit during that period. A capacity factor of 50 percent means that, for example, a power plant produces on average half of the electricity that it could have produced if operated continuously at its full capacity rating.

Capacity rating. A measure of the electrical power that a piece of equipment can be expected to produce or use if used fully under normal (non-emergency) conditions.

Capacity value. The contribution of a supply resource to the maximum capacity of an electric system. Capacity value is a measure of the reliability and predictability of a resource.

Capital recovery rate. This is the rate of return paid on the debt plus the rate of return paid on the principal.

Combined cycle generating plant. A generating plant using one or more combustion turbines in combination with a steam cycle to produce energy at a higher overall efficiency than a combustion turbine alone. In one combined-cycle configuration, hot exhaust gases from the combustion turbine are used to raise steam. The steam is then passed through a turbine, which turns a generator. Combined-cycle plants are fueled with oil, natural gas, and sometimes coal that has been converted to a gas ("gasified").

Combustion turbine (CT). Sometimes called gas turbines, these devices burn oil or natural gas, converting the heat energy from the burning fuel to mechanical energy by directing the flow of combustion gasses against rows of radial blades fastened to a central shaft. The central shaft is connected to an electric generator.

Cogeneration. The sequential production of electricity and useful thermal energy from the same energy source. Natural gas is a favored fuel for combined-cycle cogeneration units, in which waste heat is converted to electricity. Also called combined heat and power (CHP).

Coincident demand. The rate of electricity demand of a customer or group of customers at the time of an electric system's total peak demand.

Coincident peak. Customer demand at the time of electric system peak demand.

Combined heat and power. See: cogeneration.

Commercial losses. See: non-technical losses.

Commercial sector. Non-residential facilities which provide services, including retail, wholesale, finance, insurance, and public administration.

Conservation. A reduction in energy use.

Constant dollars. See: real monetary values.

Cost-effective. The present value (PV) of the benefits of the potential resource under consideration over the planning period are greater than the PV of its costs. Cost-effectiveness is always measured relative to an alternative. Cost-effectiveness can be measured from a variety of perspectives, which vary in terms of the specific costs and benefits included in the calculation.

Cost of saved energy (CSE). This is an indicator of the cost of saving electricity through a given type of DSM measure. CSE is calculated by dividing the additional cost of the efficiency measure (relative to standard technologies) by the electric savings such and efficiency measure produces.

Customer. An individual or entity which purchases electric service as one account under one contract or rate schedule. If service is supplied to a customer at more than one location, each location is generally counted a separate customer, unless the locations are served under one billing account.

Customer charge. An amount paid periodically by a customer for electric service, exclusive of demand and/or energy consumption. It is often based upon utility costs incurred for metering, meter reading, billing of customers, etc.

Customer class. A group of customers with similar characteristics, such as economic activity or level of electricity use.

Demand. The rate at which electricity is delivered by a system or part of a system, or to a load point or set of loads. It is measured in kilowatts, kilovolt amperes or other suitable unit at a given instant or averaged over a designated period of time.

> **Average demand**: The demand on, or the power output of, an electric system or any of its parts over an interval of time, determined by dividing the number of kilowatt hours by the number of hours in the interval.
>
> **Billing demand**: The demand for which a customer is billed. Since billing demand is based on the provisions of a rate schedule or contract, it does not necessarily equal the actual measured demand of the billing period.
>
> **Coincident demand**: Two or more demands that occur during the same time interval. Often used to express the demand level of subgroups of customers that occurs at the time of the electric system's overall maximum peak demand.
>
> **Instantaneous peak demand**: The demand at the instant of greatest load, usually determined from the readings of indicating meters or graphic meters.
>
> **Integrated demand**: The summation of continuously varying instantaneous demands during a specified demand interval.

Maximum demand: The greatest demand which occurs during a specified period of time.

Non-coincident demand: The peak demands of subgroups of customers which do not coincide with system peak demand.

Demand charge. The portion of the charge for electric service that is based on billing demand under an applicable rate schedule.

Demand forecast. Projected demand for electric power. A load forecast may be short-term (e.g., 15 minutes) for system operation purposes, long-term (e.g., 5 to 20 years) for generation planning purposes, or for any range in between. Load forecasts may include peak demand (kW), energy (kWh), reactive power (kVAR), and/or load profile. Forecasts may be made of total system load, transmission load, substation/feeder load, individual customers' loads, or appliance loads.

Demand-side management (DSM). The implementation of one or more demand-side management programs.

DSM assessment and selection. Identifying and evaluating key customer or market considerations and utility considerations and completing a cost/benefit analysis of these.

DSM implementation. Pilot and full-scale implementation or execution of the DSM plans and programs.

DSM monitoring and evaluation (M&E). Measuring the outcomes of program implementation and providing feedback on results.

DSM objectives. Broad utility DSM objectives, including load shape objectives.

Demand-side measure. Any hardware, equipment, device, or practice, which is installed or instituted resulting in increased efficiency in the utilization of energy at a facility.

Demand-side resource. The energy service needs met through a DSM measure or program.

Differential total resource cost method. A method for computing avoided costs for a potential resource, whereby the year-by-year total resource costs for a least cost supply plan excluding the potential resource are subtracted from the year-by-year total resource costs of a least cost supply plan including the potential resource. This method ensures consistency with integrated resource planning as a whole when the TRC test is utilized.

Discount rate. A rate at which the value of money changes over time.

Dispatch order. The order of priority in which each electric generation unit is selected for operation during a given time interval.

Dispatching. The operating control of an integrated electric system to assign load to specific generating units as loads vary, to control operations of high-voltage lines and substations, and to operate the interconnections with other electric systems, including energy transactions.

Diversity. The diversity among customers' demands, which creates variations among the loads in distribution transformers, feeders, and substations at a given time. A load diversity is the difference between the sum of the maximum of two or more individual loads and the coincident or combined maximum load. It is usually measured in kilowatts.

Economic dispatch. A dispatch order based on realizing the most economical production of electricity for customers.

Economic potential. With regard to DSM, the total electricity savings (energy and demand) that would be realized if all DSM measures that are cost-effective from the TRC perspective were to be implemented.

Emission factor. The ratio of emissions to energy produced or fuel consumed, denominated in units of tons of emissions per unit of energy.

End-use. Useful work, such as light, heat, and cooling, which is produced by electricity or other forms of energy.

Energy audit. Analysis of a facility's electricity and other energy usage, often including recommendations to alter the customer's electric demand or reduce energy usage. An audit usually is based on a visit by an energy analyst or engineer to the home, building, or manufacturing or agricultural facility.

Energy charge. The charge for electric service based upon the amount of electric energy (kWh) consumed and billed under an applicable rate schedule. See also customer charge and demand charge.

Energy efficiency program. A DSM program aimed at reducing overall electricity consumption (kWh). Such savings are generally achieved by substituting technically more efficient equipment to produce the same level of end-use services with less electricity. Compare with conservation; contrast with load management.

Energy, electric. As commonly used in the electric utility industry, electric energy means kilowatt-hours.

> **Off-peak energy.** Electricity supplied during periods of relatively low system demand.
>
> **On-peak energy.** Electricity supplied during periods of relatively low system demand.

Surplus energy. Generated electricity that is beyond the needs of the service area of an electric system.

Energy-limited resource. A supply resource (e.g., hydro) of which the total annual energy output is limited, regardless of how much rated capacity is available.

Environmental impacts. Physical impacts on the environment (air, land and water) associated with the full fuel-cycle, i.e. development, extraction, processing, transportation, storage and combustion. If these impacts are measured relative to a specific point in the fuel-cycle, e.g. the point of combustion, they may be categorized as upstream or downstream, i.e. upstream of this reference point, or downstream of this reference point.

Evaluation. See DSM monitoring and evaluation.

Externality. A cost or benefit from production or consumption that is not accounted for in market prices. Costs and benefits which do not have market value, and thus current or projected prices, are externalities. For example, the costs of damage to human health from certain air pollutants are negative environmental externalities.

Fixed charge rate (levelized). (See capital recovery rate). The annual interest, depreciation, taxes and other costs of ownership of an item of property or capital equipment, expressed as a fraction of the capital cost of the item. For example, a fixed charge rate of 15%/yr means that the annual fixed charge on a power plant costing $1,000,000 would be $150,000, allowing the capital cost of the plant to be paid over a number of years, rather than all at once.

Fixed operating and maintenance (O&M) costs. Annual costs incurred for operating and maintaining a power plant regardless of the amount of energy it produces each year. These costs are often expressed in dollars per kW of capacity per year.

Free rider. A customer who would have implemented a DS measure even in the absence of a DSM program but who takes advantage of the monetary incentives offered by the DSM program. There are various degrees to which a customer may be a free rider.

Gigawatt (GW). One gigawatt equals 1 billion watts, 1 million kilowatts or 1 thousand megawatts.

Gigawatt hour (GWh). One gigawatt hour equals one billion watt hours.

Heat rate. Generating unit efficiency, usually expressed in BTU's of input energy required to produce a kWh of electrical output in a given power plant. See British thermal Units.

HVAC. An acronym for heating, ventilating, and air conditioning services required in buildings, or for the equipment used to provide HVAC services.

Hydro or hydroelectric power. A generating station or power or energy output in which the device generating the electricity is driven by water power.

Incremental cost. The difference in costs between two alternatives, for example, between that of an efficient technology or measure and the standard technology.

ISO. (1) The International Organization for Standardization. The ISO is a worldwide federation of national standards bodies from 130 countries. (2) Acronym for Independent System Operator of a transmission system that services multiple power suppliers.

Levelized cost. The uniform annual cost that results in the same net present value over the planning horizon as the stream of actual annual average costs. An example of a levelized cost is a monthly mortgage payment.

> **Nominal levelized cost.** The uniform cost of electricity, in mixed current dollars, for which the present value of the cost of electricity produced over the life of the plant is equal to the present value of the costs of the plant.
>
> **Real levelized cost.** The uniform cost of electricity, in constant dollars, for which the present value of the electricity produced equals the present value of the costs of the plant. See also the levelization formulae following this Glossary.

Line losses. KiloWatt-hours and kiloWatts lost in the transmission and distribution lines under specified conditions.

Load. The amount of electric power consumed at any specified point or points on a system. Load originates primarily in the power consuming equipment of the customers.

Load duration curve. A graph showing a utility's hourly demand, sorted by size, as well as by the amount of time a given level of demand is exceeded during the year.

Load factor. The ratio of the average load in kilowatts supplied during a given period to the peak or maximum load in kilowatts occurring during that period. Load factor may be calculated for a customer, customer class or the entire electric system.

Load forecast. See demand forecast.

Load management. The controlling, by rescheduling or direct curtailment, of the power demands of customers or groups of customers in order to reduce the total load that a utility must meet at times of peak demand. Load management strategies are designed to either reduce or shift demand from on-peak to off-peak, while conservation (see energy efficiency) strategies reduce usage over larger multi-hour periods. Load management may take the form of normal or emergency procedures. Utilities often encourage load management by offering customers a choice of service options with varying price incentives.

Load shape. The time-varying usage pattern of customer demand for energy.

Load shedding. The turning off of electrical loads to limit peak electrical demand.

Load Shifting. Shifting load from peak to off-peak periods. Applications include use of storage water heating, storage space heating, cool storage, and customer load shifts to take advantage of time-of-use or other special rates.

Loss of load probability (LOLP). A measure of the probability that system demand will exceed available capacity during a given period.

Lost Revenues. Utility income that is lost through reduced sales due to a DSM or energy-efficiency program.

Marginal cost of energy. The cost of providing an incremental unit of energy.

Marginal cost of capacity. The cost of meeting an incremental unit of peak-demand.

Marginal resource. The most expensive resource, in terms of short-run marginal (fuel and operating) cost, needed at a given time.

Market barriers. Forces in the marketplace of goods and services which inhibit customer selection based on economic criteria and restricted access to capital.

Market Potential. An estimate of energy savings that adjusts the economic potential of DSM to account for the likely acceptance by customers of DSM programs or other market interventions.

Megawatt (MW). One million Watts.

Megawatthour (MWh). A unit of electrical energy equal to one million Wh.

Monitoring and evaluation. The process of collecting and analyzing data and drawing conclusions about the performance of supply- and demand-side resources.

Net present value (NPV). The present value of the future cash flows of an investment less the investment's current and future costs.

Net revenue loss. The portion of revenue requirements, net of avoided costs, a utility does not recover from ratepayers between rate cases because of the change in customer consumption attributable to its DSM programs.

Nominal currency values. Dollar or other currency values given in nominal terms are taken at face value. Compare with: real currency values.

Non-technical losses. Commercial losses from theft of electricity through unauthorized connections, tampering with meter reading, metering errors, etc.

Participant. Units used by a utility to measure participation in its DSM programs. Such units of measurement include customers or households for residential programs and customers, square foot floor area, and/or kW-connected for commercial, industrial, and agricultural customers.

Participant costs. Costs associated with participation in a DSM program paid by the customer and not reimbursed by the utility.

Participant Test. A cost-benefit test that identifies the quantifiable benefits and costs to participants in a DSM program. If the result of the test, i.e., benefit cost ratio, is greater than 1.0 the program is, by definition, cost-effective under the test.

Participation rate. The ratio of the number of participants in a program to the number eligible for the program, with both the numerator and denominator defined in the same units.

Peak demand. The maximum rate of electricity consumption, expressed in GW. May be expressed for groups of electricity users or the whole system, and by season (summer or winter) or annually See: demand. Also called peak load.

Peak load. See: demand.

Peaking unit, or peaker. A generating station that is normally operated to provide power during maximum load periods.

Planning period. The time period over which the utility IRP analysis is performed.

Potential resources. Resources, either supply-side or demand-side, which are either currently commercially available, feasible or are expected to be commercially available within the planning period.

Preferred plan. The plan that will best enable a utility to provide reliable service at minimum reasonable total resource cost over the planning period, in light of considerations such as risk, rate impact and total societal costs. The preferred plan is based upon the IRP that minimizes total resource costs, with such modification as the utility and other stakeholders deem appropriate to address non-direct costs and other factors. The preferred plan specifies the mix of demand- and supply-side resources that will be implemented in order to satisfy these objectives.

Present value. The value of a cost or stream of yearly costs that have been discounted to reflect the fact that future benefits or expenditures are worth less than current benefits or expenditures. Also called Present Worth. See: discount rate.

Present Worth. See: present value.

Pumped storage hydroelectric plant. An electric generation facility consisting of a higher reservoir, a lower reservoir, pipes connecting the two reservoirs, and turbine-generator units that can be reversed to become pumps. At times when electricity demand is low, base load generating plants provide electricity to pump water from the lower reservoir to the higher. During peak demand periods, water is released from the higher reservoir, spins the turbine-generator units to generate electricity, and is expelled to the lower reservoir.

Ratepayer impact test. An analytic test that includes the costs and benefits from the perspective of a non-participating consumer. In effect, this test examines the price impacts of DSM programs.

Real monetary values. Expression of the value of dollars or other currency units over several years, using the value in one specified year as the baseline, and for other years removing the effects of price inflation relative to that baseline year. This facilitates analysis of the economic advantages and disadvantages of different alternatives which occur in different time periods.

Reserve margin. The difference between an electric system's maximum capacity and the expected peak demand. Planning reserve margins are based on explicit reliability criteria.

Revenue requirements. The amount of revenues that a utility needs to receive in order to cover operating expenses, pay debt service, and provide a fair return to common equity investors.

Saturation (of energy-using equipment). The ratio of the number of specific types of appliances or equipment to the total number of customers in that class or to the total number of appliances or equipment in use (e.g., the fraction of existing homes with double-pane windows).

Social discount rate. A discount rate that reflects the rate of time preference for evaluating investments from the perspective of society. In the US, for example, the rate for US Government Treasury bonds, for a time period equal to the IRP planning period, may be used to represent this discount rate.

Societal cost test. An analytic test that evaluates all of the costs and benefits to society associated with a specific resource. A resource option is cost-effective under this test when the present value of benefits over the planning period exceeds the present value of costs, using an appropriate social discount rate. This is essentially the TRC test with the maximum feasible monetization of externalities (positive and negative).

Strategic load growth. The increase of end-use consumption during certain periods. The result is a general increase in energy sales beyond the valley filling (defined herein) strategy. Strategic load growth may involve increased market share of loads that are, or can be, served by competing fuels, as well as economic growth.

Supply-side resource. A resource option that produces electricity.

Supply-only plan. The plan, using only supply-side resources, which a utility believes will best enable it to provide reliable service at minimum reasonable total resource costs over the planning period.

Technical potential. An estimate of electric savings assuming existing appliances, equipment, building-shell measures, and industrial processes will be replaced with the most efficient commercially available measures, regardless of economic cost or achievability.

Total resource cost (TRC) test. An analytic test which evaluates all of the direct costs and benefits to society associated with a specific resource. A resource option is cost-effective under this test when the present value of benefits over the planning period exceeds the present value of costs, using an appropriate social discount rate. This test does not assess the distribution of costs and benefits among the utility and subsets of customers.

Utility discount rate. A rate that reflects the utility's weighted cost of capital. Pre-tax or, more commonly, after tax.

Utility revenue requirements test. An analytic test that includes the costs and benefits from the perspective of a utility. The costs are the utility's costs of administering and delivering DSM (excluding participant contributions). The benefits are the utility's avoided supply costs. The test does not measure the financial impact of DSM on a utility corporation.

Valley filling. The building of off peak loads. An example valley filling technology is thermal storage (water heating and/or space heating or cooling) that increases night time loads and reduces peak period loads. Valley filling may be desired in periods when the long-run incremental cost of supply is less than the average price of electricity. (Adding off-peak load under those circumstances decreases the average price.)

Variable operating and maintenance (O&M) costs. The additional cost per kWh of electricity produced that goes toward operation and maintenance of the plant. These costs vary with the output of the plant, and are expressed in cents per kWh of electricity produced.

Watt (W). The electrical unit of power or rate of doing work. A lightbulb rated at 100 W requires 100 W of power to light it fully.

Watt-hour. The total amount of energy used in one hour by a device that requires one watt of power for continuous operation. Electric energy is commonly sold by the kilowatt-hour (1000 W).

Commonly Used Formulae

Concept	Formula[1]
Nominal discount rate, r_n	$r_n = (r_r)(1+f) + f$ Where: r_n = nominal discount rate r_r = real discount rate f = inflation rate
Capital recovery factor, *CFR*	$CRF = (r) / [1- (1+ r)^{-t}]$ Where: CRF = capital recovery factor r = discount rate t = equipment lifetime
Net present value, *NPV*	$NPV = (F) / (1+ r)^t$ Where: NPV = net present value in base year ($) r = discount rate t = planning period
Life cycle cost, *LCC*	$LCC = (Cc) + (A/CRF) – SV/(1+ r)^t$ Where: LCC = life cycle cost (present value $) Cc = capital cost ($) A = annual cost ($/yr) SV = salvage value ($) r = discount rate t = equipment lifetime
Nominal levelized cost, *NLC*	NLC = (LCC) (CRF) Where: NLC = nominal levelized cost ($/year) LCC = life cycle cost ($) CRF = capital recovery factor
Real levelized cost, *RLC (calculated using Excel's PMT function)*	$RLC = -PMT(r_r, t, NPV)$ Where: RLC = real levelized cost ($/year) PMT = Excel built-in function t = equipment lifetime NPV = Net present value of investment stream ($)
Cost of saved energy, *CSE*	CSE = (CRF) (Cc) (A)/D Where: CRF, Cc, and A are as defined above D = annual energy savings (if constant)

[1]Formulae are adapted from J. Swisher et al., *Tools and Methods for Integrated Resource Planning*, cited in the Resources section above.