Incorporating Risk and Uncertainty in the Integrated Resource Planning Process

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Incorporating Risk and Uncertainty in the Integrated Resource Planning Process

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Abstract

This report explores the way in which regulated electric utilities plan for resources to meet their obligation to serve. Alternative methods of planning may produce less than acceptable outcomes, and this report suggests that incorporating risk and uncertainty into this process produces more satisfactory results.

Risk and uncertainty are increasingly important—yet often neglected—challenges in the electric industry in its resource decisions, which are typically addressed through integrated resource planning (IRP). This report describes several potential enhancements to IRP to incorporate risk and uncertainty, including mapping risks and costs associated with various technologies, using probabilities and expected values, understanding regrets, and using scenario planning to avoid regrets. Utility personnel and regulators who are interested in resource planning will find this technical report informative.

Keywords
Integrated resource planning (IRP)
Regret scores
Risk and uncertainty
Scenario planning

Executive Summary

This report examines various potential enhancements to addressing risk and/or uncertainty in the integrated resource planning (IRP) process, some of which overlap. They include:

- Understanding the risk associated with different technologies
- Enhancing IRP with probabilities, including probability trees, expected value analysis, and risk assessment curves
- Minimizing regret scores
- Applying scenario planning

Different tools provide different results. As utility planning tools and metrics changed over the decades, so did the selected resources. When metrics such as average cost per kWh or no-losers tests were used, demand-side resources were not selected. If carbon or other fossil-fuel environmental concerns are not part of the equation, carbon-based solutions are selected more frequently than when these costs are internalized. If probabilities are not used as an enhancement to typical IRP analysis, utilities might select inferior solutions if they make the decision by counting the cases with positive outcomes. If trends trump alternative future scenarios, utilities might select resources that look good today but that will have all stakeholders regretting the choices in the future.

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Section 1: Introduction and Purpose

Any industry looking decades into the future when investing in major capital projects faces risk and uncertainty. Unlike resource planning for less regulated capital-intensive industries (e.g., oil, steel, automobile), the resource planning and associated decision making for the electricity industry is subject to public review and often public approval by the industry's regulators. As part of this process, currently called Integrated Resource Planning (IRP), the electric utility must demonstrate the need for the additional resources and under traditional IRP that the resource (or portfolio of resources) is the least cost set of resources to meet the forecasted needs. IRP is a major improvement to the tools previously used the electric industry that only considered traditional utility owned supply-side resources. IRP was developed to view all resources equally, whether demand side (once called conservation and load management and now called energy efficiency and demand response). The electric utility industry has been slow to adopt enhancements to its traditional sensitivity study driven Integrated Resource Planning process. The enhancements discussed in this report are designed to increase the understanding of risk and uncertainties that can help decision makers (utility executives and utility regulators) make superior decisions about resource allocations.

The National Association of Regulatory Utility Commissioners (NARUC) has demonstrated an increased interest in how to better address risk and uncertainty in electric utility integrated resource planning. At recent meetings, some of the ideas included in this paper have been mentioned. NARUC sponsored several studies on this topic in 2013. It is important that the utility industry and its regulators find areas of agreement if regulators are to be expected to grant pre-approval of utility investment programs; a factor often required by the investment community before providing capital for major projects.

This paper examines various potential enhancements to addressing risk and/or uncertainty in the IRP process, some of which overlap. They include:

- Understanding the risk associated with different technologies
- Enhancing IRP with probabilities, including probability trees, expected value analysis and risk assessment curves
- Regret scores, and
- Scenario planning

Different tools provide different results. As utility planning tools and metrics changed over the decades, so did the selected resources. When metrics such as average cost per kWh or no-losers tests were used, demand-side resources were not selected. If carbon or other fossil-fuel environmental concerns are not part of the equation, carbon-based solutions get selected more frequently than when these costs are internalized. If probabilities are not used as an enhancement to typical IRP analysis, we might select inferior solutions if we make the decision by counting the cases with positive outcomes. If trends trump alternative future scenarios, we might select resources that look good today, but have us regretting our choice down the road.

The discussed enhancements track a continuum of risk and uncertainty management approaches discussed by Charles Thomas.[1] He discusses several basic models to incorporate risk and uncertainty into the decision-making process. These include:

- **Basic quantitative models**, which are most applicable to shorter-term forecasts such as annual business projections. Often "best", "worst" and "expected" cases (often referred to as scenarios) are included to create a band of potential outcomes. These models resemble traditional IRP, however the time frame is out of synch with the application.
- **Probabilistic models**, which build on quantitative methods, assigning probabilities to the underlying range of assumptions –allowing for the calculation of expected values. Note that when probabilities are not explicitly assigned they tend to be implicitly assigned such that all outcomes are equally likely.
- **Event-driven scenarios**, which examine specific event that might change the future like a change in environmental or energy policy, yet something beyond the typical trends considered by forecast.
- **Alternative futures**, which try to identify a select few scenarios that might occur without regard to the path that might lead to that future.

Risk and Uncertainty

Risk and uncertainty are related but different concepts. Frank H. Knight, one of the founders of the Chicago School of Economics, wrote that risk exists when probabilities can be attached to unknown outcomes and uncertainty exists where probabilities cannot be assigned.[2] Although traditional Integrated Resource Planning (IRP) examines resources based upon different assumed inputs (sensitivity analysis) it does not systematically address either risk (assigning probabilities to assumptions) or uncertainty (addressing what we know what we do not know). IRP used by electric utilities can be enhanced by considering both risk and uncertainty. Adding risk and uncertainty to IRP not only changes the process but the metrics upon which resource decisions are made. Rather than a

[1] See Types of Scenario Planning, Charles Thomas

[2] See Risk, Uncertainty and Profit, Frank H. Knight

least cost solution based upon expected assumptions, decisions look at expected values, ranges of outcomes, regret scores and always acceptable metrics.

Historically, IRP has focused on inputs where probabilities could be assigned (risks), however, the probabilities typically are not used in the regulatory phase of the IRP process. For example, these risks included ranges of forecast for load, construction costs, cost of fuel, cost of carbon, and the productivity of the chosen or alternative technology. In 2010, in an IRP type investigation[3] where the utility wanted to build an IGCC plant burning lignite and using carbon sequestration, the possible forecasts of construction costs, the price of natural gas and the cost of carbon were among the issues addressed. No probabilities were assigned to the varied assumptions of cases developed by the utility, making all the cases equally likely to occur from an analytical perspective and reducing the understanding of the project's risk, costs and benefits.

Even ranges of forecasts do not capture uncertainty. Will Rogers explained, "It is not what we don't know that gets us in trouble, it is what we know that ain't so." Lewis Mumford, the renowned futurist, cautions, "Trend is not destiny." Forecasts, even bands of forecasts don't always happen; rather than completely unexpected happens. For example, when nuclear power plants were being proposed in the 1970s, no one expected capacity factors to be closer to 100% than 60% or for oil prices not to continue to soar rather than stay around $30/barrel for decades. Who expected in 2008 that natural gas prices would be at current and now forecasted levels? In the 1970s it was common to see forecasts for electricity load growth in the 8% to 10% range; a forecast that never occurred. And this is before accounting for sea changing events such as Russia surpassing Saudi Arabia as an oil exporter, restructuring of the electric and gas industry, capital markets contracting, the Internet, the Arab Spring, the awaking of China's economy, new environmental legislation, or technology changes that allowed for more distributed and intermittent generation. Stuff happens! And sometimes doesn't. Have all electric cars penetrated markets as expected? These examples demonstrate that there are items that risk analysis does not assess, although uncertainty analysis might.

Risk and Uncertainty Management Tools Not Discussed

Except as a passing discussion, issues of uncertainty or risk allocation between utility investors and customers are not addressed in this paper. These include issues such as:

- Construction work in progress (CWIP) or other early recovery mechanisms
- Construction cost caps
- Productivity standards or incentives

[3] Mississippi Public Service Commission Docket No. 2009-UA-14

A related topic not addressed is preapproval from regulators. This step has become more of a norm as investors want some type of up-front prudence review protection when shelling out hundreds of millions in not billions of dollars. The quest for pre-approval has made regulators more concerned about addressing risk and uncertainty, as they become de facto partners in investment decisions. The issue of pre-approval is discussed in a paper[4] prepared by the National Regulatory Research Institute.

Also not discussed, except in passing are the risks that can be contracted to a third party (e.g., project general contractor, purchased power supplier, fuel price hedges). These risk management strategies or insurance policies can be included in expected value analysis and other risk analysis by increasing the price and reducing the probabilities associated with certain outcomes. All of these are important concepts, but the focus of this paper is not on incentives, disincentives or risk/uncertainty sharing, rather on broader concepts of decision making.

Although, part of IRP, the issues of system reliability, fuel mix, portfolio requirements and similar constraints and goals are also beyond the focus of this paper. These requirements can and should be included as policy constraints to IRP with and without risk and uncertainty.

[4] Pre-Approval Commitments: When And Under What Conditions Should Regulators Commit Ratepayer Dollars to Utility-Proposed Capital Projects? Scott Hempling, Esq. and Scott H. Strauss, Esq. November 2008

Section 2: Risk Associated with Specific Technologies

Different technologies present different risks. These risks are caused by issues such as a project's size, timeline, off ramps, scalability, operational record and dependability. In Practicing Risk-Aware Electricity Regulation[5], the authors attempt to map the relative risks associated with various technologies. The report starts by identifying a list of potential risks broken into two categories, cost-related and time-related risks. See Table 2-1. Most of the items in this table are risks, as it is possible to assign probabilities to various outcomes related to construction costs, production, fuel costs, etc. Some of the items are a bit too vague to be risks (e.g., environmental rules change) but a related risk could replace it (e.g., the cost of carbon). Some of these elements might be addressed by internalizing the externalities in the cost analysis.

Table 2-1
Varieties of Risk for Utility Resource Investment

Cost-based	Time-based
• Construction costs higher than expected • Availability and cost of capital underestimated • Operation costs higher than expected • Fuel costs exceed original estimates or alternative fuel costs drop • Investment so large that it threatens the firm • Imprudent management practices occur • Resource constraints (e.g. water) • Rate shock: regulators won't put costs into rates	• Construction delays occur • Competitive pressures; market changes • Environmental rules change • Load grows less than expected; excess capacity • Better supply options occur • Auxiliary resources (e.g., transmission) delayed • Other governmental policy and fiscal changes

[5] Practicing Risk-Aware Electricity Regulation: What Every State Regulator Needs to Know, Ronald Binz et al, 2012

Note that the authors only listed adverse events and could have listed these risks as symmetric (e.g., construction costs different than expected rather than "construction costs higher than expected"). This symmetric approach allows the analysis to consider the full range of potential outcomes when comparing potential resource strategies. This list also includes issues around sharing of risk (e.g., regulators won't put costs in rates due to rate shock), a real concern, but an issue about allocating risk and uncertainty rather than measuring it. Missing from the list are risks associated with many demand-side projects such as penetration and persistence – topics where there is a great deal of data that could be useful in quantifying risk.

Mapping Risks and Costs of Various Technologies

This report goes onto map technologies on to a risk and cost field (see following diagram). Technologies in the lower left corner of the mapping (e.g., efficiency) are low cost and low risk. The upper right maps high cost and high risk (e.g., coal and nuclear). These mappings and the underlying estimates of costs and risks are not quantitatively presented in this report. Still this presentation provides some guidance of which technologies should be considered first in an IRP analysis, moving from bottom left to upper right.

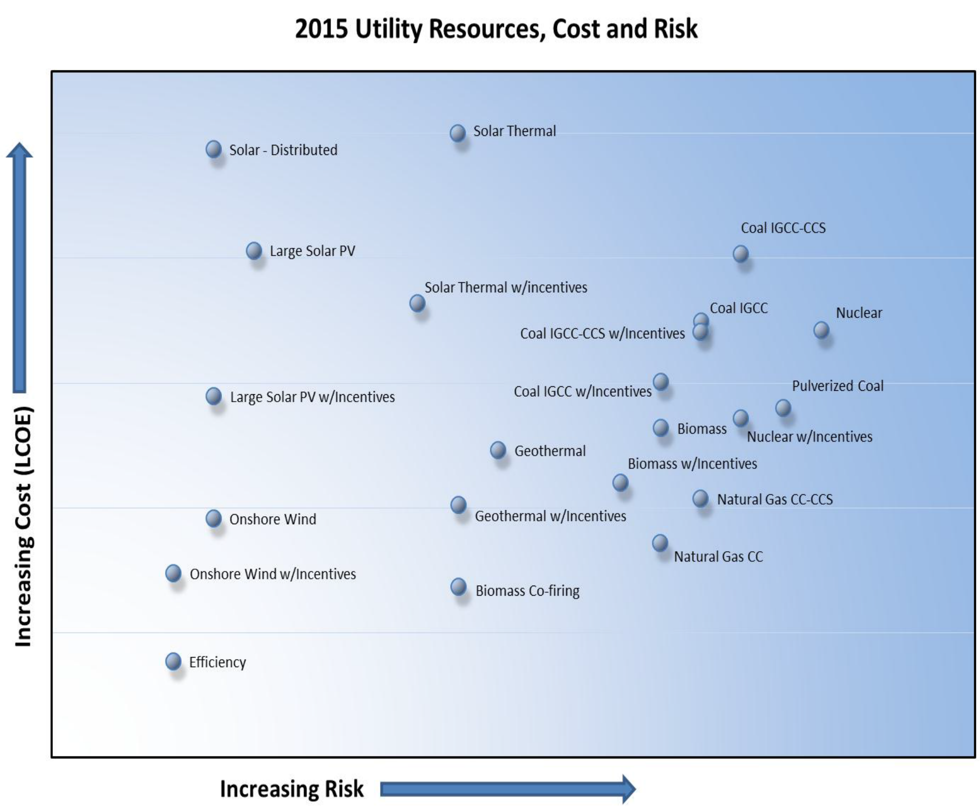

Figure 2-1
Mapping Utility Resources, Cost and Risk

Portfolios and Efficient Frontiers

The preceding mapping analysis can be used to assess the riskiness of resource portfolio. Such an analysis was done by the Tennessee Valley Authority[6] . TVA mapped (see below) five resource strategies on a plane defined by present value revenue requirement and risk and used this to define an "efficient frontier." The risk is a measurement of the difference in the revenue requirement under different assumed conditions.

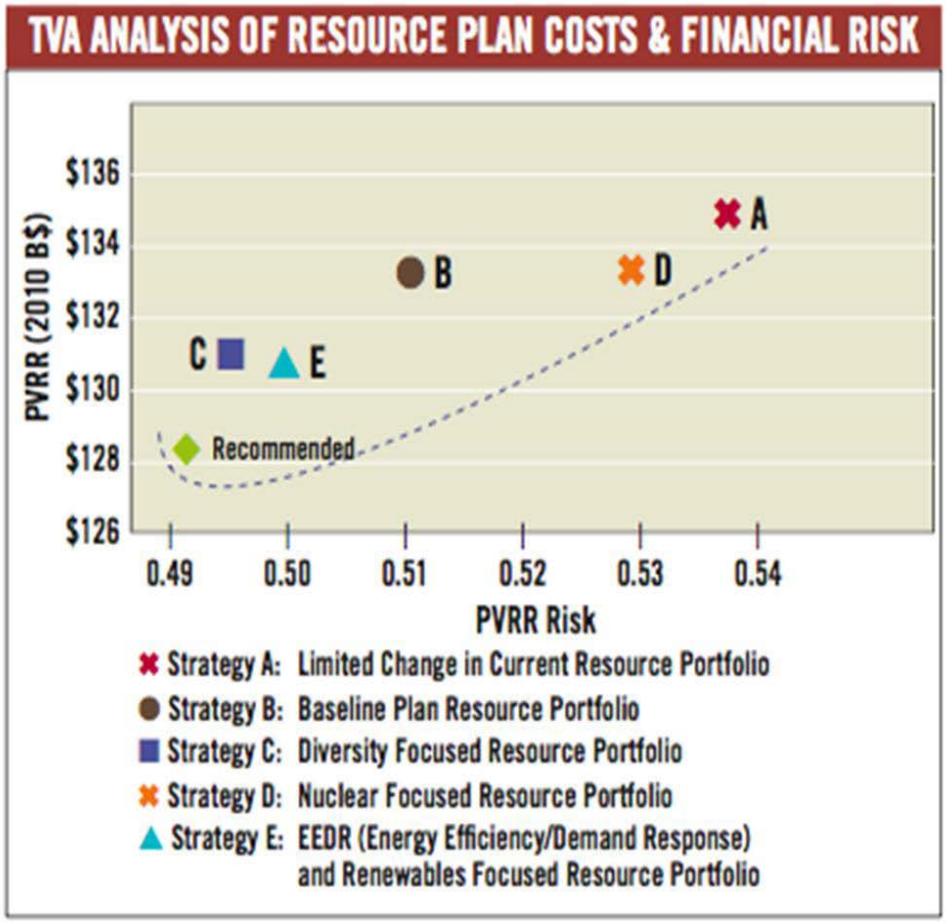

Figure 2-2
Sample Revenue Requirement and Risk

This diagram indicates that strategies using either a diverse portfolio or that are heavily dependent on energy efficiency and demand response are less risky and costly than the other resource options considered.

[6] TVA's Environmental and Energy Future, 2011

Section 3: Enhancing IRP with Probabilities

Adding probabilities to IRP helps quantify risk. It allows the analyst to calculate the probability a case will occur based upon the underlying assumptions that define the case. Note that the straightforward approaches discussed below all assume that (a) the assumptions can coexist and (b) that the assumptions and there probabilities of occurring are independent of each other. With these conditions, it is easy to calculate the probability of a case occurring by multiplying the probabilities of the underlying assumptions. For example if a case is defined by a certain price of natural gas with a probability of 20%, a cost of the technology with a probability of 40% and a cost of carbon with a 30% probability, then the probability of the case occurring is 2.4% (30% x 40% x 20%).

Some cautions about using probabilities. Probabilities are tricky. Probabilities do not have to be symmetric; they can be skewed such as there is a higher chance of the outcome being higher than expected than lower. Also assumptions are not always independent, meaning that there could be some covariance between the probabilities of each event occurring (e.g., a good economy and load growth). Not assigning probabilities is fraught with problems. By choosing not to assign probabilities to different natural gas price forecasts or persistence estimates of DSM means that all the outcomes are weighted as having the same probability of occurring. Not assigning probabilities really means assigning equal probabilities. Anecdotally a professor at the Wharton School taught that outcomes are not equal by posturing that everything had a 50/50 chance. Either the sun will rise or won't rise tomorrow – 50/50.

Although probabilities partially define the risk, the magnitude of the differences of cases also contributes to the risk. Risk is the combination of the magnitude of the effect that an assumption has on a resource's cost and its probability of occurring. If something is very probable to happen as expected (the sun coming up tomorrow), even if the effect is devastating, since the probability is so low, it is not a risk worth assessing. If the range of assumptions produce almost the same results (e.g., load growth is at 1.25% to 1.5%) and the chances are about the same, this also does not create a remarkable risk. It is when the probability of something other than the expected result has a significant probability of occurring and the effect that assumption produces a very different result that risk is greatest and needs to be integrated into the IRP process.

Estimating the Probabilities of Risk

Many of the methodologies discussed herein to enhance the IRP process require the estimation of the probability of something occurring. What is the probability that natural gas prices will be on one path versus another? What is the probability that there will be carbon legislation and if so, what is the probability of different values for carbon? By definition, probabilities can be assigned to everything that is a risk. Some probabilities can be derived from the forecasts that developed the range of assumptions. For example, econometric models produce ranges of results with probabilities statistically assigned to each result. Some probabilities can be derived from experience such as the probability that a wind farm will produce a certain level of output based upon past weather. Some probabilities are more subjective such as the acceptance and persistence effects of demand-side management under a new program (e.g., particulars of the rollout, pricing, opt in or out, etc.).

When there is not data to support the probabilities associated with various outcomes, analysts can apply subjective estimates. Both BC Hydro and Ameren Missouri use this approach. The general approach as outlined by BC Hydro[7] is:

- Gather subject matter experts
- Decompose the problem into manageable set of key drivers of risk
- Pull out the key events underlying these drivers of risk
- Use this information to rank in relative likelihood of these events from most likely to least likely
- With ranking as a starting point, get an 'order of magnitude' feel and qualitative likelihoods (e.g., very probable, almost impossible, etc.)
- Use the structure of the problem (e.g., probabilities must sum to 100 percent) to find the probabilities that the experts feel match the descriptions above
- Review the results and revise and necessary

BC Hydro calls the above approach "textbook" and references Making Hard Decisions: An Introduction to Decision Analysis by R. Clemen. They further reference A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis by M. Granger, M. Henrion and M. Small, who call the eliciting probabilities from excerpts challenging but "the only game in town." According to M. Burgman (Risks and Decisions for Conversation and Environmental Management) this approach resembles the modified Delphi approach for reaching a consensus among experts.

Ameren Missouri (with input from Charles River Associates)[8] used two experts for each variable and followed a similar process as the one outlined by BC Hydro.

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[7] BC Hydro 2013 Integrated Resource Plan, Appendix 4A – Methods for Quantifying Uncertainty

[8] Ameren Missouri 2011 Integrated Resource Plan

Where differences in the probability estimates were most pronounced, discussions were encouraged with the hope of reconciling these differences.

Probability Trees

Probability trees are a convenient way of gathering all the assumptions into cases and assigning probabilities to the assumptions and cases. It is a step in the process after the development of probabilities which follows identifying key drivers/assumptions. Ameren Missouri in its 2011 Integrated Resource Plan started with an initial probability tree called an "untrimmed probability tree", (see Figure 3-1). The utility used four carbon policy assumptions, two gas price assumptions and two load growth assumptions to create sixteen cases (4x2x2). The probabilities for each assumption and for the cases they generated was 100%. The probability of each case is the product of each of the underlying assumption's probabilities. If instead of 4, 2 and 2 assumptions, there were 4, 3 and 3 assumptions, the number of cases would grow from 16 to 36. Add another variable, say cost of construction with three outcomes, and there are 108 cases.

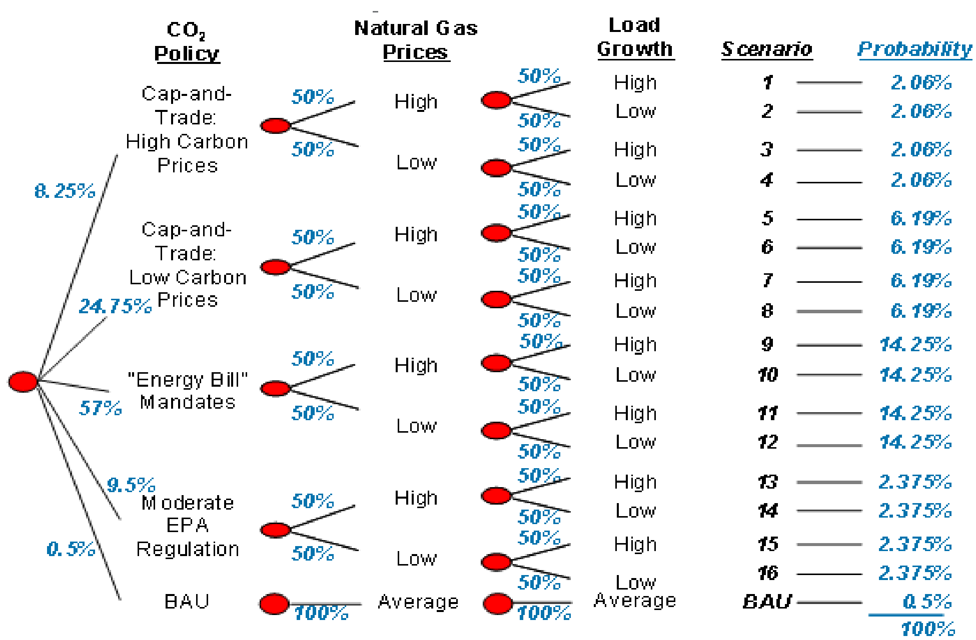

Figure 3-1
Untrimmed Probability Tree

To streamline the process, Ameren Missouri developed a final (or trimmed) probability tree (Figure 3-2) by grouping or compressing some of the underlying assumptions into fewer groups. This reduced the number of cases to nine.

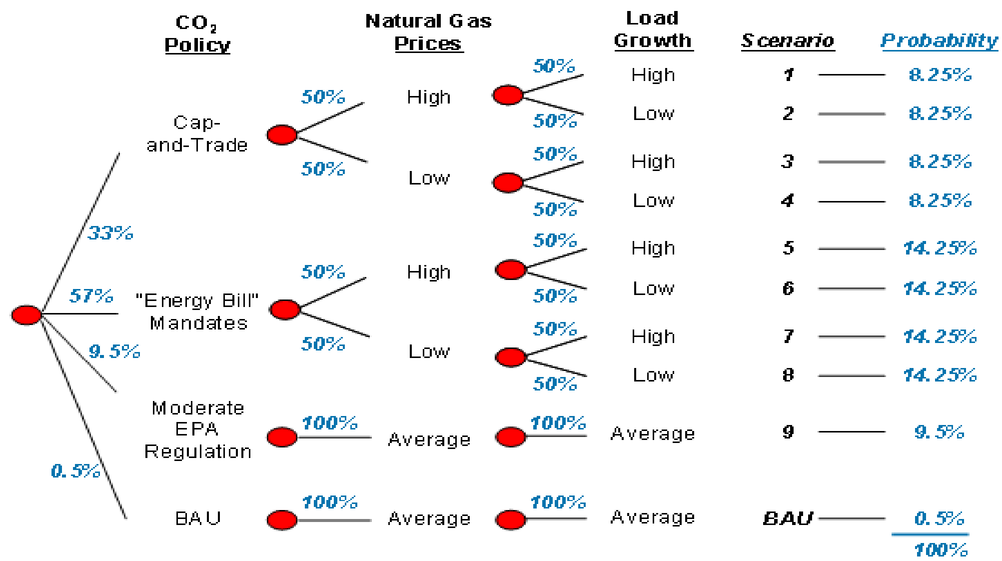

Figure 3-2
Trimmed Probability Tree

Expected Value

With assumptions that make a difference determined and the cases having probabilities associated with them, calculating the expected value of an outcome is simple arithmetic. For any resource or resource portfolio, calculate the preferred metric. This is typically some measure of net present value of a utility's revenue requirement for the proposed resource or portfolio compared to a reasonable alternative. For example, it the utility proposes to build a coal-fired facility, how does that compare to purchasing available power from IPPs or building a gas-fired unit or investing in wind, demand response and energy efficiency. Utilities add resources because of a perceived need (even if that need is economic and not reliability), so it is reasonable to do this type of comparative analysis in developing the measure of cost rather than just look at the cost of investing in a resource versus doing nothing. Note that a reasonable alternative is deferring the construction of unit. It is therefore critical, before performing an expected value analysis to have evaluated enough reasonable alternatives to have selected one as the alternative resource to the proposed resource.

With a proposed and alternative resource strategy identified, it is then a relatively mechanical process using the revenue requirement modeling tools traditional used by the utility to develop outcomes for each of the cases on the probability tree. The outcomes may be positive (the proposed resource is less costly than the alternative under a particular set of assumptions) or negative (the proposed resource is more costly under the particular set of assumptions than the alternative). Take each of the results and multiply them by the probability of that set of assumptions occurring and add the products together to get the expected value of the proposed resource to the alternative resource. Positive expected value means that under this metric, the proposed resource is superior to the alternative. If there are other alternative resources, the process can be repeated.

Risk Assessment Curves[9]

An enhancement to the probabilistic approach discussed above is a concept called the Uncertainty Distribution Curve (UDC). The author who is also the developer of the UDC has not seen this approach applied in any jurisdiction, but with the recent inclusion of probabilities and expected value analysis as discussed above, it could become an apt enhancement. Consistent with definitions used elsewhere in this paper, this is really a risk assessment curve, as it is based upon probabilities assigned to underlying assumptions. The Risk Assessment Curve (RAC) takes all the results from the expected value and probability tree analysis and maps it on a single diagram. This single mapping could allow decision makers to consider more cases without the contraction used between the untrimmed and final probability tree as discussed above.

This tool starts with the difference between a utility's revenue requirements in net present value (NPV)[10] of a proposed resource with an alternative resource and weights each potential outcome by the probability that it will occur. The RAC displays information such as the range of potential differences in net present value, the probability that the resource will produce a positive outcome and the total expected value of the resource compared to its alternative (see Figure 2-1). The x axis is cumulative probability and the y axis a measure of NPV using particular set of assumptions. This visual captures in graphic fashion information that heretofore IRP sensitivity analysis presented as disjointed and/or unweighted results.

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[9] Also see, Revisiting the Crystal Ball: Assessing Uncertainty in Utility Resource Proposals, David Boonin, Electricity Policy.com.

[10] NPV requires the use of a discount rate, the choice of which can be controversial and have material effects on the resource analysis. An examination of the possibility of replacing NPV analysis with return on investment (ROI), as a way of eliminating this potential bias may prove useful.

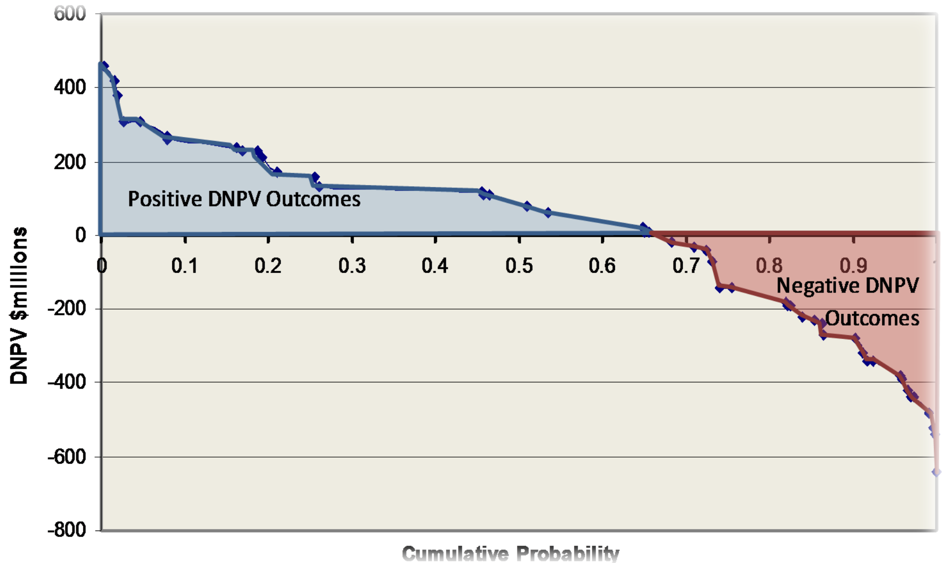

Figure 3-3
Risk Assessment Curve

All RACs have some basic characteristics.

- Each point represents the DNPV for one case (i.e., set of assumptions).
- The RAC is always downward sloping (or flat, when two cases have the same DNPV), because the outcomes are sorted and plotted in descending order.
- When the points are spaced close to one another horizontally, the case represented by the right point has a low probability. When the points are far apart horizontally, the case represented by the right point has a high probability.
- The termination of the curve on the left shows the greatest positive outcome and the termination on the right the greatest negative
- The area above the zero-axis (the x-axis) and under the RAC (shaded blue) represents the probabilistically weighted average of all the cases when the DNPV is positive. The area below the zero-axis and above the RAC (shaded in pink) represents the probabilistically weighted average of all the cases when the DNPV is negative.
- The sum of the blue and the pink areas is the expected value of the proposed solution compared to the alternative solution.
- The point where the RAC crosses the zero-axis indicates the probability that the resource will produce economically desirable results compared to the alternative resource.

In the example shown at Figure 2-1:

- DNPVs for 48 cases were calculated (four construction costs times four productivity levels times three natural gas price forecasts).
- The weighted average of DNPVs (i.e., expected value) was positive, even though the proposed resource was inferior to the alternative in most of the cases (26 of the 48).
- The proposed resource is expected to be superior to the alternative resource about 67 percent of the time.

The analysis does not stop at this point. A complete analysis requires the inclusion of the inverse analysis; using the alternative as the base case and the proposed resource as the alternative. Although it is guaranteed that the sign of the expected value will flip from the base analysis to the alternative analysis, the other metrics that might influence a decision are worth reviewing. These metrics include how bad the worst case is, over what range are do acceptable losses occur, etc.

Another use of the RAC is to display the effect of regulatory conditions on the sharing of risk. Risk allocation is beyond the scope of this paper, however, the RAC can show the difference between a case where the customer bears all risk and the risk is shared with the utility. In the diagram below, the regulator has set a cap on the cost of construction. Analytically, this would set the probability of the cost of construction exceeding the cap for revenue requirement purposes at zero percent. The green area represents the shift in responsibility of risk from the customer to the utility and provided all concerned with an insight into the effect that this regulatory action has on the viability of the project.

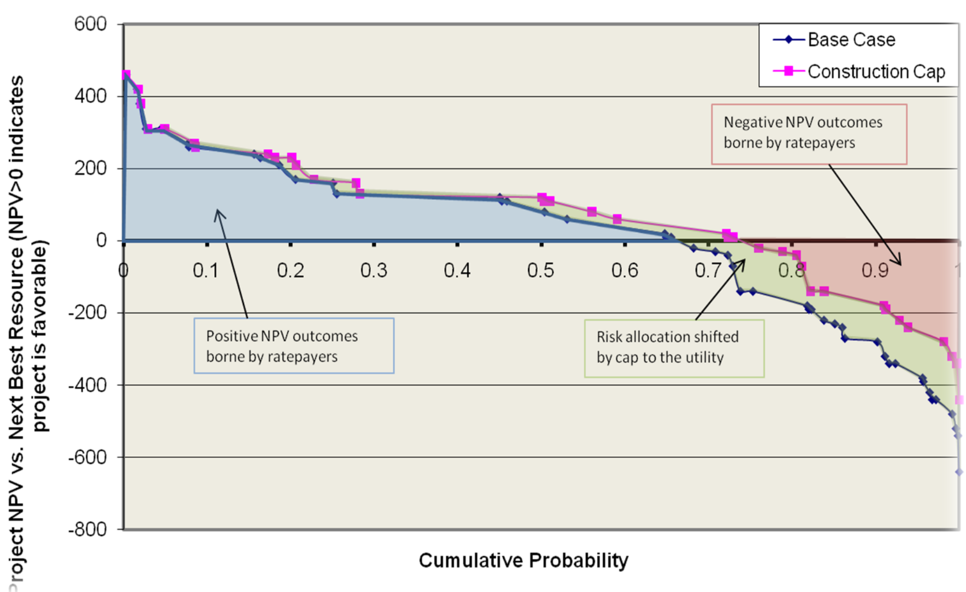

Figure 3-4
RAC with a Construction Cost Cap

Section 4: Regret Scores

Another approach to incorporating risk into the IRP is through the use of regret scores[11]. The Risk Assessment Curve and probability tree approaches indicate that regret is part of any decision. This section deals with an approach to minimize the maximize regret. Regret scores are forecasts of potential regrets (i.e., difference between the "least cost" and the alternative investment). In the following example, the calculation starts with calculating the net present value cost of three investment options under four cases (two high and low gas prices and with and without a carbon cost). To calculate the regret score, subtract the least cost NPV result under each set of assumptions (i.e., $55B for low cost gas and building a 1000MW natural gas combined-cycle plant). Next total the regret scores across each row.

Table 4-1
Regret Scores

EXAMPLE OF REGRET SCORES (TOTAL COST/REGRET SCORE)					
	Low Gas Price $0/ton carbon	**High Gas Price $0/ton carbon**	**Low Gas Price $20/ton carbon**	**High Gas Price $20/ton carbon**	**Total Regret**
Retire coal and build NGCC	$55B/$0B	$65B/$4B	$59B/$0B	$68B/$5B	$9B
Retire coal. Replace with NGCC, wind, demand response and EE	$58B/$3B	$62B/$1B	$60B/$1B	$63B/$0B	$5B
Retrofit coal with environmental controls	$60B/$5B	$61B/$0B	$68B/$9B	$69B/$6B	$20B

[11] See Calculating Regret Scores, Nicholas Institute and Duke University, 2013.

In this analysis the portfolio including NGCC, wind, demand response and energy efficiency has the lowest regret score and the coal retrofit has the largest. Note that this method does not assign probabilities and would need to be expanded to include other critical assumptions such as the risk of performance or construction cost overruns.

Regret scores are also calculated by expected value calculations, as discussed above. As scenario planning is about making decisions without regrets (or always acceptable), the concept of regret scores provides a valuable introduction into scenario planning.

Section 5: Scenario Planning

Scenario planning's purpose is to allow decision-makers to assess potential strategies over widely –perhaps even wildly – different views of the future. Scenario planning for electricity – let's call it Utility Scenario Planning (USP) – differs from traditional Integrated Resource Planning. IRP identifies a least-cost resource plan aimed at meeting future needs as applied to a small band of projected trends – e.g., variations in future loads, fuel costs, resource construction or purchased power costs. Utility Scenario Planning, by contrast, first identifies sharply different views of a distant future – call them scenarios – and then seeks to define a resource strategy that is most successful in addressing all of those potential futures. Utilities sometimes refer to their IRP process as scenario planning because they refer to what has been defined above as cases as scenarios. As decision maker have learned to regret, the future is often very different from what is forecasted.

Scenario approach is an enhancement to IRP designed to assure that regardless what future occurs that the resource choice produces always acceptable results. A challenge is to define 'always acceptable results.' Let's assume that that this means that the lights must stay on (unless part of a demand response or other DSM program), and that all mandates about fuel mix and environmental quality are met. Issues such as energy independence are subject to debate. The driving factor is, therefore, the cost of the resource or portfolio. In the discussion above about risk assessment curves, cases with different probabilities producing negative results were shown – all over a narrow definition of different cases. Scenario planning goes beyond this risk assessment and looks at different futures and resource solutions that work in each of them.

Scenario planning has at least a half-century of history, pioneered by planners for the U.S. military, and then practiced by companies such as Royal Dutch Shell starting in the early 1970s, GE, and others.[12] Others have used it for regional/land[13] use planning or global planning initiatives.[14] As discussed below, scenario planning has become more of a tool in IRP.

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[12] Liam Fahey and Robert M. Randall, Learning from the Future (Wiley & Sons, 1998).

[13] Garry Peterson, et al, Scenario Planning: a Tool for Conservation in an Uncertain World, CONS. BIOL. (Vol. 17, No. 2, April 2003, at 358-66).

[14] The United Nations used scenario planning to help guide its Global Environmental Outlook 3 project. *See* http://www.unep.org/geo/geo3.asp.

Scenario planning is particular applicable when[15]:

- The degree of uncertainty makes the future difficult to predict.
- Too many surprises have occurred in the past.
- The Industry has recently or is about to experience significant change.
- There are multiple opinions/visions of merit
- The company is expected to use scenario planning.

These conditions apply to the electricity industry.

Scenarios have been defined with different nuances by different experts.

- An internally consistent view of what the future might turn out to be – not a forecast but one possible outcome. (Michael Porter, 1985)
- An imaginative leap into the future. (Napier Collyns 1994)
- A series of imaginative but plausible and well-focused stories of the future. (Adam Kahane, 1999)

In this report, scenarios generally refer to plausible and provocative visions of how relevant external forces might interact. Scenarios provide decision-makers with different visions of the future and, therefore, different challenges and opportunities.

Scenario planning is prompted by uncertainties typically associated with long-term commitments and multiple options. Unlike traditional IRP or the probability methodologies discussed above, scenario planning does not attempt to identify the most likely future. Its purpose instead is (a) to acknowledge that uncertainties can drive the future onto very different paths, and (b) to examine how particular solutions address or fail to address those different futures. Like war games for business or government decisions, scenario planning allows decision-makers to examine several scenarios and strategies with the goal of accommodating multiple futures with one strategy – to take the first steps down a path that appears most robust, perhaps one that identifies new services and business opportunities as well as one that avoids disastrous results. Scenario planning allows decision-makers to rehearse the future and identify high-promise, low-risk responses. As an uncertainty management tool it helps identify consistently beneficial results under all scenarios. This is not necessarily the least cost method, rather a hedge against plausible futures that might occur. Since it is a hedge, it is likely not to be the 'least-cost' solution as there is an implicit premium that must be paid.

Scenario planning is only as good as the visions created and used. Well-designed scenarios define plausible, internally consistent views of the future. As compared

[15] Modified from Scenario Planning: A Tool for Strategic Thinking, Sloan Management Review, Winter 1995, Paul Schoemaker

to IRP, USP's core questions are different, the planning process is different, and the decision metrics are different. The table below summarizes key differences.

Table 5-1
Integrated Resource Planning Compared To Utility Scenario Planning

INTEGRATED RESOURCE PLANNING COMPARED TO UTILITY SCENARIO PLANNING		
	IRP	**USP**
What's the question?	What is the optimal mix of particular supply and demand resources to provide a least-cost set of resources to serve a particular future with relatively small differences? This is an optimization approach to resource planning.	What collection of resources allows the utility to meet acceptably a set of scenarios that define a broad set of plausible futures? This is an uncertainty management approach to resource planning, looking to serve multiple futures with a set of resources.
What's the view of the future?	The utility uses a limited set of forecasts of load, fuel prices, economic projections, etc., to portray the future.	The plausible futures are diverse scenarios based upon key uncertainties. No single forecast drives the planning process.
What's the focus?	The focus is on the cost of different technologies and how the analysis changes over a set of probable assumptions (sensitivity analysis). The focus is, "What should I do, given a trend-driven view of the future?"	The focus is on identifying key uncertainties that define plausible scenarios. The analytical or decision-making process shifts from many sensitivity cases to examining many resource portfolios under the range of scenarios.
What's the preferred resource?	Preferred resources are the least-cost mix of resources to meet a particular view of the future, as tested under sensitivity analysis and possibly expected value analysis.	Preferred resources are a set of resources that provide an always-acceptable solution under widely different – but plausible – views of the future.

The Scenario Planning Process

Heinrich Vogel explains, "Scenario thinking is both a process and a posture. It is the process through which scenarios are developed and then used to inform decision-making. … At its most powerful, scenarios help people and organizations find strength of purpose and strategic direction in the face of daunting, chaotic, and even frightening circumstances."[16]

Scenario planning is indeed a process. Outlined below is an eight-step scenario-planning process with an electric utility focus. Some of these steps are iterative; what planners learn in one step might cause them to circle back to a previous step.

[16] Heinrich Vogel, Why Scenarios?, Global Business Network

Step 1 - Top Level Buy-in: Scenario planning is hard and different. It requires top-level buy-in by both utility management and regulators to be useful. Scenario planning should not be attempted without this commitment.

Step 2 – Gather a team: Developing scenarios requires both internal and external human resources and ideas. Utilities and regulators need to include people other than their core planning groups. Whether initiated by the utility or the regulator, more than the typical stakeholders need to be included — e.g., business and governmental leaders, technologists, academics, and researchers, and others. The team needs thought creators, not just forecasters.

Step 3 – Select a facilitator: With all the diverse ideas and backgrounds in the room, it is imperative that the group have a strong and experienced facilitator or team of facilitators. Ideally, the facilitation team should be neutral (e.g., not from inside resource planning department, the regulatory agency or a traditional intervener) and have both utility and scenario planning experience.

Step 4 – Define a starting point: Scenario development is much harder if a starting point, based on present circumstances – such as projected loads, the cost of alternative resources, and fuel costs – is not defined. Scenarios about the unexpected require that we first define the expected. This step is similar to the trend projections that planners develop for IRP.

Step 5 – Define the question facing the decision makers: The USP asks questions broad enough to avoid focusing on a single outcome but focused enough to empower decision-makers to solve the problems they face. For example, "What actions must the utility take to be prepared, under a variety of potential futures, to supply energy service needs cleanly, reliably, and an acceptable cost?" Terms such as, reliable, clean and acceptable must also be defined. The answer is only as good as the question.

Step 6 – Explore the unexpected, identify key drivers, and develop scenarios: Scenario planning requires more than keeping current on events likely to affect utilities, such as expected changes in technology or legislation. Planners must make assumptions about the unexpected. This takes lots of research. They must ask, "Where might we be." What game-changing events are plausible? Exploring the unexpected is what identifies the key drivers. At the crux of meaningful scenarios are key drivers discovered through exploration and research. Planners must carefully and fully define each scenario. Each scenario must tell a different story while being internally consistent. The challenge is to conceive of a small set of scenarios that define a meaningful range of futures that are internally consistent, yet without redundancy and help make superior decisions.

Step 7 – Assess potential strategies and decision-making: Scenario planning is not an academic exercise. It aims to identify a single strategy that works across the range of scenarios, even if the strategy is not the —least-cost solution in any one scenario. Within a strategy, the size of a resource or its technology might not be optimal in each case but should provide an always-acceptable fit across all scenarios. This changes the analytical and decision-making process from focusing on many sensitivity cases and an 'optimal' solution to focusing on many resource solutions or portfolios and an 'always acceptable' solution. If an always-acceptable solution is not found, ask questions such as: is the time horizon too long; is it the right time to make a commitment or can the investment decision be deferred; are the scenarios reasonable and resource neutral.

Step 8 – Monitor conditions: Uncertainties change over time. New technologies that were part of plausible scenarios initially can become commercial or fail and are no longer uncertain. Environmental and tax rules change. Political and economic sea changes occur. Old uncertainties become defined paths. These changes require that scenarios be periodically revisited and changed. Scenario planning requires ongoing monitoring and reassessment of scenarios and planned actions.

Developing Useful Scenarios

The steps described above outlines the whole scenario planning process. This section focuses on the part of Step 6 of developing scenarios. Scenarios emphasize uncertainties. This differs from forecasting an expected range of outcomes. As defined above, scenarios are plausible and provocative visions of how relevant external forces might interact. Scenarios provide decision-makers with different visions of the future and, therefore, different challenges and opportunities.

There are many approaches to scenario planning, and because utility scenario planning has a public element to it, its process might be different yet. There are, however, several themes that are at the core of building effective scenarios.

Look for big differences and lots of uncertainty: This theme echoes the guidance for selecting variables to include in cases in probability analysis. The process usually starts with first generation scenarios that are typically event driven before the process can produce scenarios based upon alternative futures. Examples of major events might be: a major change in technology, and international environmental accord, a national policy banning the importation of oil. These events are initial drivers of the scenarios.

Watch out for basic pitfalls: Be careful not to develop 'cases.' Scenarios might include different consistent assumptions about key variables, but scenario planning is not just expanding the assumptions about trends. Scenarios are not good or bad – just different.

Don't focus on the industry: Focus on exogenous uncertainties about society, economics, politics, the environment and technology. Think beyond the region; in fact think globally (e.g., the effect of rare minerals from China). In a discussion with an experienced scenario planner, he related that he was part of an effort to develop scenarios for an auto company and that the final scenarios did not mention automobiles.

Focus On themes: Themes such as green or oil independence or new technology might be themes that help shape an initial concept of scenario. It is helpful to give scenarios names that let decision makers know what they are about at a high level.

Identify critical uncertainties: Below is a chart that is helpful in identifying key drivers of uncertainty. It allows the analyst to sort all the factors and issues that affect the question and focus on the issues that are placed in the upper right quadrant (very uncertain and very important). Qualitative placements within this quadrant can allow the analysis to focus on issues that are elevated to the top right corner of the quadrant.

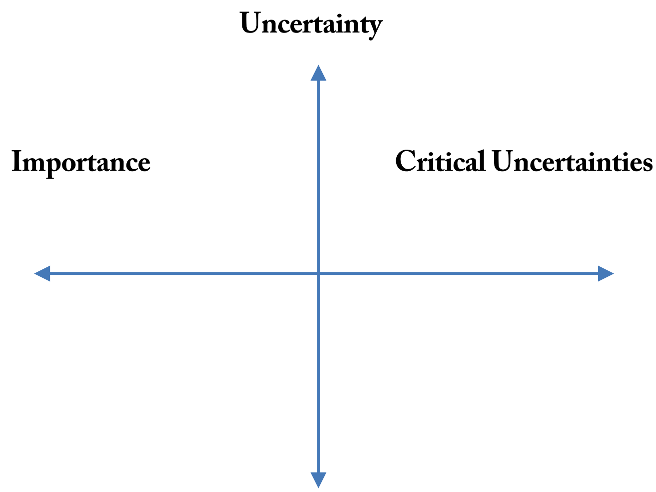

Figure 5-1
Critical Uncertainty Diagram

Select Critical Drivers: Effective scenario planning focuses on a relatively small set of scenarios. Typically, scenarios define four quadrants of outcomes that create different futures that effect the decision at hand. Add another pair of uncertainties and that 2x2 matrix expands to a 2x2x2 cube of eight scenarios. According to existing research17, those three dimensions and eight scenarios are the practical outer limit for scenario planning that is efficient and transparent. The scenarios should be relevant, internally consistent, archetypical and sustainable. They should establish plausible boundaries for alternative futures. Each of these quadrants should have a catchy and descriptive name bringing the initial phase of scenario building to a close.

Typically, scenario developers try to keep scenarios to the simple four sector matrix. To develop scenarios that assist in decision-making, we need to identify the uncertainties that are driving forces – the true game-changers that make a difference to a scenario's story. The recurring question in the scenario development process is: Does this uncertainty create a new story or just a plot

[17] *Ibid.*

twist? Examples might include: demand for fossil fuel in China, India, and other developing countries increases annually by 20 percent; or, renewable energy is lower cost than non-renewable energy; or, energy efficiency reduces U.S. consumption of energy by 50 percent in 20 years; or, the U.S. has constrained access to foreign oil supplies for a protracted period.

Experience by long-time users of scenario planning indicates that it is almost impossible to jump directly to proper decision scenarios without defining an obvious scenario as a starting point.[18] Scenario planning requires thinking about what is plausible rather than what is probable. The process focuses on what might happen, rather than on particular whys and hows.

Early Examples of Scenario Planning in IRP

Several utilities, regulatory commissions and regional planning organizations have tried to enhance their planning process and decision making process by incorporating scenario planning. A brief summary of some these efforts follows:

Green Mountain Power: In 2007, Green Mountain Power of Vermont used scenario planning as part of its IRP process. With critical drivers of geopolitical economics ranging from isolation to integration and the environment ranging from inaction to engagement, Green Mountain developed four scenarios using the quadrant approach of: Green Growth, Green Focus, Fortress America and Back to Business. The details of the scenarios were trend oriented. Green Mountain tested its resource plan against each of these scenarios.

TVA: In 2010, the Tennessee Valley Authority developed an IRP that include six scenarios:

- Economy recovers Dramatically
- Environmental Focus in National Priority
- Prolonged Economic Malaise
- Game Changing Technology
- Reduce Dependence on Foreign Oil
- Carbon Regulation Causes Economic Slowdown

TVA tested its resource portfolio against each of these scenarios. These "scenarios" are more akin to critical drivers than fully developed scenarios, as described above.

Hawaii: In 2010 the Hawaii Public Utilities Commission included scenario planning as part of its IRP process. The order (Docket 2009-108) states, "'Scenarios' means a manageable range of possible future circumstances or set of possible circumstances reflecting potential energy-related policy choices,

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[18] *See* P. Wack, Uncharted Waters Ahead, HARV. BUS. REV., Sept.-Oct. 1985; and Scenario Planning at www.NetMBA.com

uncertain circumstances, and risks facing the Utility and its customers, which will be the for the plans analyzed. A Scenario may not consist of a particular option."

In the subsequent IRP proceeding for HECO's three utilities docket, the Commission named an Independent Entity to shepherd the process and an Advisory Group. On July 29, 2013, the Independent Entity (IE) issued his final report. The report was critical of the utilities' proposed and action plan. The IE expressed concerns about:

- The uncertainty regarding the feasibility and cost of the final resource plans;
- The feasibility and cost of accommodating extensive variable renewable generation
- The feasibility and cost of interconnecting extensive distributed generation
- The feasibility of siting Extensive renewable generation on the Island of Oahu

The IE appeared more concerned about the resource assessment and action plan developed by the utility than the scenarios. The four scenarios were driven by oil prices and clean energy policy – hardly robust drivers of scenarios. The IE did not seem to appreciate the purpose and application of scenarios and was more comfortable in what could be called a probabilistic assessment as discussed in this report.

Since the 2010 order, the governor of Hawaii and all three member so Hawaii Public Utilities Commission have changed. This type of turnover makes the buy-in critical to the scenario planning process difficult to secure.

Colorado: In 20011, the Colorado Public Utilities Commission issued an order that stated, "The utility shall propose a range of possible future scenarios and input sensitivities for the purpose of testing the robustness of alternative plans under various parameters." The report presented by Excel Energy to the Colorado PUC did not meet the Commission's expectations and led the Commission to launch its own scenario planning effort.

Eastern Interconnection Planning Collaborative (EIPC): This collaborative 2011 effort looked for potential 'no-regrets' transmission solutions. EIPC considered a wide variety of potential of potential resources under the following environments: business as usual, federal carbon constraint, nuclear resurgence, national RPS, and aggressive energy efficiency, demand response and distributed generation. These environments are more akin to drivers than full-fledged scenarios.

Western Electric Coordinating Council (WECC): One of the most mature uses if scenario planning in utility planning is by WECC on its Regional Transmission Expansion Planning project. WECC identified the question, key drivers (the economy and technological innovation) and four scenarios. The scenarios are still electric-industry centric and some of the strategies and scenarios are interwoven – a potential bias.

Puget Sound Energy: Not every utility that uses the term "scenario planning" is actually doing what is defined in this paper as scenario planning. For example Puget Sound Energy uses "four complete possible futures"[19] that it calls scenarios. The 'scenarios' are more akin to four cases with varied trends of growth, gas prices and carbon costs. Some of the 'sensitivities' considered by Puget Sound Energy have characteristics of event-driven scenarios such as no Northwest coal, no peakers vs. firm pipeline gas for peakers and financial incentives for renewables.

[19] Puget Sound Energy 2011 Integrated Resource Plan.

Section 6: Conclusions and Future Actions

Why Not More Probabilities and Scenarios?

If these enhancements have the potential of providing such improved insights and better decisions about resource choices, why haven't they been adopted universally? These are not new concepts. Scenario planning is often done by companies that need a competitive advantage and in private. With IRP done in the public view, the hard work and competitive edge associated with scenario planning, does not stay with the utility. It must be an effort and cost appreciated by both the utility and its regulators.

Change is hard. Scenario planning will require that utilities and regulators accept a planning process that introduces softer numbers and concepts (e.g., probabilities and scenarios designed by committee) to better understand risk and uncertainty. Adopting these enhancements requires moving from the safety of narrow set of sensitivity cases that implicitly assign equal probabilities to a single view of the future to one where sometimes soft probabilities drive the answer or we consider resources that provide acceptable rather than some supposed least-cost solution.

Not only must the industry buy-in, but so must the regulators. Recent electric industry and NARUC activity indicates that this is happening. Utilities and regulators need to design processes that respect each other's riles. The recent experience in Hawaii where the Independent Entity was redefining the Commission's order is not going work. The driving element must remain with the utility, with stakeholders contributing to the determination of probabilities and scenarios. The system needs to be transparent. Everyone needs to get onto the same page and accept that to achieve the benefits of these enhancements to IRP, hard work is required by all.

Still change is coming. Most recently it seems that almost no one was doing anything that looked like the probability and scenario analysis discussed above. Over the last thirty years there has been the birth IRP, replacing much narrower views of utility planning. The use of metrics like average cost per kWh, once the gold standard for IRP, debunked for its supply-side bias. No-losers tests have been shown to be losers. Tools to better appreciate risk and uncertainty will soon become the norm; the challenge is to use the best tools practical.

Focus on what matters: Regardless of what approach one chooses, it is critical to focus on the things that make a difference. Whether you are building an econometric forecast or scenarios, and banana production is a good fit, don't use it. It doesn't make sense. We have known for decades to focus a sensitivity analysis on issues that have a significant effect on the analysis. When looking at risk and the effect an item has on the outcome or expected value, two components matter – the probability and the change on the outcome. With scenario development, the more important and the more uncertain the outcome, the more it needs to be included in the scenarios.

Small is Beautiful: E. F. Schumacher, in his 1973 book entitled "Small is Beautiful," found that numerous small items rather than one big item provides more acceptable solutions. In conducting numerous workshops on managing risk and uncertainty in IRP, a common conclusion by the attendants as they try to find resource portfolios that produce always acceptable results is (a) focus on scalable resources such as energy efficiency, DSR and small renewables and (b) shorten the planning horizon. Comparing resources with different life spans is a difficult problem to solve with traditional IRP, even when enhanced by the use of probabilities. How do you compare a resource with a forty-year life (e.g., a base load power plant to ones with ten year life spans (e.g., a purchased power agreement or energy efficiency programs). Scenario planning has a tendency to force the resource discussion towards planning horizons where acceptable results exist rather than towards a prescribed length based upon various resources' lives. Consistent 'winners' from these not overly rigorous workshop analyses are energy efficiency and demand side response programs and to a lesser degree low-carbon distributed generation (green power).

Why Should IRP be Enhanced to Better Understand Risk and Uncertainty

Everything is uncertain. The unexpected happens. It is all too easy to allow our own biases to influence our decisions. Some stakeholders are staunchly opposed to nuclear energy while others see them as major asset in a carbon constrained environment. Some see energy efficiency and demand response as a key component of our energy portfolios while others see them as intrusive and unreliable. We need to introduce tools that help eliminate these biases from our planning.

Phrases such as "too big to fail" or "all your eggs in one basket" or "viable off-ramps" permeate the discussions about utility planning but are seldom rigorously integrated into risk and uncertainty discussions. People are concerned about being stuck with inferior decisions. We need tools such as the ones discussed above that help decision makers compare the risk of a power plant under or over performing to a range of penetration and persistence rates for energy efficiency programs. We need tools that enable decision makers to consider the effects of deferring resource decisions or changing the planning time horizon. We need decision tools that give us insights into doing nothing or placing conditions on regulatory approvals.

Not using probabilities or scenarios as enhancements creates its own set of challenges. Utilities might select a regretted strategy and face a regulatory finding of imprudence. Inferior decisions by regulators can lead to a loss of public confidence. Unacceptable or biased decisions will hurt the region's economy and the utility's customers.

As much as anything, we need an IRP process that gives regulators more confidence in their decisions pre-approving a resource because in today's credit market, pre-approval is something investors want to see. If we are to keep the lights on at a reasonable cost and reasonable cost of capital, regulators, utilities and other stakeholders need to better understand the uncertainty and risk inherent with making and not making decisions. There needs to an implicit partnership in these decisions.

Future Activities

The electric industry in the United States has come a long way in improving its understanding of how uncertainty and risk affects the cost effectiveness of reliability of the electric system that hundreds of millions of Americans rely upon. There is still room to improve how uncertainty and risk are incorporated into the IRP process, enabling utility executives and regulators to make superior decisions. Potential areas of further EPRI involvement include:

- Develop a core set of alternative futures applicable to the electric industry, but not particular to the electric industry, possibly by region.
- Develop a set of event driven scenarios applicable to the electric industry, that all can use as a starting point, again possibly by region.
- Develop a common set of probabilities that can be used in probabilistic analysis.

All of these activities are recommended as future activities for incorporating risk and uncertainty into the IRP process, as they each remove the barriers of pursuing any of the enhancements to traditional IRP. (Another study would be to address the age-old question of appropriate discount rates). Unlike other industries, long-term strategic planning, rather than being proprietary and confidential activity of the boardroom is a public and sometimes collaborative or contentious process. These various methods of addressing risk and uncertainty into the IRP process may not be universally accepted by all utilities, all regulators or even all IRP interveners. The development of a core set of scenarios and/or probabilities outside of a contested process that can be adjusted and applied to specific investigations add transparency and efficiency to the enhanced IRP process. This transparency and efficiency can make these tools more acceptable to the wide variety of participants in the IRP process and help improve the resource commitment decision-making process in the face of uncertainty.

Uncertainty and risk will continue to grow in importance in the IRP process. It is only a question of who will lead and who will follow in the development of these planning process enhancements.

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