RENEWABLE ENERGY

Special Report March 2007

RISK ASSESSMENT



Risk Assessment Methods for Power Utility Planning

Donald Hertzmark

ESMAP

Energy Sector Management Assistance Program

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In Memoriam: Shimon Awerbuch

One of the rewards of international development work is the opportunity to meet, often unexpectedly, top professionals and thinkers. The best of them can change the way we look at some part of the world. Shimon was such a professional. His zeal and verve to bring the best thinking in financial economics to bear on energy problems and his matchless ability to explain his ideas with rigor, clarity and humor marked Shimon as a unique contributors to our work.

We were shocked and saddened to learn of his sudden passing in an airline accident in late February, along with his companion and child. We would like to dedicate this volume to his memory, since he had so much to do with generating the ideas that percolate through these pages.

Donald Hertzmark, Tae Jung and Anil Cabraal. March 2007.

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Acronyms and Abbreviations

A&E	Architecture & Engineering
ANL	Argonne National Laboratory
CCGT	Combined Cycle Gas Turbine
CFE	Federal Electricity Commission (Comisión Federal Electricidad)
CRE	Comisión Reguladora de Energía
DMC	Developing Member Countries
DSM	Demand-Side Management
EMCAS	Center for Energy, Environmental and Economics System Analysis
ENPEP	Energy and Power Evaluation Program
ESMAP	Energy Sector Management Assistance Program
FIs	Financial Institutions
GE	General Electric
GEF	Global Environment Facility
HFO	Heavy Fuel Oil
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPP	Independent Power Producers
IRP	Integrated Resource Planning
LCP	Least Cost Planning
LOLP	Loss of Load Probability
MAPS	Multi-Area Production Simulation
MARS	Multi-Area Reliability Simulation
MB	Multiseller Multibuyer Market Structure
NERA	International Economic Consulting Firm
NY	New York
PJM	Regional Transmission Organization (Pennsylvania Utility Regulator)
PPA	Power Purchase Agreement
RE	Renewable Energy
RoR	Run of River
RPS	Renewable Portfolio Standards
SOE	State-owned Enterprise
TA	Technical Assistance
WASP	Wien Automatic System Planning Package

Foreword

More than 15 years ago, the World Bank reported in a series of papers that the planning environment for the Bank's client electric utilities was becoming increasingly difficult. The papers cited the increasingly unstable nature of world commodity markets combined with the unreliability of demand forecasts and uncertainty or even systematic bias that plagued cost estimates for new power plants and called for an approach to electricity system planning which could account explicitly for risk and uncertainty. Today, the situation for power system planners is even more fraught with uncertainties about prices and costs. The continued volatility of fuel prices has increased significantly the normal risks of projecting future investment economics. In addition, the structures of the power systems themselves, formerly stable as vertically integrated monopolies, now come in a variety of states of reorganization, privatization, unbundling and market orientation.

For some time, it was widely thought that the adoption of market transactions for electricity would sidestep the analytical issues raised in earlier investigations. As has become increasingly apparent, the various degrees of marketization have not resolved fundamental issues of risk assessment, with the increased attention to environmental protection and use of renewable resources in electricity generation adding new dimensions of risk to traditional investment assessments.

The introduction of new parties into the power market through Independent Power Producers (IPPs), power marketing companies and privatization of distribution in some countries has introduced new and more sophisticated financial concepts into electricity investment analysis. The overall thrust of the financial community is to systematize the assessment of risk, so as to plan for its mitigation.

In a sense, the current work is then a logical extension of earlier attempts to identify and mitigate risks, keeping in mind the new tools which are available today. With the traditional risks and newly identified risks in mind, the Energy Sector Management Assistance Program (ESMAP) put together an expert consultation workshop on June 27-28, 2006. The workshop brought together practitioners, analysts, regulators and software vendors to discuss the changes in both the external environment affecting the use of simulation models for investment planning and the advances in the art and science of such modeling over the past few years.

The analytical and empirical presentations from the workshop, discussed in this ESMAP report, indicate renewed interest in the overall subject of investment assessment, especially in regard with the integration of risk analysis. The conclusions from this workshop point towards greater use of more detailed and integrated approaches to modeling investments in unbundled and privatized power syste.

This workshop has pointed the way towards several concrete activities. These activities entail integration of different types of analytical models to capture the differentiated functions in modern utility system, assistance to borrowers in the construction of risk assessment and mitigation simulations and provision of training to member-countries in the new techniques.

Jamal Saghir
Director, Energy, Transport and Water
Chair, Energy and Mining Sector Board

Acknowledgments

This project was undertaken by the ESMAP unit under the overall management guidance of the Manager, Mr. Ede Ijjasz-Vasquez. The project manager was Mr. Tae Yong Jung (ESMAP) and coordination was provided by Mr. Anil Cabraal (ETWEN). This team played an essential role in providing structure and focus to the workshop and the subsequent ESMAP report. Oversight and coordination with World Bank initiatives in this area was overseen by Mr. Enrique Crousillat (LCSEG), who also gave useful comments on the selection of topics and on the earlier drafts of the ESMAP report.

Special thanks to Ms. Nyra Wallace-Crawford (ESMAP) for having provided excellent assistance with the organization of the Conference and also to Ms. Ananda Swaroop and Ms. Marjorie K. Araya for the editing and production of this report.

The draft was reviewed by ESMAP and World Bank specialists and I am grateful for their comments. Nevertheless, any remaining errors or misinterpretations remain the responsibility of the author.

1. Outline of this Report

This ESMAP report summarizes an expert consultation on electricity system investment planning and modeling held at World Bank in Washington D.C. on June 27-28, 2006. The workshop brought together practitioners, analysts, regulators and software vendors to discuss the changes in both the external environment affecting the use of simulation models for investment planning and the advances in the art and science of such modeling over the past few years. In addition to the focus on generation investment modeling, a key subject of interest at the workshop was the ability to identify, quantify and, where possible, mitigate risks in power systems investments.

The report is organized as follows:

- Introduction to the issues;
- Synopsis of the workshop and summary of discussions;
- Findings and recommendations;
- Annexes: World Bank/ESMAP Workshop on Electricity Investment Modeling and Risk Mitigation; and
- CD containing list of participants, papers and presentations delivered at the expert consultation.

2. Introduction

More than 15 years ago, the World Bank reported in a series of papers that the planning environment World Bank's client electric utilities was becoming increasingly difficult. The papers cited the increasingly unstable nature of world commodity markets combined with the unreliability of demand forecasts and uncertainty or even systematic bias which plagued cost estimates for new power plants and called for an approach to electricity system planning which could account explicitly for risk and uncertainty. Today, the situation for power system planners is even more fraught with uncertainties about prices and costs. The continued volatility of fuel prices has increased significantly the normal risks of projecting future investment economics. In addition, the structures of the power systems themselves, formerly stable as vertically integrated monopolies, now come in a variety of states of reorganization, privatization, unbundling and market orientation. As a final blow to the older certainties of power system investment planning, the increasing power of independent regulators, many of whom were created during the past 10 years, means that non-specialists are increasingly relied on to vet and to approve highly technical plans based on complex modeling activities.

In the current electricity market environment, virtually all of the key parameters on which generation expansion plans are based, are in play. The planning supply function, once normally the responsibility of a state-owned enterprise, has, in many instances, also fallen victim to changes in the structure of the electric power system. Some countries have devolved decision authority for generation planning to the point that no one is responsible for system expansion planning, now that the central planning function of the power company or of the government itself has shrunk. And in most countries, the reliance on IPPs for future expansion of generation capacity, reduces the proscriptive power of a single generation expansion plan. It is now better understood that regulated utilities in decentralized systems, regardless of the structure or ownership of the system, need more guidance on future investment opportunities. At the same time, the regulators in these countries are charged with the responsibility to ensure that investments in new capacity are "prudent" and that ratepayers and plant owners are not left with excessive payment liabilities for inappropriate investments. Thus, interest in planning has re-emerged as an issue in many of the World Bank's Developing Member Countries (DMC) utilities and regulators.

In an effort to discern some orderly investment procedures on an otherwise fluid reality, and to assure national authorities and regulators that the ratepayers and/or the taxpayers are making sound expenditures, utilities try to assess what the best generation plant investments might be for their systems. Historically, this has involved constructing simulation models of the relevant power generation system, extrapolating future demands, and calculating the most efficient path to meet that demand over a specified planning horizon.

An *efficient* investment path has been understood historically to mean a least-cost path, subject to certain performance constraints. Acceptance of this approach among planners has led to the development of optimization models which will calculate the generation mix and investment schedule that can meet projected demand at an acceptable Loss of Load Probability (LOLP).

The accepted way to accommodate the shifting investment cost, fuel price and plant performance parameters has been through the construction of scenarios. Each scenario, usually a high, low and medium, is presented with a description of the essential output elements – plant mix, generation cost, investment needs to meet the plan. Typically, the medium scenario has been constructed to represent the *most likely* set of outcomes.

It was quickly understood that a plethora of least-cost expansion models, while perhaps desirable from a scientific viewpoint, would complicate tremendously the work of those who must ultimately approve and fund the resulting expansion plans. Banks and regulators, in particular, need to be able to compare results from one country to another with some confidence that valid comparisons can be made. Developing country utilities cannot be expected to pay for "one-off" models, and such initiatives can strain training budgets, entrench a "model priesthood" and increase the costs of data-gathering and data input to the model. As a result, the World Bank and other international institutions have favored an approach to system expansion and investment simulation which makes use of internationally recognized tools which can be readily shifted from one situation to another, where people can be trained in a standard manner, and where the results are believed to be accurate, computationally efficient and reproducible.

The Wien Automatic System Planning Package (WASP), developed at the International Atomic Energy Agency (IAEA), has emerged as the most-used simulator program of its kind. WASP has been distributed to more than 75 countries and has become the standard approach to investment planning in World Bank's developing member-countries and is still used in other countries as well.

This expert consultation workshop is aimed at exploring the strengths and weaknesses of the standard, examining alternative approaches, and assessing the usefulness of different simulation models to a world of increasing uncertainty about costs and prices. Newer approaches, some from modern finance theory, challenge the validity of the types of results produced by WASP and its associated models. The workshop has provided a forum for a vigorous exchange of views on these matters.

What are the Issues which Need to be Addressed?

Planning investment strategies with least cost optimization models have generally involved answering the question: *What is the least expensive way to meet future demand while maintaining a LOLP no greater than some specific target?* Today, a host of additional issues and concerns have been added to the traditional formulation.

Experience with a variety of approaches to planning has conclusively demonstrated that the era of "one-size-fits-all" modeling is over and that the tools used for investment planning need to be tailored to the system, and for which the planners need to have tools which are consistent with the structure of that system:

- Is it an unbundled market or a planned vertically integrated enterprise?
- Is trading important in the system, and does trading use contracts or markets or both?

- Do the participants in the system understand the consequences of planning mistakes, and if so, who is responsible for mitigating the impacts of these mistakes?

The environment which surrounds investment planning today has changed dramatically and there are new participants and new goals in the planning process, even in countries with state-owned monopoly systems. These new participants and their goals include:

- Ministry of finance – which will wish to reduce the impact of power sector financing on the public budget;
- Private investors – who will seek to transfer as much risk as possible to the public sector;
- Regulators – who will seek to bring a broader and more independent perspective to the process; and
- Other parties – who will seek to promote environmental, technological and other interests in the power sector.

To support the changing technical nature of investment analysis and planning, increasingly complex information flows must become endogenous to the overall planning activity. Not only do the diverse points of view of an enlarged set of participants need to be accommodated, but these information flows present a challenge to both the planners and the users of planning output, since newer, more complex analytical models also tend to be less transparent to a lay audience.

Risk has increasingly become a central element in electricity system investment planning. This means that it must be dealt with systematically, comprehensively and appropriately, given the tools available.

- Risks must be identified and their relationships to other risks understood;
- Mitigation methods must be devised which are consistent with market structure, financial sophistication and system size; and
- Smaller power systems should be able to benefit from better tools through the development of either direct or proxy measures which permit explicit consideration of risk.

To address these four categories of issues and problems in electricity system investment modeling, the expert consultation workshop was divided into the following substantive sessions:

Current Approaches to Electricity System Investment Modeling: What Works and What Needs Fixing – subjects covered included an overview of current issues and problems in electricity generation investment modeling, as well as two presentations on the WASP model and other current modeling approaches.

Investment Decisions for Public and Regulated Generators – with presentations on public sector perspectives on investment planning, and the regulator's viewpoint on modeling techniques and results.

Alternative Formulations of the Investment Decision and Mitigating Measures – covering a critique of optimization approaches and an introduction to risk-return methodology for investment planning, and a companion presentation on risk mitigation methods in portfolio optimization.

Case Studies and the Way Forward – to give some flavor of how new approaches and methods might be put into use, there was a final session of case studies focusing on implementation of new modeling techniques in system planning in the US and a case study of the risk-return approach in Mexico for Renewable Energy (RE) project assessment.

3. Synopsis of the Expert Consultation Workshop

Current Approaches to Electricity System Investment Modeling – What Works and What Needs Fixing

The simulation and planning tools, commonly used in World Bank's DMCs, came of age in an era of vertical integration and state ownership of the electricity sector. With the political system exercising supervision over the power sector through a minister of energy or a similar senior official, there was no perceived need for further oversight and intervention, especially by an outside and independent regulator. Indeed, if any outside considerations regarding system expansion and investment were put into play, it was likely from either the World Bank and regional development banks or from equipment suppliers and Architecture & Engineering (A&E) firms. In this environment, the planning function for both generation and transmission was seen as a largely technical matter. Structural issues in the electricity sector were generally limited to whether to separate rural service from urban electricity supply and the necessity or wisdom of forming separate regional distribution companies. Generation and transmission were seen as indissoluble elements of the national economic planning apparatus.

The Single-company Approach – WASP and Related Models

The ideal of treating system planning as a technical matter was honored largely, in fact, and occasionally in the breach. In many countries, the planning process was constrained to yield specific results. In particular, after the oil price hikes of the 70s, many countries consciously adopted fuel diversification goals as a specific constraint on the results of the planning process.[1] Even when some oil use was probably least-cost (e.g., Heavy Fuel Oil (HFO) in some oil exporters during the 80s and most of the 90s) the power system planners would exclude such possible outcomes a priori.[2] As was observed during this session, legitimate constraints on technology and fuel choice often became confounded with efforts to "fiddle" the expansion plan, clearly not the intent of serious system planners.

System planning models became more useful as they migrated from mainframes and minis to desktop computers in the late 80s, allowing more interaction with planners and better fine-tuning of the assumptions and results. As a result of the focus on a single approach and a long-term effort to train local engineers in the use of the WASP

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[1] This conscious process contributed to the expansion of coal-fired generation around the world in the 1980s and 1990s when other fuel cycles might have proven competitive.

[2] In many oil-exporting countries, a surplus of HFO was exported at low prices due to a dearth of upgrading capacity in regional refineries in South-East Asia and the Eastern Mediterranean. In contrast, US refiners invested billions in upgrading capacity to use HFO as a feedstock, effectively eliminating the fuel from the power market on a price basis alone.

model, executives and planners became increasingly comfortable with the results of this process. In effect, WASP became the planning framework for scores of DMC utilities and its output was broadly respected as appropriately accurate and complete.

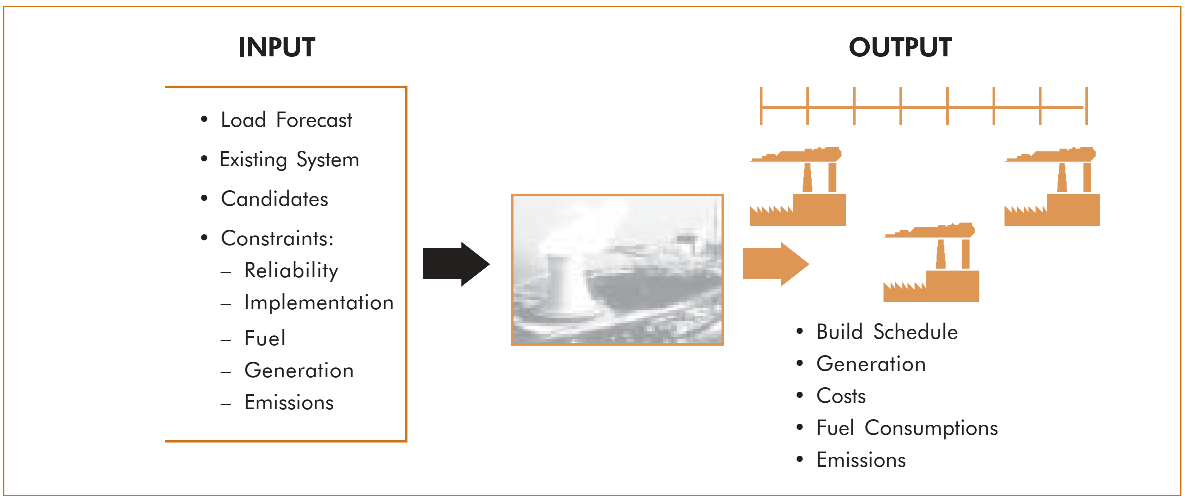
Traditional power system planning models, à la WASP, include limited stochastic information. This information deals mostly with the LOLP connected with the expected reserves and plant availability of a particular system configuration.

To obtain a probabilistic estimate of the LOLP connected with hydro plants, another model, Valoragua, must be used as well. The canonical problem for WASP takes the general form:

Min Σ (investment cost$_{jk}$ + operating cost$_{jk}$), subject to
Demand$_k \geq$ constraint
LOLP$_k \geq$ constraint
Fuel price$_k$ = price path
Technological parameters$_j$ = assumed or calculated values; where
j and k represent technology and time period.

This formulation, though somewhat stylized, addresses the major questions of cost, fuel choice, technology and system reliability. WASP identifies the least-cost expansion plan

Figure 3.1: Wien Automatic System Planning Package (WASP)



Box 3.1: The Evolution of WASP as a Planning and Simulation Tool

It has been well understood from the start that system planning models represent reality, but do not reproduce reality. Due to the abstraction from certain details in the power system, it is always easy to find problems with simulation models. In response to peer reviews and critiques of various planning approaches, the model architects and software developers have put together packages which respond to the demands of their marketplaces. In the 80s, WASP was modified so that it could run on desktop computers; in the 90s, emissions of major pollutants were added to the WASP output set (as Decades, and later WASP IV). In response to criticism about how hydro plants were handled in the WASP framework, Valoragua was added to the suite. And finally, as systems have restructured and the finer resolution of plant dispatch has come to the fore as a concern, WASP has been combined with dispatch and IPP-oriented models, such as GTMax, to improve the resolution of results and identify generation-transmission interactions and bottlenecks.

from the point of view of a single decision maker (one company).

Figure 3.1 shows the logical sequence of WASP data and output flows:[3]

A presentation early in the workshop by Argonne National Laboratory specialists on WASP and other system models, demonstrated the evolution in the capabilities of the WASP model and the ability to augment its output with modules which improve the ability of the model to project valid results for hydro plants (Valoragua), IPP and transmission (GTMax), and market Center for Energy, Environmental and Economics System Analysis (EMCAS).

In systems which still conform reasonably close to the one-company model, WASP can develop a least-cost expansion plan as a basis for planning and investment. Specific plant investments can be inserted or removed to assess the impact on overall generation cost and reliability. In partially restructured systems, especially those making heavy use of IPPs within a single-buyer type of model, WASP can provide a reference expansion plan against which future investments may be compared. Such an approach is still used in South Korea and Poland.

The Argonne presenters identified several categories of risks or resolutions which are not endogenous to WASP including:

- Fuel prices;[4]
- Plant dispatchability and load concurrence;
- Construction cost;[5]
- Environmental standards;
- Technology concerns;
- Diversification (or its absence);[6]
- Other operational factors; and
- Market risk – consisting of both supply-side and demand-side risks.

For each of these issues a separate scenario must be constructed in the context of WASP. The interaction of different risks (i.e., correlation) is not addressed by most scenario methods, although a skilled analyst should be able to construct reasonably integrated alternatives. However, even the most skilled scenarist might have difficulty answering an increasingly common question today: “How likely is that series of events you just described to us?” Probability of risks and interaction with investment planning is discussed in the next section. Suffice it to say, without systematic and quantitative risk identification and measurement, assigning probabilities to scenarios is difficult at best.

To remedy these perceived limitations while still using WASP as a reference scenario, it is possible to combine WASP output with the other models – Valoragua, GTMax and EMCAS. This approach allows some of the risks listed above to find explicit representation in the overall modeling framework. In particular, using this combination of models will help to explicitly account for plant dispatchability, transmission constraints, contracts for power delivery and diverse corporate goals. However, the approach will still require a scenario approach to grapple with risks posed by fuel prices, construction costs and demand uncertainties. Specific modeling of risks and devising mitigation

[3] A. Gritsevskyi, The Needs for International Comparable (sic) Energy and Environmental Statistics, International Atomic Energy Agency (IAEA), 2006.
[4] Ryan H. Wiser, Lawrence Berkeley National Laboratory, The Value of Renewable Energy as a Hedge Against Fuel Price Risk, 2004; and Mark Bollinger, Ryan Wiser, and William Golove, Accounting for Fuel Price Risk, LBNL-53587, Lawrence Berkeley Lab, 2003.
[5] See Merrow, Edward W. and Ralph F. Shangraw Jr, Understanding the Costs and Schedules of World Bank-supported Hydroelectric Projects, World Bank, Washington, 1990; and Bacon, Robert and John Besant-Jones, Estimating Construction Costs and Schedules, World Bank, Washington, 1996.
[6] Crousillat, Enrique, and Sprios Martzoukos, Decision Making Under Uncertainty: An Option Valuation Approach to Power Planning, Washington, 1991; and Shimon Awerbuch, The Role of Wind Generation in Enhancing Scotland’s Energy Diversity and Security, ECN, Netherlands, 2006.

measures against these risks will still be external to such models. The next subsection includes a discussion of incorporating risk explicitly into an optimization model environment.

Systematic Treatment of Risk Identification and Risk Mitigation – an Initial Approach

Identification, measurement and quantification of risk are essential elements in formulating a strategy to incorporate both the consideration of risk and suitable mitigating measures in an investment plan. Many energy companies use a P_5, P_{50} and P_{90} set of probabilities when assessing the attractiveness of a particular investment. By bracketing the potential returns, the company can compare the relative riskiness of different investment alternatives. However, to call for such risk-based assessments neither identifies the risk, nor its potential impact on an investment, nor a suitable mitigating strategy.

A first step in the assessment of the relative riskiness of various investment alternatives is an understanding of two key attributes of risk: impact (or importance) and controllability. The importance of a given risk element in system expansion varies with the impact of that element on the rate of return and the variability of that return. Fuel prices are very important risks in a thermal-dominated system, but far less so in one that relies more on nuclear, hydro or wind. Conversely, plant

Box 3.2: Fitting Reality into a Four-part Grid: How to Work with the Risk Matrix

One way to focus on analysis and assessment of investment risks in electric power systems, is to perform a type of analytical *triage*. In this formulation, issues or individual risks are categorized by (i) how important they are to the success of the project; and (ii) whether the party making the analysis has some degree of control over that risk. The most important elements of this exercise are the identification of the risks and the judgment about which ones are vital to the success of the project.

Risks which are important (they can make or break the project) and which are controllable (the investor can initiate activities on his own, which will mitigate or reduce a potential risk) are located in Quadrant I and are considered strategic risks. These should be tended to first, since they are controllable to some degree and not tending to them can be damaging to the overall project.

The next priority focus is on those risks which are important, but not easily controlled by the investor. Somehow, the investors must find ways to reduce the unknown impacts on the project. Typically, for important risks, this can involve some type of reformulation for the overall investment project so as to circumvent that risk, mitigate portions of the risk, or devise loss-mitigation instruments to insure against the impacts of that risk. Even if nothing is or can be done to mitigate the contingency risks, it is important to understand what these are so as to reduce the potential adverse impacts on the overall project.

Risks which are neither important nor controllable (Quadrant III) are best identified, so that time and energy is wasted on mitigation strategies.

Finally, Quadrant IV identifies risks which can be controlled, but with little overall impact on the project. Some of these risks may fall in the general heading of “nice to have, but not entirely necessary” and can be mitigated as time and resources permit.

dispatchability may represent a significant economic risk in a wind or run-of-river hydro system, but a lesser one in a coal or Combined Cycle Gas Turbine (CCGT) system.

The second key to understanding risk is to look at the controllability of that risk. Some risks can be mitigated by actions of the plant owner or system regulator, while other risks fall beyond a reasonable attempt at mitigation.

- Tougher environmental standards;
- Technology concerns;
- Diversification (or its absence); and
- Operational factors.

Each of these factors has a distinct locus on the risk and controllability axes given the characteristics of the specific risk element as well as the characteristics of the system where this risk

Figure 3.2: Importance and Controllability of Power System Risks

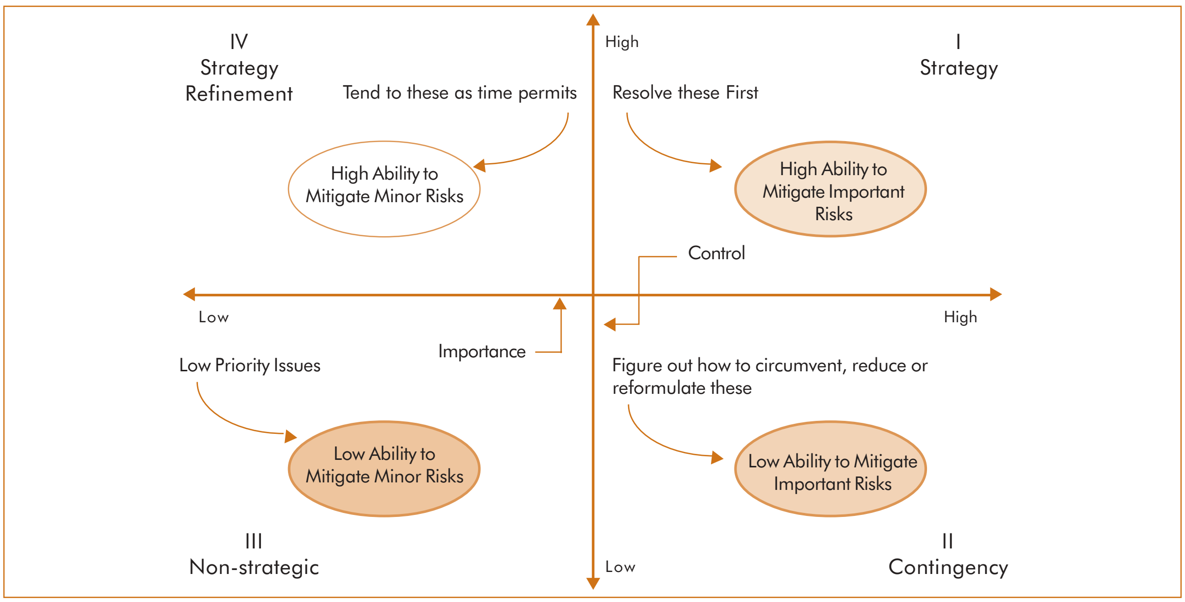


Figure 3.2 shows one approach to assessing the importance and controllability of risk in the context of power system generation expansion.

System planners and regulators will want to know where different risk elements stand in the schema of a particular system expansion exercise.

Consider the following seven risk elements:

- Fuel prices;
- Plant dispatchability;
- Construction cost;

needs to be mitigated. Figures 3.3 and 3.4 indicate how each of these factors might look in different types of systems.

In a nuclear-dominated system (Figure 3.3), fuel price risks represent, if anything, an opportunity for the plant owners. Generally, they are considered relatively unimportant, and, hence, non-strategic. However, technology and construction risks, historically two of the biggest concerns of the nuclear industry, are both highly strategic and relatively controllable.[7]

[7] *Note that dispatchability, long a problematic feature of nuclear power, is no longer considered important, as operational improvements in plant management have raised the availability factors for such plants dramatically in the past 10-15 years.*

Any system which is dominated by a single technology is definitionally short on diversity in its technologies and fuel cycles. Whether this represents a controllable or uncontrollable risk may depend significantly on specific choices by the power suppliers vis-à-vis other technologies.

The correlation of risks may also be significant. For the nuclear industry, technological and construction risks have traditionally moved together. This means that risk with respect to one attribute may often be exacerbated by risk in the other.[8]

Figure 3.3: Importance and Controllability of Power System Risks – Nuclear-dominated System

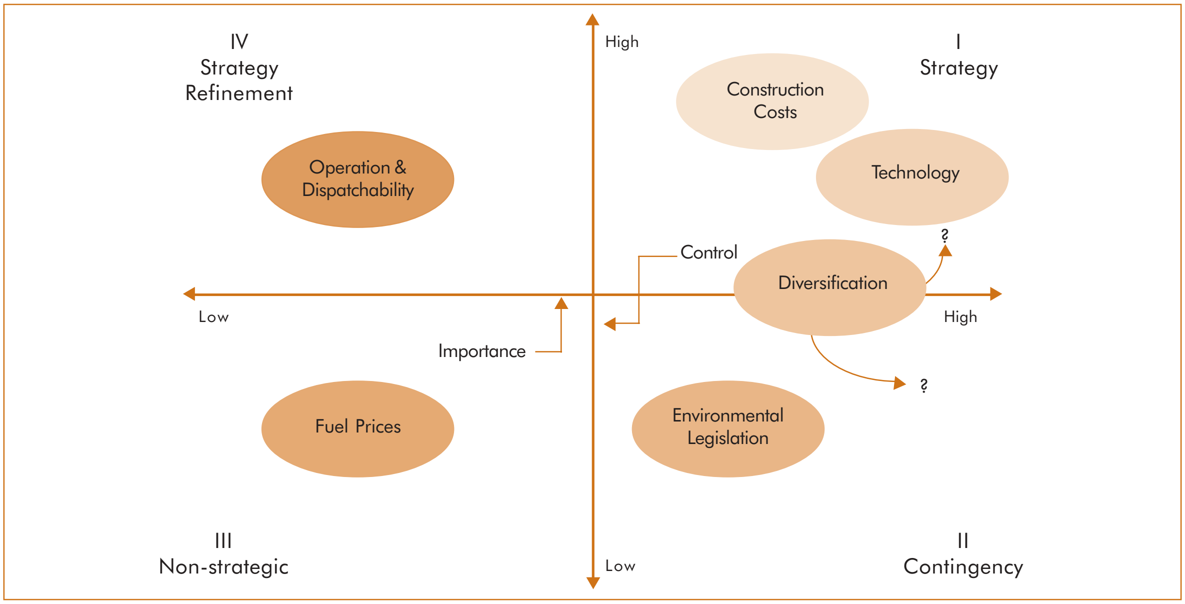
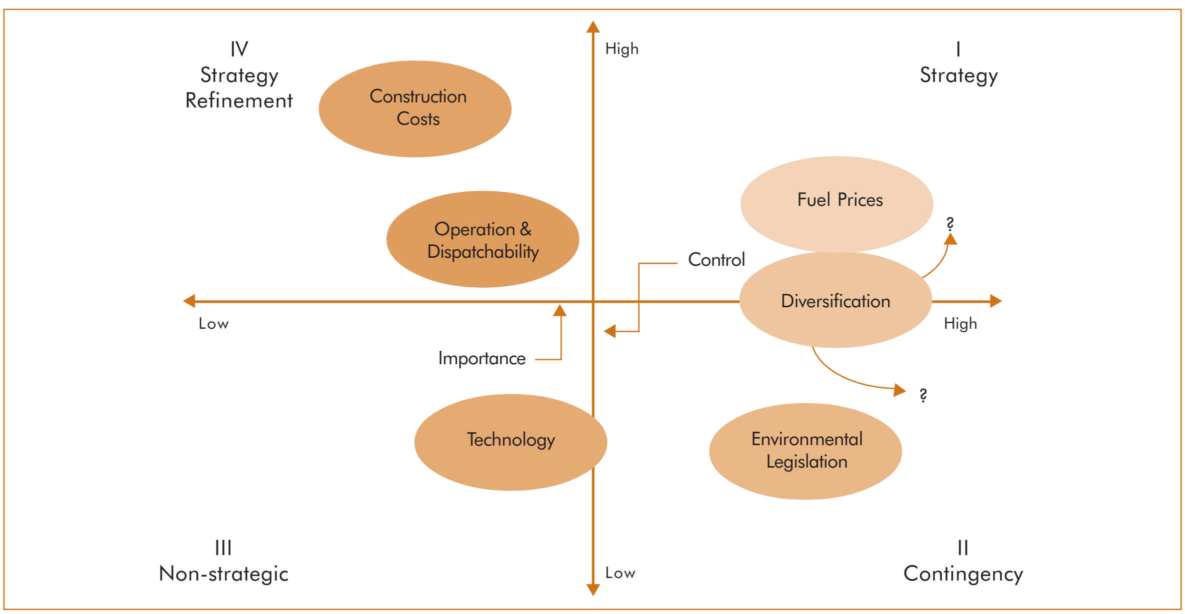


Figure 3.4: Importance and Controllability of Power System Risks – Gas/CCGT-dominated System



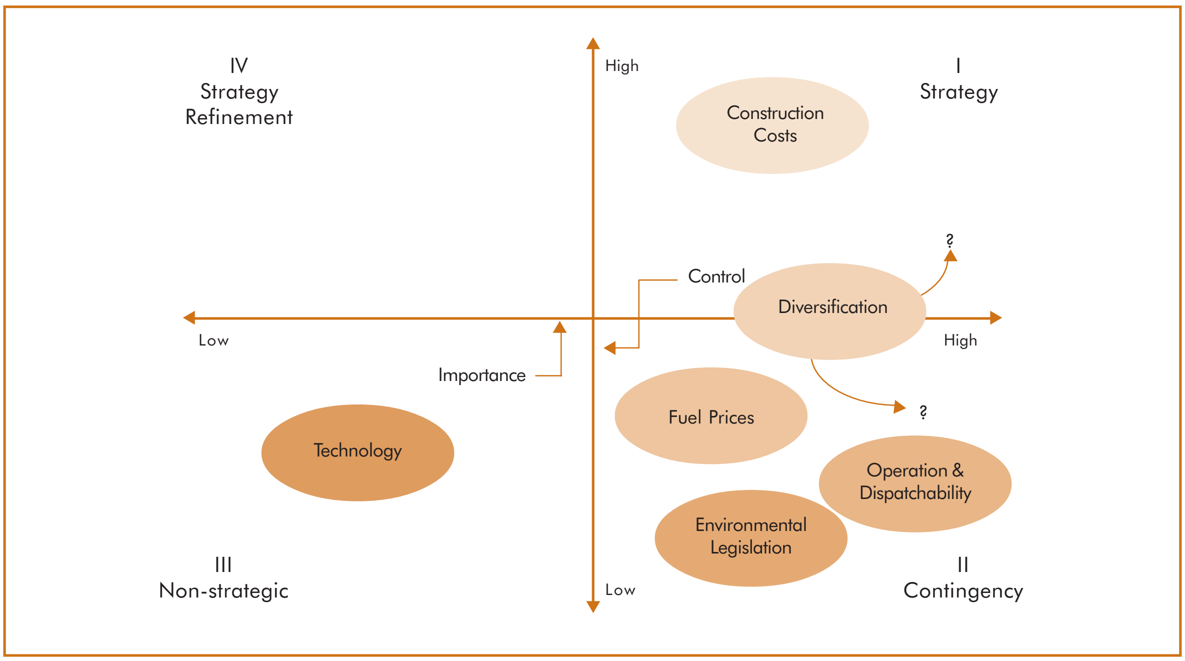
[8] *For the nuclear industry, both construction cost and technological risk are commonly positively correlated with regulatory risk as well.*

A far different risk profile emerges in a gas-dominated CCGT system:

Unlike the nuclear system, fuel prices represent a strategic risk – how controllable are they? In many systems today, the very factors which render construction costs and technology relatively unimportant in CCGT plants – a proven technology largely factory-built – may well be correlated with both fuel price and legislative risk. Certainly in many countries, including the US, many CCGT plants were built as a response to looming limitations on various pollutants from other fuel cycles, especially coal.

ROR system. Technology, largely proven and not subject to significant innovation, is non-strategic. Fuel prices, which could impact a decision to invest in better operational control of the peak period output capability, assume a greater importance than for a nuclear system, given the trade-off between better water management and the use of combustion turbines to meet peak demand. Indeed, the fuel price and the operational risks are correlated to some degree. For example, improved controllability of peak period plant availability from ROR hydro will also make fuel costs more controllable. Success in this theater comes from converting a contingency to a strategy element.

Figure 3.5: Importance and Controllability of Power System Risks – Hydro-dominated System



Finally, a well-run hydro system, dominated by run-of-river (RoR) plants, generates yet a third risk profile:

For almost any hydro-dominated system, construction costs are extremely important and largely controllable. However, operational risk, especially the issue of the plant's availability during peak periods, is a matter of high importance to the planners, but relatively low controllability in a pure

The nature of risks will change over time and planning must recognize that as well. Some risks which are both important and controllable for certain types of systems (for example, those associated with hydro in Quebec or gas supply in Indonesia) may not be as controllable for other types of systems. Even within one system, the impacts of investments and policies may change the nature and controllability of certain risks over time. For example, fuel price risk in

Mexico has grown over time as the roles of gas-fired CCGT plants *and* imported gas have assumed greater roles in system capacity and output.

How much Consideration of Risk has been Incorporated into a Unified Contemporary Modeling Framework?

The various modules associated with WASP, Energy and Power Evaluation Program (ENPEP) for demand forecast and fuel supply, GTMax for plant dispatch and IPP contract simulation, Valoragua for hydro project simulation, all plug into the input or output sides of WASP. EMCAS is a downstream model which follows a decision-theoretic framework for modeling the decisions of individual agents. Specific consideration of various risk factors can then be attributed to different "agents" along with different risk mitigation strategies.

WASP can now incorporate some of the risks discussed above for some generation technologies. For example, with the inclusion of GTMax, WASP can now address the dispatchability issue. Along with Valoragua, the estimated firm capacity of ROR hydro can be estimated to some degree, better endogenizing technology and operational risks in the model's framework. Most of the other risk categories must still be included through the use of scenarios with varying parameterizations.

Other modeling systems have been developed as well. Both General Electric (GE) Power Systems and Siemens have suites of models for utility system planning and investment analysis. These models contain feature sets which correspond to the needs of the market, as does WASP. Naturally, the emphasis of a given approach will vary from one company to another as regards certain key aspects of electricity investment system simulation, including:

- Endogenous plant dispatch;
- Iterative dispatch and generation planning;
- Treatment of IPPs; and
- Plant dispatch bidding.

These models will clearly reflect the interests of the people that pay for the results. Thus, Aurora, the product of yet another electricity modeling firm, is oriented towards identifying optimal generation portfolios in a relatively deregulated US environment. The model addresses explicitly certain risk issues raised above, specifically fuel prices and diversification value. Since IPP bidding is an important part of the model's output, the integrated dispatchability module helps address an important risk element.

Siemens uses a different approach, and has specific modules to address various segments of the business – resource planning, dispatch (Figure 3.6).

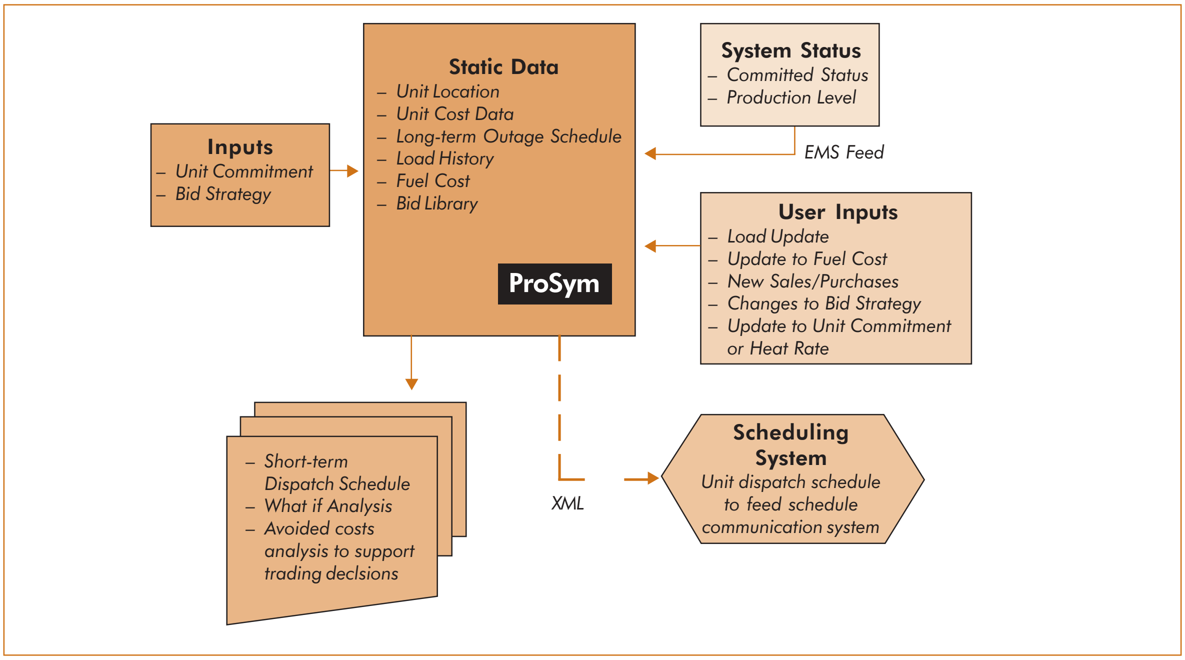
Key risks are addressed parametrically. For example, models using the ProSym engine (Figure 3.6) for plant dispatch simulation, allow "what-if?" scenario analysis of selected variations in key parameters. One module, "Risks and Markets," addresses risk in a systematic manner.

Generally, model developers will only incorporate and endogenize feature sets which users are willing to pay for. As a result, some of the risks noted above, but especially the correlation of different risks, remain outside the explicit simulation engines discussed above.

During the workshop, modelers from GE Power Systems presented an approach which provides explicit consideration of market structure, fuel policy, environmental policies and fuel price volatility. To cope with a Multiseller Multibuyer Market Structure (MSMB), the GE Power Systems approach permits three different modes of pricing behavior in the power market: (i) price-takers; (ii) cost-based pricing; and (iii) market share pricing.

Since the GE models were developed by a vendor of several of the non-hydro technologies currently available for generation, their approach

Figure 3.6: Siemen's Model for Risk Assessment



Source: New Energy Associates, a Siemens Energy Company, Product Descriptions (http://www.newenergyassoc.com/products/promod), 2006.

specifically includes technology. These technological parameters include:

- Adoption curves for new technologies;
- Explicit inclusion of non-dispatchable or intermittent technologies;
- Demand-side programs; and
- Transmission investments and trade-offs vis-à-vis generation resources.

Acknowledging the appeal of a reference case, the GE modeling system is also able to produce a "one-company" integrated plan, which can be used as a reference case for the market-oriented simulation. The GE model suite stops short of an explicit risk-return frontier[9] using portfolio theory, which will be discussed in the next subsection.

In addition to the commercially available models, some companies and individuals have developed a variety of simulation approaches to power system expansion. As a rule, these models are

Box 3.3: Portfolio Theory: What it is and What it can Do

Portfolio theory is not a system modeling approach. Rather, it is part of the tool kit of a more comprehensive approach to investment modeling and simulation. The main points of using portfolio theory are to (i) Redefine the efficient frontier of investment choices from least-cost to optimal risk-return; (ii) Endogenize the specific risk elements which need to be considered; and (iii) Identify correlated risks so as to reduce the probability of foreseeable negative outcomes.[10]

[9] Awerbuch, op cit , has focused attention on the efficient risk frontier. Internal to that concept is not only the variability and risk associated with individual parameters, but also the correlations between and among different risk factors.

[10] As a generic tool, the portfolio optimization approach can be used to focus on most types of quantifiable risks. However, in practical terms, the important risks would need to be identified and measured beforehand.

developed with feature sets which correspond to the perceived needs of the situation and the preferences of the architect. For example, one model which was used for the economic evaluation of wind in Mexico also contains gas production, pipeline and liquefaction modules, as well as power system expansion modules, since much of the model's structure was developed primarily to provide decision support for private investments in "midstream" gas to power or gas to liquids.[11] The electricity system simulation module of this model was intended to support Power Purchase Agreement (PPA) negotiations, and thus endogenizes several of the risk elements discussed above. Since the model results must be expressed for a specific client in terms of probabilities, the entire model is run using probabilistic simulation of several of the key parameters, including fuel prices, plant operations and conversion efficiency. Construction costs and operational factors for non-target plants are treated parametrically.

Investment Decisions for Public and Regulated Generators

The second major topic of the workshop concerned issues of key importance to utility regulators and publicly owned and vertically integrated utility companies. The focus of this session was: (i) what information do public sector regulators and company executives need to make optimal decisions; (ii) how do their decision-support needs differ, if at all, from private sector entities; and (iii) what are the key elements of credibility in decision-support for regulatory bodies?

Two presentations, one by the Chief of Planning for Federal Electricity Commission (Comisión Federal Electricidad-CFE), the Mexican state electricity company (and summarized in box 3.4), and the other by the head of Mexico's electricity regulator, Comisión Reguladora de Energía (CRE), brought focus to the matters of public decision-making regarding utility investments. The regulator noted that regulators in World Bank's DMCs still tend, for now, to come from the ranks of utility industry professionals. This means that they are generally conversant with the main concepts contained in an optimal planning approach and believe themselves to be proficient in interpreting the results.

The flip side of this confidence in the planning process is the potential for getting attached to approaches which may be superseded by technological progress or advances in understanding of markets.[12] As technical capabilities evolve, understanding of dynamic markets improves and the remit of regulators changes, the decision-support environment will, of necessity, evolve as well. Tools which were once both useful and sufficient for decision-support, may fall victim to a changing environment and advancing capabilities. There are significant trade-offs when this occurs. Figure 3.7 illustrates some of these issues.

Analysis and assessment techniques which can be performed on a handheld calculator, such as the next plant or production cost approaches, have limited output flexibility. However, they are highly transparent and their assumptions, methods and results, can be explained to a lay regulatory audience quite readily. As with most decision-support systems, there are trade-offs. Simple analytical approaches are relatively easy to explain to regulators and public funding authorities.

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[11] *ESMAP, Mexico: technical assistance for Long-term Program of Renewable Energy Development, Washington, D.C., February 2006, pp.85-86. This model also produced the incremental cost results for the GEF Project Appraisal, published in May 2006.*
[12] *See the Workshop paper by A. Peraza, Regulatory Tools: Promoting Renewables.*

More complex tools, relying on sophisticated models and computational techniques, are by definition less transparent, even as they become more useful to specialists. Regulators will (rightly) note that the analytical capabilities should not run ahead of the ability to explain important public sector investment choices even as more private investment brings the need for better identification and mitigation of risk factors.

A confluence of changing industry structure, new analytical methods and new generation technologies are creating a concerted challenge to the least-cost method. As Dr. Peraza noted, the increased interest in renewable and intermittent energy sources in World Bank's DMCs not only creates a decision conundrum for investors and regulators, but also for those providing the decision-support. The discussion at the workshop supported the idea that multiple methods of analysis, along the lines of extensions to WASP or the GE Power Systems family of simulation tools, would be needed to keep up with the decision needs of regulators and public entities.

A key issue noted by Dr. Soler or CFE[13] is the continuing obligation of state-owned companies to abide by least-cost procurement regulations, typical of state enterprise regulation. It is not the intention of the workshop to devise methods of circumventing this wholly justified constraint on the use of the public money; rather the workshop discussants looked at how this fundamental principle might be augmented by additional analytical methods.

Two other presentations in this session by analysts from World Bank and the Pennsylvania Utility Regulator (PJM)[14] added important embellishments to Dr. Peraza's material. In particular, it was noted that an increased focus on RE should probably have some legislative backing, and not simply be a regulatory initiative. Such an approach would resolve at least some of the problems which complicate investment planning under a legal mandate to obtain the least-cost supply mix (see Box 3.4 on Dr. Soler's comments in this regard).

Further, it was shown that the changing structure of the utility industry, even in systems where a vertically integrated entity still maintains nominal control over investment decisions, creates significant pressure for accommodating additional points of view in the regulatory and planning processes. One of the commentators noted that this tension was healthy, since modelers may be more aware of the strengths of their approach rather than that of the weaknesses. A public airing of the issues might represent progress in forcing both users of the model output, as well as the modelers themselves to think hard about what kind of information and presentation improves both comprehensibility and transparency, the beginning of any resolution to what seems the most difficult trade-off identified in the workshop.

Consensus Viewpoints on Public Sector Issues in Modeling

An emerging consensus from the workshop was that the output of a least-cost optimization was sufficiently understood, and both its strengths and weaknesses fairly well-known to both users and to regulators, that continued use of a WASP type of approach had significant ongoing value. Additional decision-support for the public sector, especially where structural change in the utility system is ongoing, would then involve

[13] *See the workshop paper, Investment Planning in the Electricity Sector: Differences from Private Electricity Companies.*
[14] *See workshop papers by Barua, Regulators' Viewpoint on Modeling: How Does a New Approach/Tool Pass Regulatory Muster; and J. Besant-Jones, What is Required for New Planning Techniques to Become Acceptable Within the New Regulatory Framework.*

Box 3.4: What are the Decision-support Needs of a Publicly-owned Integrated Utility?

A key interest in putting together this workshop was to provide a forum for model developers and model users to reflect on their diverse viewpoints and needs. In a presentation which followed the Argonne and GE papers, the head of planning for Mexico's CFE, the state-owned electricity supplier, provided a list of key decision-support needs for his utility and generalized his observations to other similar organizations.

From the point of view of an integrated state-owned utility, the economic analysis of an investment plan is considered just as important as its financial implications. This observation has direct relevance to the choice of modeling instruments, as it provides a continuing role for a "reference" investment plan that keys to social and economic opportunity costs.

Another key difference, one that does not affect the choice of models, is the discount rate – generally higher for private companies – which reflects the greater risk associated with specific projects and fuel cycles. And unlike a private generator, CFE must explicitly account for the costs to society of unserved energy.

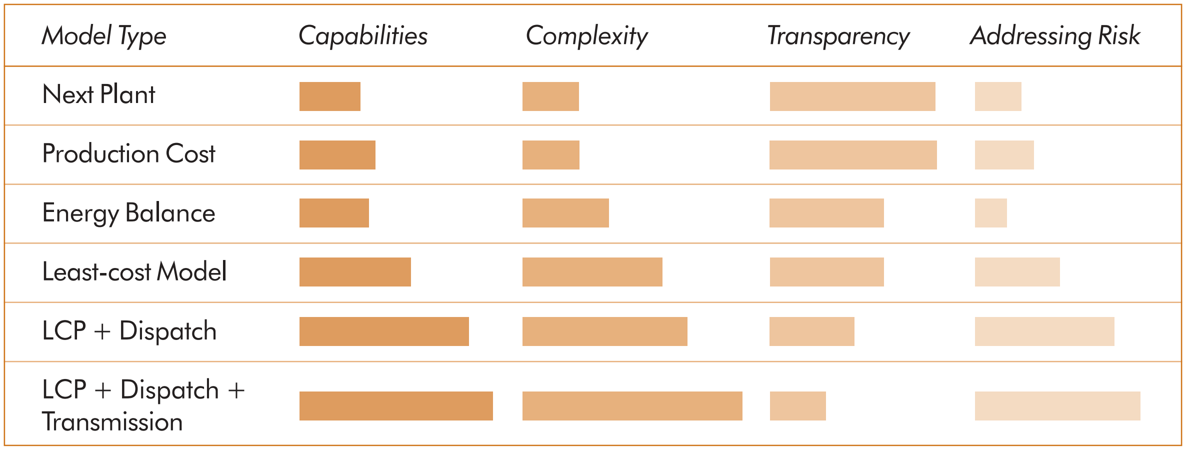
These considerations, and the need for a paper (or electron) trail that can be vetted by its regulator, CRE, argue for the continued use of a WASP type of model, one that produces a reference least-cost generation expansion plan. Other considerations, especially dispatch and fuel choice, will remain subsidiary elements of the forecast. As long as the current legal and regulatory environment remains in force the construction of a risk-return frontier provides background but not dispositive calculations, which must remain with the least-cost generation plan according to the Government of Mexico's overall fuel and demand forecasts.

This last point is a key one in the case of state-owned vertically integrated utilities. CRE is not free to generate its own fuel price forecasts and must use the same planning figures for prices, costs, and demand as other state entities. In such a structure, fuel price risk, technology diversification, and other parameters must be seen as scenarios or excursions on the reference case. The explicit inclusion of such parameterization of a reference case optimization was discussed on the second day of the workshop and will be included as an activity in the Global Environment Facility's (GEF) current wind project in Mexico.

augmenting the least-cost output with additional analytical modeling activities to address the key risk factors. In addition to the dispatch, transmission and water submodels, participants concluded that:

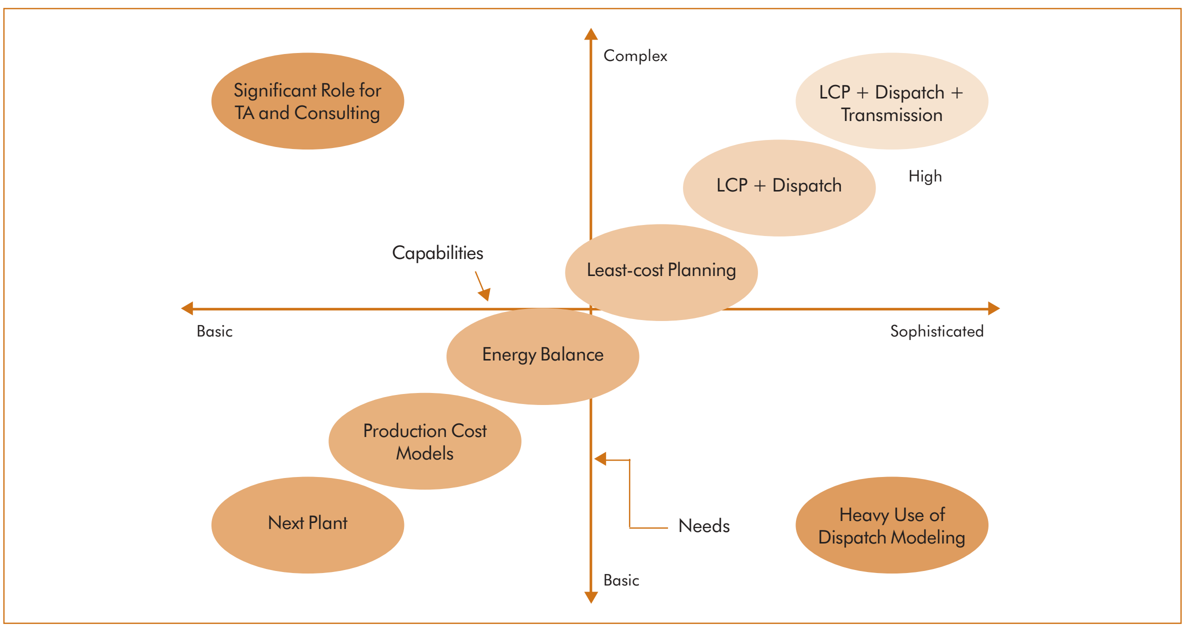
- A specific measure of the riskiness should be constructed for each of the least-cost scenarios which emerges from the optimization process as a recommended future generation mix;
- Special attention should be paid to the confluence of generation with load for evaluation of RE resources (i.e., improved temporal resolution); and
- Spatial analysis of load confluence should be made to determine whether risk in renewable

Figure 3.7: Modeling Trade-offs: Capabilities vs Transparency (Longer Bars are Better)



Note: The use of an integrated risk assessment tool, such as risk-return modeling, will generally increase the ability to assess risk, while adding complexity and reducing transparency.

Figure 3.8: Capabilities and Needs in Power System Investment Planning



generation can be reduced from use of multiple locations for generation.

For each of these recommendations – more models, more statistical analysis, more advanced financial techniques – the transparency and comprehensibility of the results for regulators will fall. Figure 3.7 illustrates some of the trade-offs between comprehensiveness and comprehensibility and transparency:

Resolving these trade-offs will become the key activities of any effort to improve the decision-support for energy investments. As with the development phase of any new technology, there will need to be a variety of tests, including:

- Comparisons of optimal solutions from different models;

- Comparisons of reference solutions with market outcomes; and
- Assessments of multi-model vs single model approaches (also, multi-model *family* comparisons).

Alternative Formulations of Investment Decisions and Risk-mitigating Measures

The third session of the workshop focused on specific suggestions for combining analytical approaches to endogenize the treatment of risk in the investment planning process. This session introduced a discussion of the particular measures of risk identification and mitigation which might be critical elements in a new, hybrid investment modeling approach.

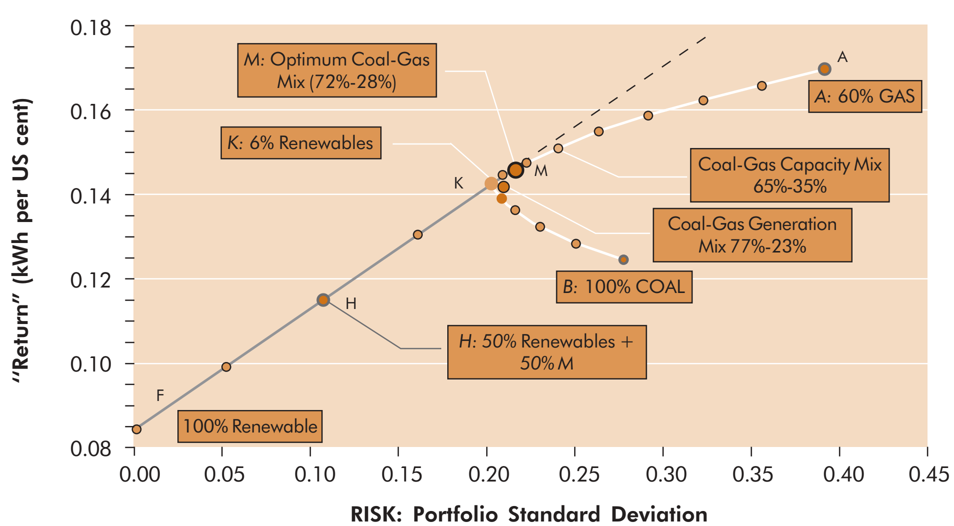
Drawing upon the consensus from earlier presentations and adding yet another dimension to the trade-offs discussed above, a suite of recommended planning techniques will need to be:

- Policy-focused;
- Suited to current and expected future market structures;
- Manageable by its practitioners;
- Transparent; and
- Participatory.

Some of these criteria have been discussed above, especially transparency, market structure compatibility and policy focus. The present discussion will then focus largely on how to incorporate risk identification and mitigation and how to make sure that the planning process incorporates the views of important stakeholders in the system.

If using point estimates of costs by themselves is no longer reasonable from a best practices viewpoint,[15] then explicit incorporation of risk assessment must be ushered into both the modeling process and the regulatory oversight. The first essential step is to identify the types of

Figure 3.9: Risk and "Return" for Three-technology US Generating Portfolio Assumed Cost for Riskless Renewable: US$12/kWh



Source: S. Awerbuch, "Getting it Right: The Real Cost Impacts of a Renewables Portfolio Standard." Public Utilities Fortnightly February 15, 2000.

[15] *See the workshop paper by S. Awerbuch, Generation Investment Planning and Modeling: A Finance Theory Perspective.*

risks which are relevant. Returning to the menu of risks listed earlier in this report:

- Fuel prices;
- Plant dispatchability and load concurrence;
- Construction cost;
- Environmental standards;
- Technology concerns;
- Diversification (or its absence);[16] and
- Market and demand risks.

These risks may be either random and, therefore, subject to mitigation through diversification or systematic method and, therefore, not readily remediable through diversification.[17] Random risks include the generation of electricity from a run-of-river hydro plant or a single wind generator. Systematic risks include factors which can make a generation portfolio co-vary with a market portfolio. An ideal generation portfolio from a risk standpoint is one whose systematic risk is as low as is practicable for a given return (measured as the costs of electricity output).

For each return on the generation portfolio there is an associated systematic risk, and an efficient portfolio from the financial standpoint is one in which there is no excess systematic risk. In other words, there is a risk-return frontier which defines a set of generation paths, each providing the best ratio of risk-to-return available. Other generation paths will not be on the frontier, either because they are too risky relative to the return or the returns are too low relative to the risk. Figure 3.9 shows the efficient frontier for several different generation paths.

Any generation paths or "portfolios" in the language of finance theory, to the right of the line, are inefficient in that there exists another portfolio, which, holding either risk or return constant, will yield better results. Generation paths to the left of the line are infeasible. Risk mitigation measures should aim at bringing the feasible generation paths as close to the efficient frontier as possible.[18]

As was discussed above and in Chapter 4, whether the risks listed above are systematic or random depends in part on the particular generation technology. Technological risk is essentially random (and low) for CCGT and hydro plants, but is a major factor in nuclear, and perhaps wind technologies. Construction cost risk is a correlated risk factor (with technology risk) in nuclear power plants, but not in hydro plants. Fuel cost risk is a systematic risk, and a powerful one (high co-variance with market portfolio) for gas and oil plants, but a weaker one for coal plants and still weaker for nuclear plants. It is the high risk associated with gas and oil generation technologies which has motivated much of the current investigation of efficient portfolios in generation investment.

A first step in the integration of risk into investment planning for utilities is the identification of risk. This means categorizing – random or systematic – and then determining how important various types of risks may prove to be for different generation technologies.[19] Once the risks to be included in the analysis have been identified, it will become necessary to measure

[16] *Crousillat, Enrique, and Sprios Martzoukos, Decision-making Under Uncertainty: An Option Valuation Approach to Power Planning, Washington, 1991; and Shimon Awerbuch, The Role of Wind Generation in Enhancing Scotland's Energy Diversity and Security, ECN, Netherlands, 2006.*
[17] *This section is a highly simplified and stylistic representation of financial portfolio theory. The reader is referred to standard graduate business school financial management texts. For an application to electricity portfolios see S. Awerbuch and Martin Berger, Applying Portfolio Theory to EU Electricity Planning and Policy-making, International Energy Agency (IEA) 2003.*
[18] *Long-term mitigation measures would seek to move the efficient frontier to the left, reducing the risk of each portfolio or generation path.*
[19] *This inevitably brings up the matter of how far one should go in the measurement of second-order impacts. It was noted at the conference that since different models will treat second-order impacts with varying levels of thoroughness, the results provided by different approaches can be graded in their applicability according to how the highest priority second-level impacts are handled.*

them. This step is likely to be more difficult than it may seem and is described in another document project from the current project, *New Approaches to Electricity Investment Simulation and Assessment – A Proposed Way Forward* (World Bank, unpublished, 2006).

Finally, the appropriate measures of risk will need to be incorporated into the normal investment planning project assessment for investors and regulators. This need to incorporate risk into the investment framework was featured in the recent World Energy Council report (summarized in Box 3.5), and provides a concise summary of the array of risk issues facing power sector investors.

In a nutshell, this summary article links fuel price risk, regulatory and policy risk and random risks to a recommendation which diversified efficient portfolios, combined with effective and predictable regulation, remain the only real methods of reducing systematic risk in a generation portfolio. The workshop addressed the question of how to operationalize and internalize risk mitigation analysis in analytical modeling of generation investments once the relevant information has been identified and gathered. This effort was beyond the scope of the workshop, except in a general sense, and will comprise a subsequent ESMAP-funded activity in this area.

Box 3.5: How does the World Energy Council see the Role of Risk Analysis in Power Generation Investments?

In an article published in the second issue of *The World Energy Book* from the World Energy Council, two senior NERA (an economic consulting firm) economists examined the various uncertainties confronted by potential North American power generators while making investment decisions. The authors noted that, in addition to the **commodity and regulatory risks** which have been affecting the industry for years, North America is also facing uncertainty over **environmental policy** and the implications it will have for recapitalization of the generation sector. In addition, **recent experience has highlighted the risks posed by the inherent unpredictability of fuel prices over the normal lifetime of generation assets**, which increases the business risk of generation projects. While the authors acknowledge that the issues confronting the industry are challenging, especially in light of the greater levels of uncertainty, the paper offers a list of concrete steps which regulators, policymakers, and companies can take to minimize the cost and risk in future power supply choices. The recommendations can be summarized as:

- Regulatory and policy stability and certainty in the rules of the game are core criteria in investment decisions. It is essential that the regulatory and policy framework is well developed, consistent, and predictable in order to remove risk (and cost) from the industry and from consumers;
- Companies should realize that their operating future is inherently unpredictable. Thus, companies must choose their supply options based on portfolios which are robust and can withstand the outcomes which are guaranteed to be different than those forecast by even the best prognosticators; and
- Finally, regulators, policy makers, producers, utilities and consumers will all benefit by re-embracing the development of robust and competitive markets for wholesale power. In conjunction with greater regulatory and policy certainty, trading provides tools to quantify future risk and to hedge its effects, thus reducing a primary investment disincentive.

Source: Mike King and Dr. Michael Rosenzweig, The World Energy Book, *World Energy Council, September 1, 2006.*

Nevertheless, it is possible to provide a general outline of cautions regarding the endogenization of risk measures in generation investment models. These cautions are intended primarily to guide future efforts to incorporate risk into pathways which meet the guidelines listed in this chapter under the title "Alternative Formulations of Investment Decisions and Risk-mitigating Measures," especially those which require interface with regulators and other stakeholders – transparency, policy-focused, participatory. The following subsection indicates some of the types of risks which can be internalized and what issues modelers might face in maintaining accurate, transparent and clear modeling procedures and methods.

How much Consideration of Risk can be Incorporated into a Coherent Modeling Framework?

Technical Considerations: One of the key factors facing any modeler is the question of what to exclude. For example, it is easy to talk about a WASP model which has endogenous Monte Carlo implementation of fuel price risks, technology risks, construction cost and timing risks, and the like. One must question, though, what such an increase in computation requirements would add to the model and its associated framework in complication, computing time, data needs, and understandability of the results. Some models can handle add-ons better than others and the tractability of the resulting modeling system is likely to vary from one product to another.

One approach to this issue is to make specific risk endogenization a second stage analysis, to be undertaken once a family of least-cost generation paths have been computed from the interaction of generation, transmission and dispatch modeling. This procedure, similar to the one used in some of the candidate models, can result in a wide array of potential generation paths, which can then be analyzed according to their risk-and-return efficiencies.

In theory, it is possible to provide probability ranges for variables and for the pricing parameters. This is probably feasible in the context of a "home-made" model for some countries. However, it is highly unlikely that this could work in the context of a generally disseminated initiative in investment simulation and evaluation. Computational and data complexity would make the results very difficult to explain beyond the "black box level of reporting." This would violate the transparency requirement and could be a fatal flaw to widespread regulatory acceptance of such an approach.

The final section of this report lists some of the specific data activities which will be needed to make this integration of financial and optimization models a reality. However, the most important information activities will include:

- Country-specific computation of systematic risks wherever possible and proxy measures of such risks where measurement is not possible;
- Measurement of random *and* systematic risks associated with renewable technologies and identification of potential mitigating measures; and
- A systematic assessment of the importance and controllability of both systematic and random risks in RE systems, including improved transmission investments, spatial separation of wind units, short-term storage at hydro plants and improved dispatch response to transients in renewable supplies.[20]

[20] *The workshop was fortunate to have participation from 3Tier Group, who provided the paper Risk Assessment in Renewable Energy Projects. Much of the discussion of integration of risk identification and mitigation is based on that paper and the discussion following its presentation.*

Regulatory Acceptability: Regulators, even if they possess significant industry experience, will tend to find more complex model outputs difficult to assess and approve on the same basis as more specific and focused models. It is generally better to explain to a regulator what types of information a particular model cannot provide, than to claim that it can provide almost everything, but that "it might take some time to go through an explanation." Beyond a certain point, the results of some models, especially when computing with probabilities parameters which are correlated to varying degrees, can become difficult to explain intuitively. Subsequent efforts in this area will have to be worked out with regulators and other members of the public to assess how more complex methods can be framed in public *fora* to provide acceptable and understandable results.

Other key issues for regulators which relate to the criteria appearing in this chapter under the title "Alternative Formulations of Investment Decisions and Risk-mitigating Measures," and can affect the choice of modeling suites include:

Public sector goals: Demand-Side Management (DSM), renewable portfolios, integrated resource planning are all features of the current energy regulatory landscape worldwide. Even if the regulated companies cannot implement the Integrated Resource Planning (IRP) which has been produced, regulators of public policy reasons may still want to see what specific goal-oriented IRPs might look like. Some models are more oriented towards public sector planning than are others.

Electricity system structure and ownership: Some modeling approaches may be more acceptable to integrated systems than to unbundled ones. Other models may be more oriented towards private generation firms rather than publicly-owned ones. A systematic assessment of different models and their suitability to different market and ownership structures should be undertaken as a part of the next phase of this activity.[21]

Consistency with approaches used in other sectors: Some regulators, especially those in multi-sector settings (gas, refined oil, telecoms), may prefer consistent approaches across sectors, so that regulated rates of return in gas can be compared to the returns of other regulated industries. This approach often leads to the adoption of specific "home-made" simulation models.

Sophistication of Public Sector Enterprises: In some countries, the state-owned utility may be constrained by reasons of budget, staffing, procurement procedures or lack of interest in pursuing new approaches. In other cases, the State-owned Electricity Generating Companies (SOE) may be willing to devote the time and internal resources necessary to take new approaches, but may be constrained by lack of funds, regulatory disapproval or state-related purchasing difficulties.

The tractability and coherence of a particular approach is a dynamic process. As computers increase in power and user interfaces grow more sophisticated, more complex approaches become increasingly feasible. Simply to imagine how complicated it would have been to add the material balance feature of Decades to the WASP of the early '80s, is to understand how far the art of system modeling has come.

In similar ways, the interests of the current age – fuel price risks, intermittent generation/

[21] *A first cut at comparing several different models for their suitability to a changing business and technology environment in Mexico was made as a part of an earlier work on the Mexico GEF Wind Project. This working paper could provide the basis of a cross-model comparison.*

dispatchability risks for renewable technologies, efficient diversification of generation portfolios – may not yet be elegantly addressable by existing tools in addition to the current range of answers. How to put the appropriate analysis kit together without sacrificing accuracy, comprehensibility or public acceptability is the challenge which future efforts will need to address.

Case Studies

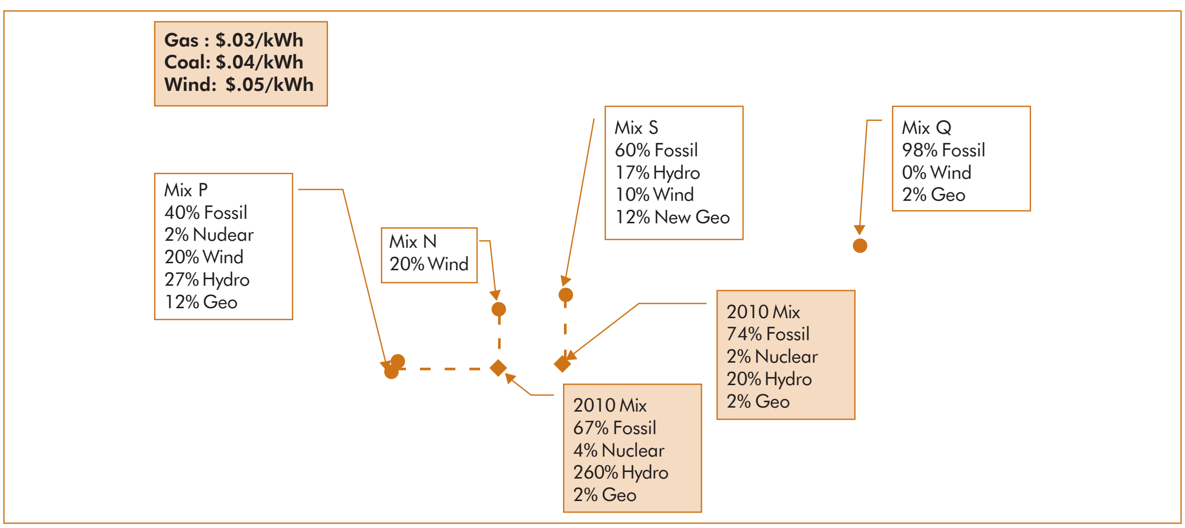
A final set of workshop presentations gave assessments of wind investments and their role in a broad-based generation portfolio. Both papers[22] stressed the need to integrate the analysis of a specific investment with a more broad-based look at the risk in the system receiving the power output.

The first approach, using elements of the GE modeling suite, showed how technical analysis from a powerflow model could be integrated with statistical measures of risk, transmission system performance and bidding behavior, to give a basis for estimating the reliability of supply with and without the wind resources. Very detailed wind studies, with resolutions down to one second in some cases, were combined with New York ISO hourly load data and day-ahead forecasts. These measurement efforts were analyzed to determine the variance in system performance with regard to meeting load with and without wind generation.

Using day-ahead wind forecasting, it was possible to reduce substantially the use of fuel to meet peak demand for power when wind was available. As was indicated by an earlier presentation by 3Tier, the ability to predict wind even one day in advance, at a fairly rudimentary level of precision can result in significant savings over the no-prediction case.

The GE researchers found that it was necessary to combine production simulation, transmission system performance and wind data to effectively understand the behavior of the system with additional wind generation. In addition, they found that load varies more than does wind availability from one day to another, minimizing the stability impacts of wind on the overall system. However,

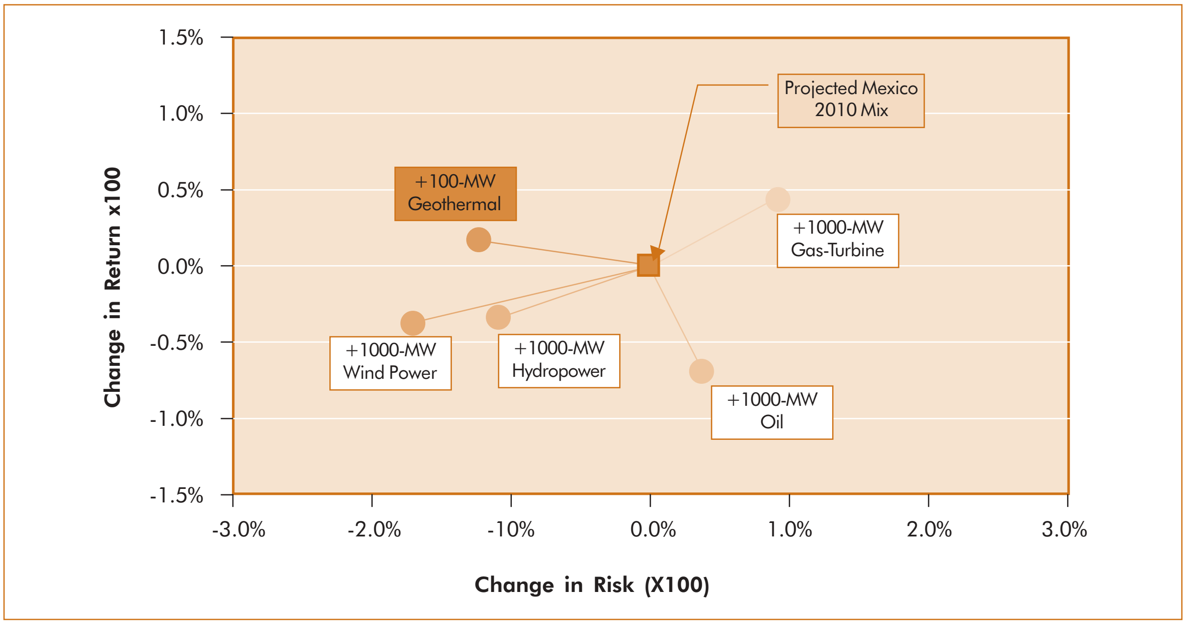
Figure 3.10: Wind/RE Lowers Mexico Generating Cost



© Dr. Shimon Awerbuch.

[22] *See Doug Welsh, The Effects of Integrating Wind Power on the New York State Power System; and Shimon Awerbuch, Generation Investment Planning and Modeling: A Finance Theory Perspective II: Portfolio-based Planning.*

Figure 3.11: One-step Analysis for Planners



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the authors suggested that seasonal wind characteristics needed to be assessed as part of an optimal generation portfolio so as not to induce the underbuilding of other system resources, with a consequent degradation in reliability. These results represent the type of concrete outputs which a new modeling approach might yield for RE.

Even the GE modeling effort stopped short of comparing different generation portfolios for systematic risk. A second paper by Dr. Awerbuch looked at specific generation portfolios for Mexico using the risk-return approach.

Using generalized performance and cost data for wind, coal, CCGT-gas and hydro, the paper compared a variety of portfolios for risk and cost. As was predicted by the theory, ignoring the systematic risk degrades the financial performance of a particular generation portfolio and the assessment of future generation investments generally.

One of the most powerful techniques in the finance tool kit, after the efficient frontier itself, is the ability to assess whether any given addition to generation capacity will move the system closer to or further away from the efficient frontier. Figures 3.10 and 3.11 show the results of such "comparative statics" analysis for Mexico. Figure 3.10 represents Mexico's efficient frontier for generation portfolios and Figure 3.11 is the comparative statics representation.

The analysis in this paper shows that certain elements of risk can indeed be applied directly to investment assessment modeling. Two of the proposed follow-up steps for this activity are to (i) identify and measure the risk elements; and (ii) derive a sequence of modeling activities which can be undertaken so as to endogenize this risk analysis into the portfolio evaluation.

One of the major implications of the use of more sophisticated risk assessment techniques is that single-plant evaluations become, paradoxically, more feasible if the reference case generation path has already undergone transformation to a risk-reward frontier format. This will mean generalizing the risk assessment of generation portfolios along the lines suggested in this chapter under the title "How much Consideration of Risk can be Incorporated into a Coherent Modeling Framework?"

Practical Applications of Multiple Model Approaches

If the era of "one-size-fits-all" modeling is over for electricity system investments, then it is reasonable to ask which tools are currently available, and how they might be combined, so as to incorporate some of the important observations from this workshop. A detailed investigation into how to combine two or more of these models, and the circumstances under which such combinations would be most useful, is the subject of the next phase of this work. However, experience in some of World Bank's DMCs, and in the New York wind study by GE, already point towards fruitful decisions regarding innovative ways to make use of existing tools.

The key desiderata about the appropriate modeling approach, shown in Figures 3.7 and 3.8, indicate the key decision considerations about what models to use and in what combination are: (i) needs; and (ii) capabilities. By needs we mean the entire set of issues regarding system size, structure, variety of prime movers and fuel cycles, ownership patterns and the likelihood of significant restructuring in the near future. By capabilities we mean the training, size, responsibilities, sophistication of the current utility planners along with the abilities of the financial sector and regulators to comprehend the output of a chosen modeling approach in an approval vein.

A final set of considerations is operational. As noted above, modeling suites cannot become too complex in their results, especially if these results must be presented to a public sector entity for approval of prudence or finance. Moreover, different modeling suites will have differing data input formats and may vary considerably from one family to another. However, for effective planning in utilities, especially publicly-owned ones, there should be a reasonable degree of continuity from one

Table 3.1: Modeling Combinations: Needs and Resources

Modeling Needs	*WASP Family*	*GE Family*	*Siemens Family*
Least-cost Model	WASP (+ Valoragua)	WASP + MARS	Strategist
LCP + Dispatch	WASP + Valoragua + GTMax	WASP + MARS + MAPS	Strategist + ProMod
LCP + Dispatch + Transmission	WASP + Valoragua + GTMax/EMCAS, or WASP + Strategist + GTMax/EMCAS	WASP + MARS + MAPS	Strategist + ProMod
LCP + Dispatch + Transmission + Risk	WASP + Valoragua + GTMax/EMCAS, or WASP + Strategist + GTMax/EMCAS + Proprietary Risk Model[23]	WASP + MAPS + Proprietary Risk Model	Strategist + ProMod + Nostradamus or PowerBase

Notes: Strategist can use the WASP database. Neither Nostradamus nor PowerBase is a portfolio model in the sense that is laid out in Professor Awerbuch's papers. The choice of GTMax or EMCAS is a needs-based one. In more market-oriented systems, a user might opt for EMCAS, whereas in a largely integrated system with some market aspects, GTMax is probably more appropriate.

[23] *One possible output of the next phase of this project is a generalized risk-return portfolio model which would stand in for the "proprietary" model now slotted in the WASP and GE family trees.*

year to the next so that model results can be readily compared.

With these cautions in mind, Table 3.1 provides a general guide to reasonable uses and combinations of models for system planning:

As Table 3.1 indicates, there is no one family which provides an entirely integrated solution to the more complex problems which have been raised in this workshop. However, it is reasonable to look at whether the members of a particular family of models can address the issues which are likely to arise with additional needs in the future.

As the case studies showed, there is already a significant amount of work which combines one or more of these models. The GE case study on wind energy in New York State used the results of a least-cost generation plan + power flow simulation from MAPS + specific wind data + load variance simulation to derive the expected contribution of wind energy at different times of the year and under varying wind conditions.

Another case study, cited by the Argonne National Laboratory (ANL) presenters, combined WASP and GTMax to assess generation and transmission system options for South-East Europe. This study provides a textbook-type examination of how the two models can be combined.

The ongoing GEF project in Mexico will attempt to extend the work done by GE and ANL, by combining the least-cost planning activities with hydro and wind assessments using Valoragua and GTMax.

4. Results of the Workshop and the Way Forward

Findings, Conclusions and Recommendations

On June 27-28, 2006, the World Bank's Energy Sector Management Assistance Program (ESMAP) conducted a workshop on electricity system investment modeling and risk mitigation. The focus of the workshop was to find ways of integrating appropriate risk considerations into advanced simulation models in a way which will improve the ability of planning and investment models to capture the complex trade-offs which must be made in successful electricity investments.

Practitioners of the art of electricity planning and modeling from Argonne National Laboratory (USA), GE Power Systems, World Bank and Mexico's CFE were brought together with electricity regulators, analysts, financial economists and climate science specialists to present their views on the central theme of the workshop: how can modelers improve the treatment of risk in large-scale simulations of power system investments?

To address this theme, the conference participants presented papers on a wide variety of germane topics, including:

- Currently available simulation tools;
- Desired characteristics of future simulation tools;
- Regulatory issues and concerns with models and simulation;
- Endogenizing financial risk assessment in simulation models; and
- Case studies on risks and risk mitigation in RE.

Workshop Findings

The focus on risk assessment and risk mitigation in power systems has been motivated by several changes in the power industry environment. Power systems have been restructured, breaking the vertical integration which allowed transmission to be treated as a technical matter. Private power producers are more concerned about plant dispatchability in a competitive setting, fuel prices have once again destabilized investment plans, and environmental concerns have increased awareness of the need to treat renewable generation resources in a more detailed manner. And finally, estimates of plant construction costs still loom large as risk factors for some generation technologies.

Participants in the workshop noted that the structural changes in the power sector, among World Bank's DMCs, have brought into question the ability of any single approach to investment planning to address appropriately the key issues facing investors and regulators. In addition to the structural and technological changes, the following issues were identified by the conference participants as key factors in the decision-support environment:

- Characteristics of the system: Size and structure; degree of market opening; and interaction with other power systems in neighboring countries;
- Policy priorities – diversification, RE, domestic resource mobilization;

- Integration of diverse concerns of financial community, regulators, IPP developers;
- Increased perception of the importance of information flows between generation and transmission;
- Risk and uncertainty identification and mitigation strategies; and
- Loss tolerance – the ability of a power system to absorb planning mistakes.

This led to the first finding of the workshop:

Finding 1: There has been material change in the utility industry environment and structure in the Bank's DMCs, vitiating many of the assumptions upon which the current investment planning process operates.

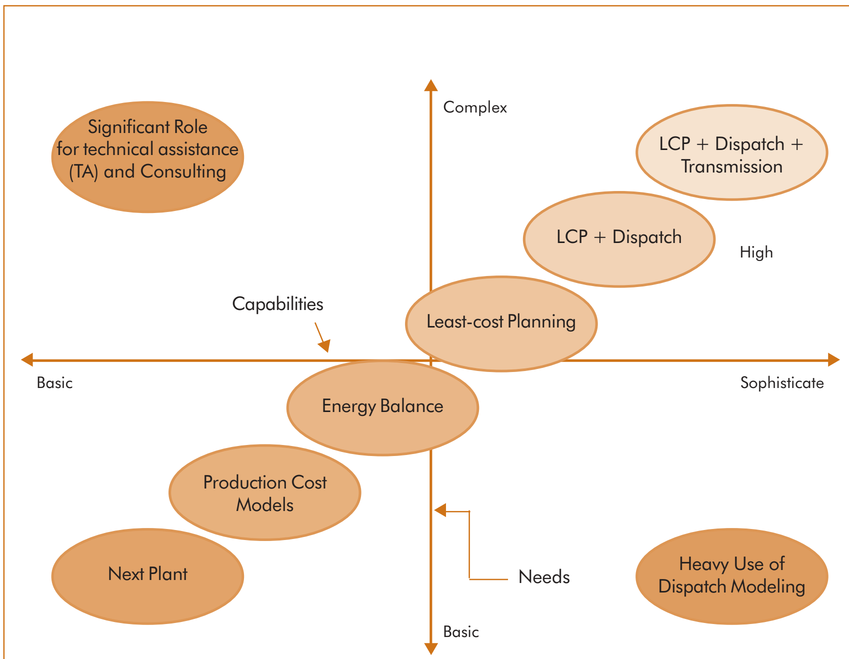
What has emerged is the desire to see, first of all, an improved planning process. In this changed environment, the planning process must address the issues of ownership, objectivity, comprehensiveness and comprehensibility of both the process and its outputs. In countries as diverse as Mexico, Indonesia and Jamaica, the planning process for generation has itself become controversial as an accompaniment to new power sector participants, new financial constraints, and emerging technologies.

As a part of an improved planning process, some entity, agreed to by other market participants, must take *ownership* of that process. A key part of the credibility of putting one institution in charge is the need to safeguard the *objectivity* of both the process and its results. Trade-offs are inevitable because it is clear that the more *comprehensive* the planning process, the more the various concerns can be taken into account. However, such richness may come at the cost of *comprehensibility*, especially for some of the market participants who may not be specialists in the arcana of power system modeling and planning methods; leading to:

Finding 2: New investment analysis tools and approaches are available which address a broader range of issues than least-cost planning alone can do.

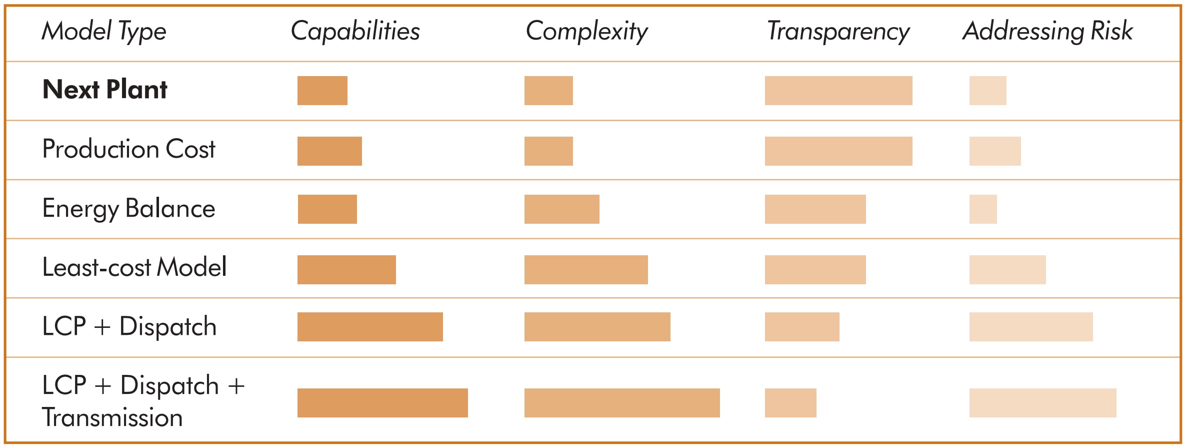
The trade-offs are illustrated in Figures 4.1 and 4.2.

Figure 4.1: Capabilities and Needs in Power System Investment Planning



National power systems move from basic planning and investment assessment to increasingly sophisticated forms of least-cost system planning. As with most decision-support systems, there are trade-offs. Simple analytical approaches are relatively easy to explain to regulators and public funding authorities. They are highly transparent. More complex tools, relying on sophisticated models and computational techniques, are by definition less transparent, even as they become more useful. Regulators will (rightly) note that the analytical capabilities should not run ahead of the ability to explain important public sector investment choices even as more private investment brings the need for better identification and mitigation of risk factors.

Figure 4.2: Complex Tools Allow Earlier Recognition of Risks



Note: The use of an integrated risk assessment tool, such as risk-return modeling, will generally increase the ability to assess risk while adding complexity and reducing transparency.

Figure 4.1 shows how complexity increases as needs and capabilities evolve. Unfortunately, some of this complexity and richness of detail in output is gained at the cost of transparency. Figure 4.2 shows that as the complexity of the tool kit rises, so will the ability to identify risk earlier and more explicitly so as to better mitigate them. This trade-off between transparency and sufficiency of approach will make itself felt in how regulators must grapple with investment and tariff approvals based on increasingly complex simulation models and with the success of the national authorities in attracting investment to replace the public funds previously used to pay for system expansion.

World Bank has played a key role in leading the evolution of its DMCs from basic methods to more sophisticated ones. WASP, the most widely used least-cost planning tool, has been promoted by the Bank and others as a relatively inexpensive, standardized and well-understood approach. Its ubiquity adds a degree of transparency to the model which other tools with similar capabilities might not be granted by regulators and financers.

However, because such tools as WASP evolved in an era of vertically integrated and state-owned power systems, treatment of dispatch, various systematic risks and transmission was outside the detailed economic planning process. Generation has remained the main focus of the effort. Fuel price variations, rainfall (for hydro), wind speeds, construction cost risk along with other risk factors are dealt with through the mechanism of defined scenarios.

For each of these issues, a separate scenario must be constructed. The interaction of different risks (i.e., correlation) is not addressed by most scenario methods.

Such an approach has proved insufficient where system deintegration, increased private investment and a constant improvement in simulation tools has raised the bar for what are considered useful and appropriate investment planning tools and points towards the third finding of the workshop.

Finding 3: New investors and altered industry structures have brought the explicit consideration of new types of risks to the forefront of investment planning and analysis.

To improve the usefulness of simulation and investment planning tools, the participants at the workshop agreed that models should assist in the identification of key risk factors and trade-offs and also show the impacts of potential mitigation measures. One way to do that is a simple grid which shows the relationship between two key attributes of risk: impact (or importance) and controllability. The importance of a given risk element in system expansion varies with the impact of that element on the rate of return and the variability of that return. Fuel prices are very important risks in a thermal-dominated system, but far less so in one which relies more on nuclear, hydro or wind. Conversely, plant dispatchability may represent a significant economic risk in a wind or run-of-river hydro system, but a far lesser one in a coal or CCGT system.

The second key to understanding risk is to look at the controllability of that risk. Some risks can be mitigated by actions of the plant owner or system regulator, while other risks fall beyond reasonable attempts at mitigation. The risk and controllability matrix looks like the one depicted in Figure 4.3 for investment problems generally:

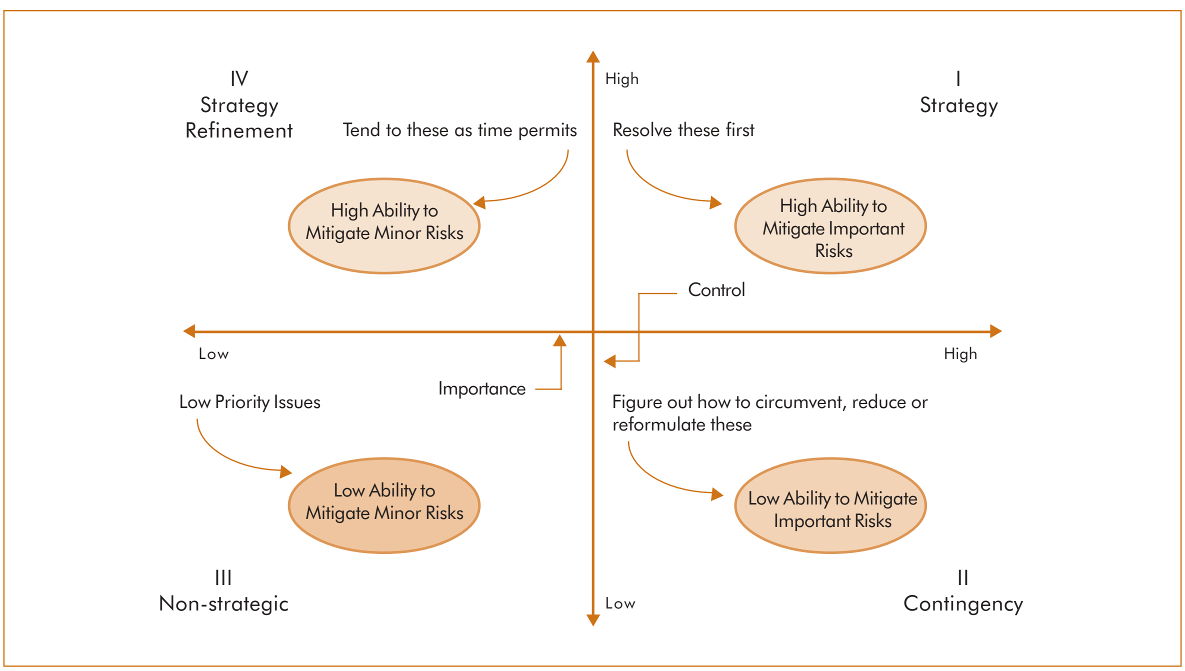
For a particular power system, the risk controllability matrix can point to specific problems, issues and trade-offs, as these will often be both location- and technology-dependent, implying that:

Finding 4: The specific characteristics of a power system, including size, structure, ownership and prime mover types, will all play key roles in determining the appropriate planning tools for system expansion and investment analysis. The "one-size-fits-all" era is over.

Throughout the workshop, the presenters demonstrated the factors which have led to calls for a more inclusive approach to investment modeling. These factors include:

- Structural changes in utility systems – unbundled systems require different analytical approaches – call for modeling of the distinct segments of the businesses, generation, transmission and distribution;
- Ownership changes, including IPPs in otherwise integrated systems, have brought new investors, with new perspectives into the investment mix. The presence of new participants has led to a greater appreciation for the endogenization of risk analysis in investment portfolios;
- Increased capabilities in simulation modeling

Figure 4.3: Importance and Controllability of Power System Risks



have made possible more sophisticated and time differentiated approaches to investment evaluation and modeling; and

- Greater interest in new generation technologies, especially renewable ones, has made clear the need for approaches which can explicitly assess the costs and benefits of such technologies, not as an afterthought, but rather as an integral element in system planning.

Workshop Recommendations

A new approach to the investment planning process must start from the understanding that today's investors and regulators are more demanding with regard to the results of the planning process. They are also far more aware of the mistakes and problems have arisen in the past as a result of insufficient attention to risk factors.

Based on the discussions and presentations in the workshop, as well as the findings presented above, the following recommendations have emerged from the proceedings:

- Current least-cost generation planning tools should remain as a part of the overall planning process, but dispatch and transmission models should be integrated with the least-cost models where appropriate; and

- For example, Mexico currently uses all three techniques for operations or planning in its electricity system. However, these efforts are not integrated, nor are the results and data uniform. As a result, the insights into planning offered by dispatch modeling are not explicitly and systematically available to CFE, the Mexican electricity operator.

Least-cost generation planning should be augmented with explicit endogenization of key risk factors appropriate to the system and the technologies in use in that system;

- Risk factors need to be better quantified, including correlation, if any, among different risk factors. This should include:
  - Fuel price risks, including gas/oil/coal correlations;
  - Construction cost and/or delay risks, especially the correlations between large hydro, coal and nuclear plants;
  - System operation risks, including coincidence of expected generation from intermittent sources over the load curve; and
  - Ability of transmission investments to reduce generation-side risks by enabling better use of generation resources, especially to back up intermittent generation sources.
- Proxy measures for risk as well as risk mitigation need to be developed for smaller systems where necessary data for risk analysis may be insufficient or unavailable, including:
  - Wind and hydro-effective capabilities to contribute capacity;
  - Mitigating measures which may improve the ability of wind and hydro to contribute capacity (e.g., operational coordination between wind generation and dispatch of storage hydro plants); and
  - Role of transmission and improved dispatch procedures.

Concerns and issues key to Financial Institutions (FIs), IPP developers and regulators remain largely unaddressed and need to be more explicitly considered in investment planning process:

- Important sources of risk and uncertainty need to be identified, including:
  - Construction and technology risks;
  - Regulatory concerns and mitigating measures, especially with regard to intermittent generating technologies;
  - Fuel price risks and methods to mitigate such risks; and
  - Trade-offs between expected generating costs and systemic variability in generating costs.

- Dispatch and transmission modeling need to become integral to generation investment planning process:
  - Integrated dispatch and LCP models need to become the norm in larger systems;
  - Transmission models need to be integrated with generation planning to assess generation:transmission trade-offs and risk reduction options; and
  - Modeling for planning needs to be province of a trusted party to avoid charges of bias or omission.
- Improved planning process needs to be explained carefully to regulators to improve transparency and allay fears of "black box" syndrome.

Activities starting up under the GEF's Mexico Wind Energy Project point the way for one possible approach for organizing and implementing enhanced investment planning for utilities. The technical assistance for this project seeks to:
(i) quantify the risks in wind generation;
(ii) identify mitigating dispatch strategies with hydro operations through integrated planning and dispatch simulations; and (iii) use *a posteriori* analysis from the dispatch and planning models to estimate an increasingly accurate value for generation using wind. In addition, it will be possible, using the suite of simulation models proposed for the GEF Mexico project, to estimate the parameters of a more accurate and sophisticated risk-return frontier, as an essential step to integrating such analysis into investment planning using optimization techniques.

In other DMCs, the issues will be different from those in Mexico, especially as regards system size and ownership. If World Bank's DMCs are able to take advantage of new methods of system planning and risk identification and mitigation, then Bank will need to move affirmatively to make adoption of such new methods simpler and less costly, both in time and money, than they now are. Specific measures which World Bank can take in this regard include the following ones:

As a first step, World Bank should canvas its DMCs to assess what *their* needs are in the new investment planning environment. This means talking to regulators, IPPs, private financial institutions and market operators and determining the key decision-support elements which the new environment requires. World Bank also needs to investigate whether current planning and investment activities generate systematic biases with regard to future demand, cost of new plants, and the operational and dispatch characteristics of different types of plants.

Important risk categories, such as those identified above, need to be better quantified and World Bank can play a role in generating such information and disseminating it to the DMCs. In particular, World Bank needs to support efforts to gather and construct both country-specific and proxy measure of the following risk elements:

- Fuel price risks, including gas/oil/coal correlations;
- Construction cost and/or delay risks, especially the correlations between large hydro, coal and nuclear plants *and* the correlations of such construction risks with worldwide heavy engineering activity in mining and oil/gas production; closely related to construction risks are
- Market measures of risk which continue to create noticeable differences between *ex ante* assessments of plant returns based on demand studies and *ex post* plant dispatch and utilization results;
- Output and operational data for wind and ROR hydro plants to better gauge the operational risks and the effective capacity contributions associated with such plants;
- Potential role of transmission investments to reduce generation-side risks by enabling better use of generation resources, especially to back up intermittent generation sources; and

- Mitigating measures which may improve the ability of wind and hydro to contribute capacity (for example, operational coordination between wind generation and dispatch of storage hydro plants), improved short-term water management in RoR hydro units.

Risk analysis needs to be explicitly integrated into planning models and analyses.

- World Bank should investigate how to take the quantitative measures of risk and its proxies mentioned in the paragraph above detailing the important risk categories, and integrate these measures into larger simulation and investment analysis models in a manner which produces consistent and robust results;
- World Bank should work with one or more of the software publishers in this business space to define appropriate ways to integrate the risk measures already enumerated; and
- World Bank should work with its DMC clients to improve demand forecasting and prepare methods of mitigating market-related risks.

Where conditions warrant, World Bank should promote the use of integrated generation and transmission planning, augmenting the use of least-cost generation planning models with other transmission and dispatch-oriented programs.

- Specific models and their integration should be investigated further to assess their ability to integrate with current approaches and appropriate integration programs need to be devised; and
- World Bank should help to implement the use of models which explicitly include contracts with IPPs or other bilateral instruments, as well as pool prices.

At the same time, World Bank can help promote economy of effort in simulation modeling of investment and system expansion by supporting high quality tools with training programs and data acquisition support which has been vetted by the testing activities and data analysis explained in the above paragraphs; and

Training programs need to be designed to assist World Bank's DMCs in making use of the new investment analysis and planning methods to design and implement coherent investment planning, analysis and risk mitigation capabilities, including the need to report results to regulators and investors in a manner which enhances the quality of regulatory decisions, especially with regard to transparency and stakeholder participation.

ANNEX 1
World Bank/ESMAP Workshop on Electricity Investment Modeling and Risk Mitigation

World Bank and ESMAP have embarked upon a study to contribute to improving power systems planning methodologies to better reflect supply and price uncertainties, and valuation of supply diversity. To support this work, we are co-hosting this workshop to lay the groundwork for a systematic assessment of planning methods and attempt to reach consensus on a development path which will ultimately mainstream such approaches in the power sector. The output from this workshop will contribute to preparation of model specifications and terms of reference for the development of new planning tools, and ultimately to the development and validation of improved models for power systems planning.

Workshop Agenda

Tuesday, June 27

08:30-09:00	Continental Breakfast at Meeting Room
09:00-09:15	Welcome and Introduction – Anil Cabraal, The World Bank

Morning Sessions: Current Approaches to Electricity System Investment Modeling – What Works and What Needs Fixing – Session Chair Anil Cabraal, The World Bank

09:15-09:30	Issues and Problems in Electricity Generation Investment Modeling, Current Practices and Results – Donald Hertzmark, Consultant, The World Bank
09:30-10:15	New Approaches, WASP and Beyond I – Günter Conzelmann and Tom Veselka, Argonne National Laboratory
10:15-10:30	*Q&A with commentary by Enrique Crousillat, The World Bank*
10:30-10:45	Coffee Break
10:45-11:30	New Approaches, WASP and Beyond II – E LaRose, GE Power Systems;
11:30-12:15	*Q&A with commentary by Shimon Awerbuch, Tyndall Center, University of Sussex*

12:15-13:30 Lunch

Afternoon Sessions I: Investment Decisions for Public and Regulated Generators – Session Chair Charles Feinstein, The World Bank

13:30-14:15	Public Sector Perspectives on Investment Planning, How do the Needs of State Enterprises Differ from Private Electricity Companies? – Andres Soler, Comision Federal de Electricidad (Mexico), Günter Conzelmann, Argonne National Laboratory
14:15-15:10	Regulator's Viewpoint on Modeling, How does a New Modeling Approach or Tool Pass Regulatory Muster? – Alejandro Peraza, Comision Reguladora de Energia (Mexico), Rajnish Barua, Pennsylvania Public Utility Commission, John Besant-Jones, Consultant, The World Bank

15:10-15:30 *Q&A with commentary by Charles Feinstein, The World Bank*
15:30-15:45 Coffee Break

Afternoon Sessions II: Alternative Formulations of the Investment Decision and Mitigating Measures – Session Chair John Besant-Jones, Consultant, The World Bank

15:45-16:20 Critique of Optimization Approaches and Introduction of Risk-return Criteria for Investment Planning in Power Systems – Shimon Awerbuch, Tyndall Center, University of Sussex
16:20-17:00 Risk Mitigation Methods in Portfolio Optimization – Victor Niemeyer, EPRI; Bart Nijssen, 3Tier Environmental Forecasting Group
17:00-17:20 *Q&A with commentary by Günter Conzleman, Argonne National Laboratory*
17:20-17:45 Lessons Learned and Round-table Discussion – Moderated by Donald Hertzmark, Consultant, The World Bank
17:45-19:00 Reception

Wednesday, June 28

08:30-09:00 Breakfast

Case Studies and the Way Forward – Session Chair Enrique Crousillat, The World Bank

09:00-09:40 Managing a Transition to New Approaches – E LaRose, GE Power Systems; Andres Soler, CFE
09:40-10:30 Case Studies of Alternative Approaches – Shimon Awerbuch, D Welsh, GE Power Systems
10:30-10:45 Coffee Break
10:45-11:10 *Q&A with commentary by Bart Nijsson, 3Tier*
11:10-12:00 Round-table Discussion – Summary, Next Steps, Relevance to World Bank Members – Moderated by Donald Hertzmark and Andres Soler, Comision Federal de Electricidad (Mexico)
12:00-12:20 Closing Remarks, Enrique Crousillat, The World Bank
12:20 Workshop Adjourns

RENEWABLE ENERGY

Moving into a world with less carbon emissions, better energy security through a more diversified energy supply, and increased availability of energy in unserved areas, in particular where the poorest people live.

ESMAP supports renewable energy with advice on policy formulation and development incentives adapted to local conditions. The program assists in design of renewable energy projects suitable for financing by bilateral assistance, international institutions, or the private sector.

The analytical work of ESMAP includes legal and regulatory frameworks for renewables, efficient integration of distributed generation in electrical power systems, and better energy access for remote and poor communities.

ESMAP is a knowledge clearing house for good practice and opportunities for renewable energy ranging from large scale electricity generation to biomass serving household heating and cooking needs.

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