# LEAST-COST ELECTRICITY PLANNING IN THE 21ST CENTURY

MARK COOPER, SENIOR FELLOW
INSTITUTE FOR ENERGY AND THE ENVIRONMENT, VERMONT LAW SCHOOL

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## EXECUTIVE SUMMARY

### THE INCREASINGLY COMPLEX CHALLENGE OF RESOURCE ACQUISITION

Energy policy and regulatory decision making in the American electricity sector have always been a challenge because the U. S. is among the most electricity intensive of all nations and it has an extremely wide set of resources with which to meet its electricity needs. Moreover, in the past quarter of a century a fierce debate about the existence and response to climate change, a roller coaster ride in fossil fuel prices and a fizzled "nuclear renaissance" have made things much more difficult by casting doubt on the three primary fuels on which the U.S. relies for almost 90 percent of its electricity. In spite of this uncertainty, because electricity is an essential building block of modern life decision makers are under constant real-time pressures to ensure electricity supply at affordable prices.

This paper argues that the insights and recommendations from the study of financial portfolio and real option analysis, technology risk assessment, reliability and risk mitigation management, and Black Swan Theory all indicate that the 20th century approach to resource acquisition in the electric utility industry is ill-suited to the 21st century economic environment. Indeed, it can be argued that the approaches taken in a wide range of regulatory proceedings such as integrated resource planning, purchase power agreement reviews and general rate cases may have been rendered obsolete by a dramatic change in the terrain of decision making.

Traditionally, in resource acquisition proceedings utilities are required to do what a prudent person would. Using the best decision making tools applied to the best available data with the full range of options and possibilities considered, they should choose the least cost resources to provide reliable electricity. In the current environment these core principles should be reaffirmed, but a prudent, integrated, least cost resource plan must

- be hedged against **risk**,
- maximize options to reduce **uncertainty**,
- be flexible with respect to outcomes that are, at best, **<u>vague</u>** and
- be insulated against **<u>ignorance</u>** of the unknown.

### RECOMMENDATIONS AND CONCLUSIONS

This paper uses contemporary theories of knowledge and decision making applied widely in other fields to build a comprehensive approach to analyzing the increasingly complex conditions under which regulators and policymakers must make decisions about resource acquisition. Applying this framework to familiar data sets on electricity resources, the paper makes an economic/analytic case for a richer and more nuanced view of prudence and offers practical advice for regulators.

- Identify the trade-offs between cost and risk and lower risk through hedging.
- Reduce exposure to uncertainty by buying time.
- Keep options open by acquiring small assets that can be added quickly.
- Minimize surprises by avoiding assets that have unknown or uncontrollable effects.
- Create systems that monitor conditions and can adapt to change in order to maintain system performance.
- Buy insurance where possible.
- Recognize that diversity is the best insurance.
- Build resilience with diversified assets by increasing the variety, balance and disparity of the resource mix.

This analysis calls into question many of the long standing tendencies in utility resource acquisition and capital allocation.

- Acquisition of central station facilities, particularly nuclear, makes long-term commitments in exactly the wrong way for the current decision making environment. It commits to assets that have high risk (e.g. fossil fuel and nuclear facilities) or create large exposure to uncertainty (large size, high capital costs, or long lead times) with technologies that have vague long-term prospects (unstable resource availability and poorly understood environmental impacts).
- The dash to gas that is developing is being significantly overdone because it unnecessarily exposes ratepayers to risk, uncertainty and vagueness.
- A balanced approach that begins with a great deal more efficiency and locally abundant renewables that can be acquired more quickly and in much smaller increments, combined with natural gas, yields lower expected costs.
- Long-term contracts for smaller increments of the more attractive resources, like wind, diversify the resource base, while reducing ratepayer risk and lowering the cost of the resources. They are a form of insurance that public utility commissions should require utilities to acquire.

As long as the conditions in the electricity sector did not deviate from the assumed stability and relative certainty, commissions did not have to incorporate tools of risk, option and diversity analysis. Now that it is obvious that the dramatic change in the underlying conditions have called entrenched approaches into question, public utility commissions simply cannot continue to claim that they are properly evaluating prudency without utilizing the tools that prudent decision makers throughout society are using.

### ANALYTIC FRAMEWORK FOR EXPLORING THE TERRAIN OF DECISION MAKING

Over the past half century a number of analytic tools and investment strategies have been developed to deal with the ambiguity that affects decision making, as shown in Exhibit ES-1. These efforts start from the premise that there are two primary sources of ambiguity – lack of knowledge about the nature of outcomes and/or lack of knowledge about the

## EXHIBIT ES-1: TOPOGRAPHY AND NAVIGATION TOOLS FOR THE REGIONS OF KNOWLEDGE

| | REGIONS<br>IGNORANCE | VAGUENESS | UNCERTAINTY | RISK |
|---|---|---|---|---|
| **TOPOGRAPHY** | | | | |
| **Technology Risk Assessment** | | | | |
| Challenges | Unanticipated effects | Contested framing | Nonlinear systems | Familiar systems |
| Outcomes | Unclear | Unclear | Clear | Clear |
| Probabilities | Unpredictable | Predictable | Unpredictable | Predictable |
| **Black Swan Theory** | | | | |
| Challenges | Black Swans<br>Wild randomness | Sort of Safe | Safe | Extremely safe<br>Mild randomness |
| Conditions | Extremely fragile | Quite robust | Quite robust | Extremely robust |
| Distributions | Fat tailed | Thin tailed | Fat tailed | Thin tailed |
| Payoffs | Complex | Complex | Simple | Simple |
| **Reliability & Risk Mitigation Management** | | | | |
| Challenges | Chaos | Unforeseen uncertainty | Foreseen uncertainty | Variation |
| Conditions | Unknown/ unknowns | Unknown/ knowns | Known/ unknowns | Known/knowns |
| **Characterizations** | | | | |
| Religious | Hell | Limbo | Purgatory | Land of the living |
| Greek Mythology | Pandora,<br>Pythia | Damocles,<br>Cassandra | Cyclops | Medusa |
| **NAVIGATION** | | | | |
| **Analysis** | | | | |
| Approach | Multi-criteria analysis | Fuzzy logic | Decision heuristics | Statistics |
| Tools | Diversity assessment | Sensitivity analysis | Scenario analysis | Portfolio evaluation |
| Focus | Internal resources/ structure | Internal resources/ structure | External challenges | External challenges |
| Data | Swan Search<br>Consistency<br>Unintended consequences<br>Externalities<br>Diversity<br>Structural<br>Variety, balance, disparity<br>Alternative Instrument<br>Sufficiency<br>Adequacy<br>Sequence | Vagueness<br>Supply security<br>Resource base<br>Market scope<br>Environmental impact<br>Pollutants (air. Land water, waste)<br>Greenhouse gasses | Uncertainty<br>Capacity<br>Construction period<br>Sunk cost<br>(Total capital = MW * $/MW) | Cost -Risk<br>Levelized cost of energy<br>Cost variability<br>Fuel<br>O&M<br>Carbon<br>½ nuclear capital |
| **Policy Tools** | | | | |
| Processes | Learning | Learning | Planning | Planning |
| Instruments | Insurance/diversity | Monitor & Adjust | Optionality | Hedging |
| Rules | TECHNOLOGY RISK ASSESSMENT<br>Precaution<br>Buy insurance for system survival<br>Accept non-optimization<br>Diversity<br>Variety<br>Balance<br>Disparity<br><br>BLACK SWAN THEORY<br>Truncate Exposure<br>Buy insurance for system survival<br>Accept non-optimization<br>Redundancy<br>Numerical<br>Functional<br>Adaptive | TECHNOLOGY RISK ASSESSMENT<br>Resilience<br>Adaptability<br>BLACK SWAN THEORY<br>Multi- functionality<br>What Works | TECHNOLOGY RISK ASSESSMENT<br>Flexibility<br>Across Time<br>Across Space<br>BLACK SWAN THEORY<br>Optionality | TECHNOLOGY RISK ASSESSMENT<br>Resilience<br>Robustness<br>Hedge<br>BLACK SWAN THEORY<br>Robust to Error<br>Small, Confined, Early Mistakes<br>Incentive & disincentives<br>Avoid Moral Hazard<br>Hedge |

Sources: Black Swan: Nassim Nicholas Taleb, *The Black Swan* (New York: Random House, 2010), Postscript; Technology risk Assessment: Andrew Stirling, *On Science and Precaution in the Management of Technological Risk* (European Science and Technology Observatory, May 1999), p. 17, *On the Economics and Analysis of Diversity* (Science Policy Research Unit, University of Sussex, 2000), Chapter 2; "Risk, Precaution and Science; Toward a More Constructive Policy Debate," *EMBO Reports,* 8:4, 2007;Reliability and Risk Mitigation David A. Maluf, Yuri O. Gawdisk and David G. Bell, *On Space Exploration and Human Error: A Paper on Reliability and Safety,* N.D.; Gele B. Alleman, *Five Easy Pieces of Risk Management,* May 8, 2008; see also, Arnoud De Meyer, ChristophER H. Lock and Michel T. Pich, "Managing Project Uncertainty: From Variation to Chaos," *MIT Sloan Management Review*, Winter 2002.

probabilities of outcomes. Four regions of knowledge result from this basic analytic scheme – risk, uncertainty, vagueness and ignorance – each presenting a distinct challenge to the decision maker. The purpose of the framework is to identify the characteristics of each region, the analytic tools that are best suited to exploring it and the policy tools that are best able to navigate it, given with the state of knowledge. The integrated approach allows the decision maker to array the options under consideration in a multi-attribute space.

**Risk:** In some circumstances the decision maker can clearly describe the outcomes and attach probabilities to them. Risk analysis allows the decision maker to hedge by creating a portfolio that balances more and less risky assets. This risk analysis has it origin in the financial sector and was first articulated over half a century ago.

**Uncertainty:** In some circumstances the decision maker can clearly describe the outcomes but cannot attach probabilities to them. Here the decision maker would like to keep options open – to delay decisions if possible – until more information reduces the uncertainty. If the decision maker cannot wait, then the path chosen should be flexible, so that it affords the opportunity to deal with whatever outcomes occur. Real option analysis also emerged from the financial sector – a little over a quarter of a century ago.

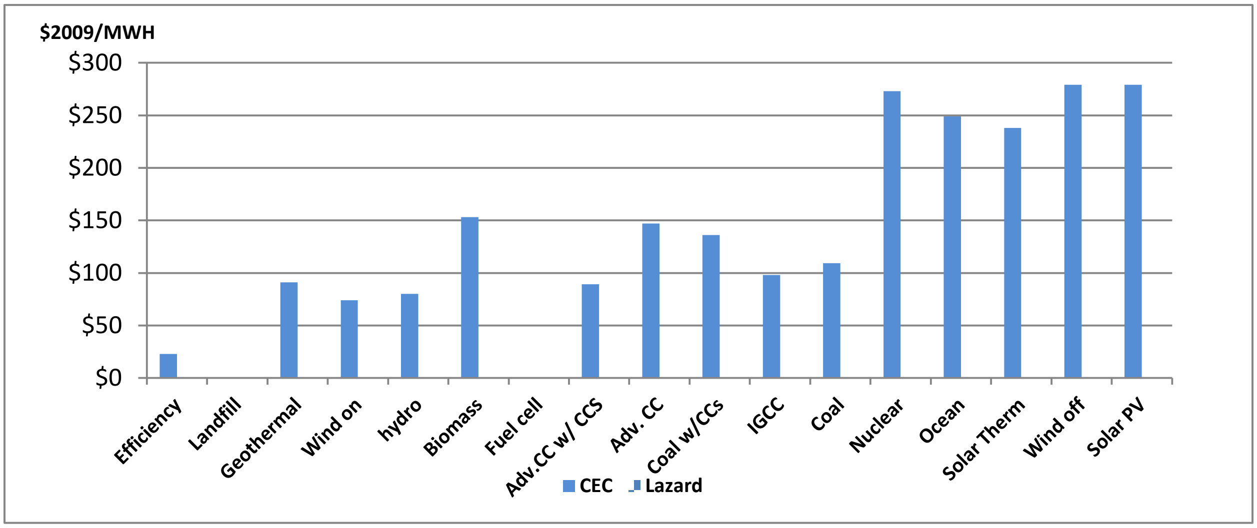
**Vagueness:** In yet another circumstance, decision makers may not be able to clearly identify the outcomes, but they know that the system will fluctuate. Here the decision maker wants to take an approach that can monitor the condition of the system and adapt as it changes. An approach to this situation of vagueness called "fuzzy logic" emerged from the computer science and engineering fields at about the same time as real option analysis.

**Ignorance:** In the most challenging situation, knowledge of the nature of the outcomes and probabilities is limited. Even in this state of ignorance, decision makers have strategies to cope and policies that can insulate the system. Here the analyst looks more inward, to the characteristics of the system to identify those that are most important, and seeks to build systems that ensure critical system functions are performed adequately to maintain system viability under the most trying of circumstances. Multi-criteria evaluations of outcomes point to strategies that buy insurance and diversify assets – summarized in the expression, "put lots of eggs in lots of baskets." This framework has been developing for about two decades in technology risk assessment and the energy sector.

## EMPIRICAL DEMONSTRATION OF THE APPROACH

**Cost and Other Data:** To demonstrate the usefulness of the proposed framework, I focus on a carbon-constrained future and apply the framework to the levelized cost of two well-known data sets, sourced in Exhibit ES-2. These two studies are also the source for the data used in the risk analysis and the uncertainty analysis. Exhibit ES-2 shows the average levelized cost for Lazard and the CEC (supplemented by several EIA estimates). There are half a dozen low-cost, low-carbon resources and half a dozen moderate cost, potentially low carbon resources.

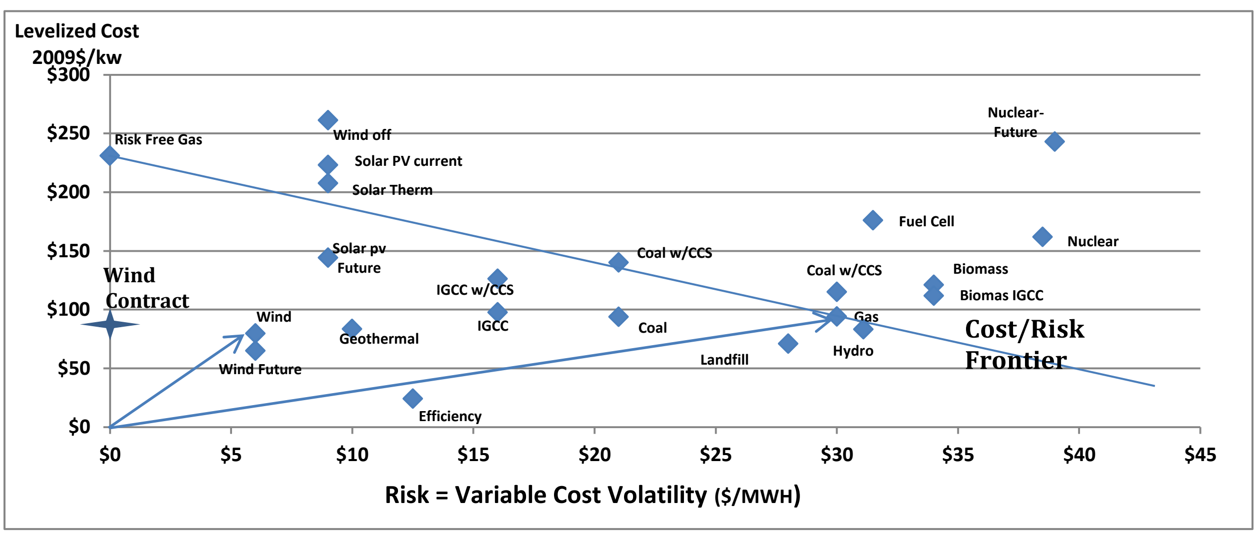
**EXHIBIT ES-2: LEVELIZED COST OF ENERGY**




Source: Lazard, *Levelized Cost of Energy Analysis – Version 4.0, June 2010:* California Energy Commission, *Comparative Cost of Central Station Electricity Generation,* January 2010; *EIA, Annual Energy Outlook: 2011, Levelized Cost of New Electricity Generating Technologies,* is used to provide the second estimate in the case of Lazard hydro and wind-off and CEC, coal w/CCS and coal.

**Risk:** Exhibit ES-3 builds the risk analysis from the cost data. The levelized cost is on the y-axis. The variability of cost is on the x-axis, which includes fuel cost, O&M, and carbon costs. The framework identifies two key measures by which alternatives are evaluated. It identifies a cost-risk frontier, defined by natural gas, which is the fuel of choice at present. The frontier is defined by the base case cost of gas and the "risk free" price of gas, which is the highest price that would occur if all the causes of variability in gas prices are at their highest level. Any option below the cost-risk frontier should be strongly considered since it embodies lower cost and/or risk. Options above the frontier are not attractive. The arrows in the Exhibit represent one method for calculating scales or scores for each resource. The farther from the origin (the greater the Euclidean distance), the less attractive the resource.

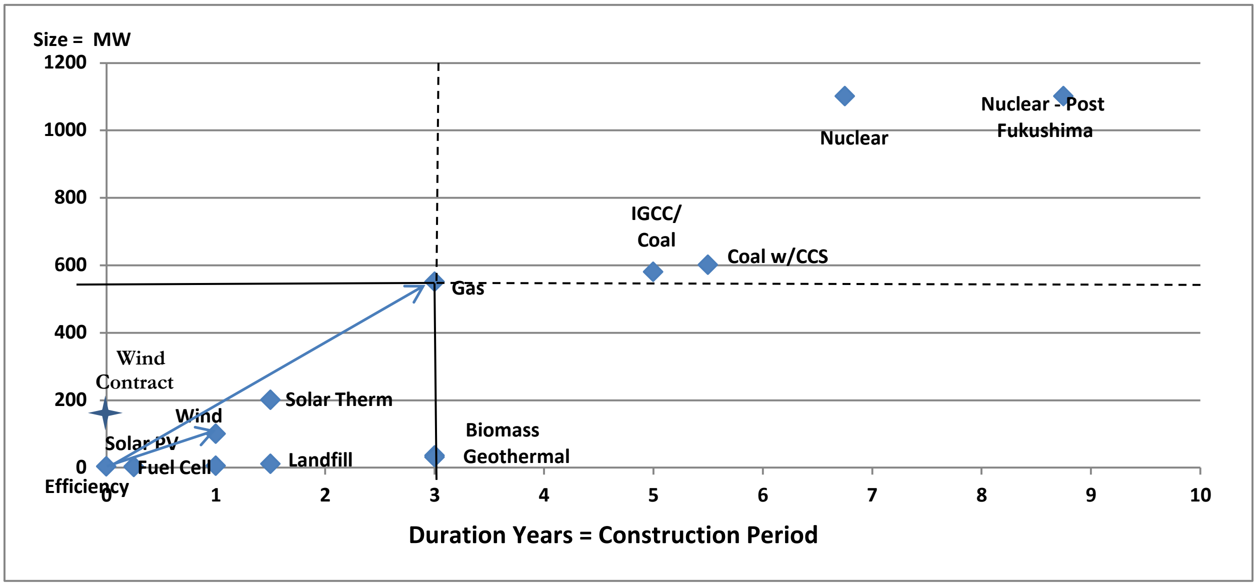
**EXHIBIT ES-3: RISK AVERAGE LEVELIZED COST V. VARIABLE COST**




Source: see ES-2

**Uncertainty:** The key to dealing with uncertainty is to keep options open. Several characteristics of technology options affect the ability to wait – the construction period, the size of the facility and the capital costs that must be sunk into the project. Exhibit ES-4 shows the size and lead time and identifies the "efficient" frontier as a rectangular area with gas as the referent. Anything inside the rectangle is preferable on both the size and duration of exposure to risk. The resources that fall outside the rectangle are less attractive.

**EXHIBIT ES-4: EXPOSURE TO UNCERTAINTY**



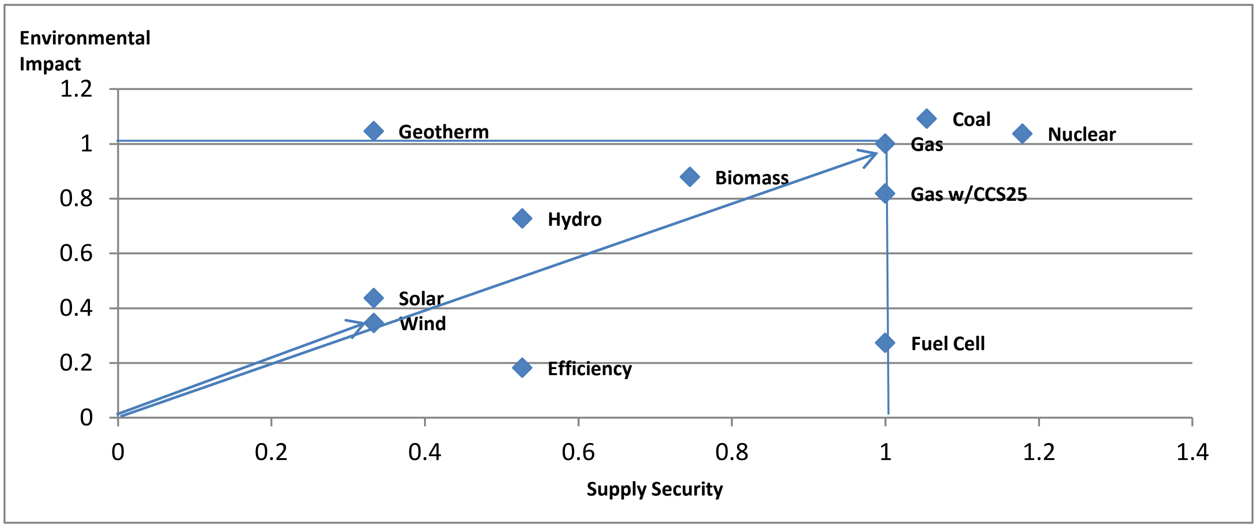

**Source: Lazard, *Levelized Cost of Energy Analysis – Version 4.0, June 2010,***

**Vagueness**: The analysis of vagueness is a much more qualitative area than risk and uncertainty, as should be expected given that the underlying problem in this space is a lack of knowledge about the outcomes. In this region, the strategy is to avoid areas of vagueness. Several outcomes that fall in the area of vagueness in the utility sector are readily identifiable in the literature – security of supply and environmental impacts. Exhibit ES-5 ranks the resources compared to gas. These considerations reinforce the conclusions reached on the basis of the analysis of risk and uncertainty.

**The Region of Ignorance:** The analysis of risk, uncertainty and vagueness produces a very clear ranking of the resources, as shown in Exhibit ES-6. Efficiency and renewables are clearly preferable, with gas as the complementary and transitional resource. Central station facilities are the least attractive options. However, there are additional analyses that should round out the map of the terrain of decision making.

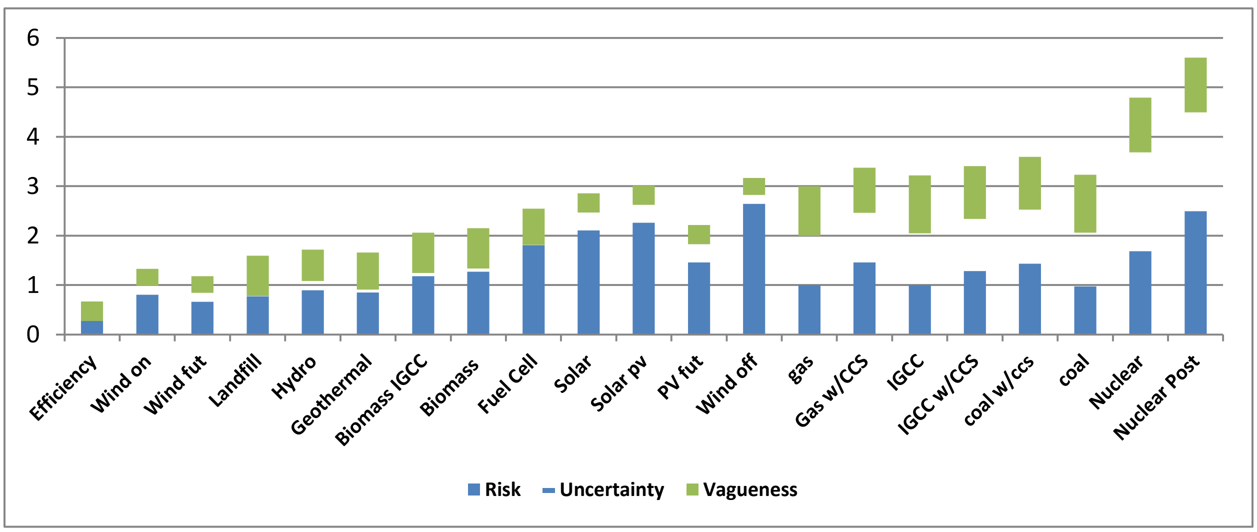
**Search for Swans:** Decision makers must be on guard against additional surprises. They should look for black or white swans that could be lurking beyond the area were the analysis has shed light. While surprises are not predictable, there are places to look. **Consistency:** One obvious step is to explore areas where the analysis in the other three regions has resulted in contradictory conclusions. These would indicate an important area for analysis in the ignorance region. We have not observed contradictory results.

**EXHIBIT ES-5: VAGUENESS: SUPPLY SECURITY AND ENVIRONMENTAL IMPACT**




**Source: Author, see text**

**EXHIBIT ES-6: THE SEQUENCE OF RESOURCE ACQUISITION IN AN AMBIGUOUS ENVIRONMENT**




**Source: Author, see text**

**Unintended Consequences:** Similar to inconsistencies, but broader, are unintended consequences. For example, increasing the reliance on variable renewables can create grid management challenges. At current relatively low levels of reliance on variable renewables, this is not a major problem, but as their use rises it becomes more serious and requires management responses. **Additional Externalities:** Identify potential costs and benefits that have not been factored into the risk, uncertainty or vagueness analyses – e.g. gas: fracking and other environmental concerns; wind: managing capacity factor, reduced natural gas consumption compared to a "dash to gas scenario; efficiency – execution sufficiency, rebound effect, consumption externalities of conservation.

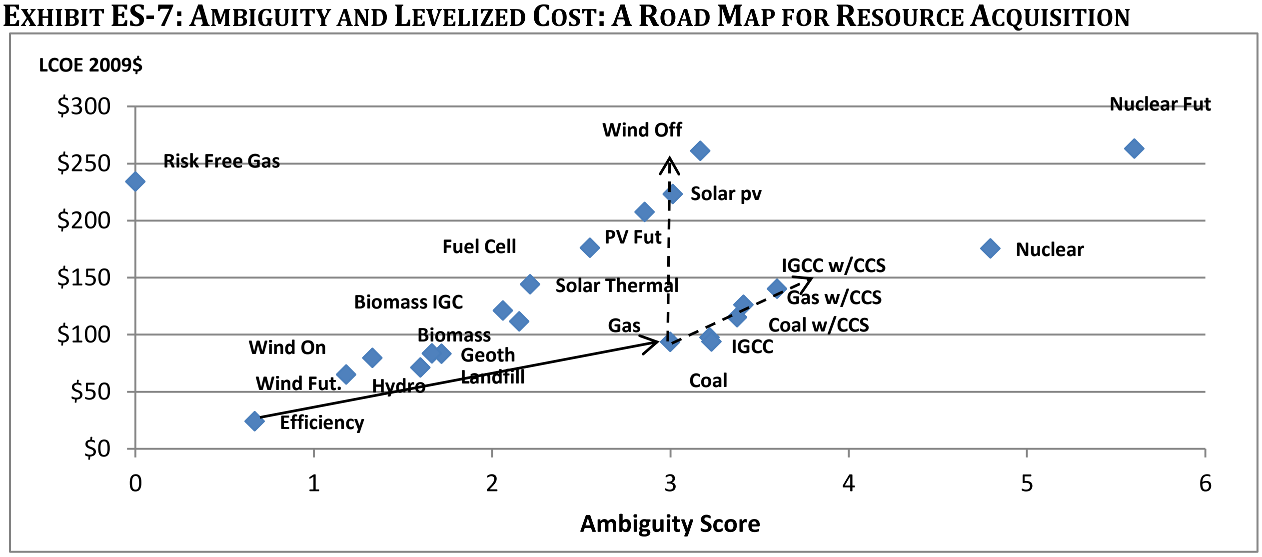
**Diversity:** Diversity is the key to building a robust resources acquisition strategy. Diversity has several aspects. **Structural:** In order to achieve the resiliency benefits of diversity, the portfolio requires resources that are varied, balanced and disparate. **Alternative Instruments:** Within the broad pursuit of diversity as a form of insurance, the examination of the opportunity to pursue diversity through alternative acquisition instruments is an important are of analysis. One approach to stretching the resources is to buy insurance in the form of long term contracts that acquire resources identified as preferable by the analysis of the other three regions.

**Sufficiency:** Given the primary purpose of ensuring an adequate supply, the sufficiency of the resources that are identified as preferable to meet the need for electricity should be considered as an independent question. **Adequacy:** The potential for the resources that are identified as attractive is substantial. Given the fact that five of the six resources that are attractive play a relatively small role in the current resource portfolio, adding these resources in significant quantities over the next decade is not likely to raise serious issues in this region. **Sequence:** These resources have short lead times, ensuring sufficient supply and allowing decision makers to wait to decide about less attractive options.

## CONCLUSION

The analytic tools and policy instruments identified in the study of decision making in the face of ambiguity can help decision makers to become 'comfortable with' dramatically increased uncertainty and to be better able 'to manage what they have become much less able to master.' Exhibit ES-7 combines the 'new" ambiguity scale with the traditional core of utility regulation – levelized cost to identify the best path to the future. The route is clear. It begins with efficiency, wind and a mix of other renewables, with gas as a complement. It can then proceed on one of two paths, a renewable route that goes through solar and offshore wind, or a fossil fuel path that includes carbon capture and storage. Nuclear is the most unattractive of the resources.

**EXHIBIT ES-7: AMBIGUITY AND LEVELIZED COST: A ROAD MAP FOR RESOURCE ACQUISITION**




**Source: author, see text**