CHAPTER 14

Lost in Option Space: Risk Partitioning to Guide Climate and Energy Policy

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Every action taken or not taken, every investment made or not made, every capability gained or lost brings consequences that reach far into the future and remain unforeseen and unforeseeable. Yet, policy choices must be made, and even inaction becomes, in reality, another form of strategic choice. Climate and energy policy, strongly linked through the combustion of carbonaceous fuels, requires planners to persuade a properly skeptical public and their elected officials that the policy "bets" they must place now will perform well far into an unknowable future. To accomplish this fully, they must consider the full spectrum of likelihoods and outcomes, and employ analytical tools better suited to the task.

Two modes of thought tend to underlie the choices made or implied by energy and climate policies: a focus on the likelihood of some future event or a focus on the possible outcomes of future events. "Likelihood" thinking provides the foundation for much of the technology-based regulation predominant in the developed countries—transportation safety and nuclear reactor regulation are two examples. Likelihood thinking tends to the analytical and implicitly discounts future events whose probabilities cannot be quantified. In contrast, "outcome" thinking concerns itself chiefly with possibilities—the consequences of an airplane crash, for example, or a terrorist attack on a nuclear power plant. Outcome thinking need not always be negative, but it tends to lightly regard means and likelihood. Witness, for example, the highly positive State of the Union speech by President Bush in January 2001, which focused on the advantages of the hydrogen economy but provided little technical or policy detail on how to bring this new economy into existence.

Policy planners must integrate their thinking about both likelihood and outcomes if they are to design options that are robust against an uncertain climatic future and if they are to help elected officials and private citizens understand the choices before them. The planners' concern should not be to predict the nature and consequences of future societal risks. Instead, energy planners must focus on options that are wise and that can endure well into an unknowable future. Whether inclined toward likelihood or outcomes thinking, those charged with energy/climate policy must include in their plans the full spectrum of likelihoods and outcomes—the future implications of present decisions.

Uncertainty, Ambiguity, and Ignorance: The Monsters under the Bed

Risk is a time-dependent concept. Whether the hurricane will strike tomorrow and with what consequence can be forecast today, though not precisely. By the end of the week, however, all that will be known—only to be replaced by other unknowns about the future. Similarly, the passage of enough time will eventually illuminate each present-day energy/climate uncertainty, ultimately revealing what could have been done if perfect foresight had been granted the decision maker.

In the case of energy/climate issues, however, waiting for the passage of time to provide clarity raises the prospect of severe and irreversible damage—yet, the nature and extent of this damage cannot be demonstrated convincingly in advance. Thus, the general policy problem persists: Appropriate actions must be taken before it can be shown that they really are appropriate (Bodde et al., 2005).

In the Domain of Risk and Beyond

Where the consequences of prospective hazards can be identified and where their probabilities of occurrence can reasonably be estimated, policy decisions fall into the domain of "risk" as it is properly understood. For decisions that incur this kind of risk, historical experience serves well as the basis for a priori probability estimates and thus provides an invaluable guide to the future. Financial markets, for example, commonly employ the variance of return around the historical mean as a measure of risk for portfolios of financial assets. Thus, an investment in energy conserving technology can be made with a reasonably clear view of its risks and range of payoffs.

Many important policy issues, however, do not fall within the domain of risk because there is a monster hiding under the policy bed: the prospect that events beyond the range of historical experience and unknowable at the time that a decision must be made can emerge to influence its outcome. This prospect cannot properly be called "risk" because neither the probabilities nor the outcomes of these events can be understood adequately in advance. Indeed, they might not be understandable, since historical experience provides no insight into events that never happened or that occurred when nobody was taking the data. Under such circumstances, internally self-referencing tools for managing risk become blind guides to decision making.

Policy planners must think outside the risk box, searching out and planning for strategic surprise, which dwells outside the domain of risk, in order to prepare an option portfolio for issues that are poorly understood, both in terms of the likelihood of the event in question and of its consequences if it should occur. They must consider the monsters under the bed:

- Uncertainty, where reliable estimates cannot be made for the likelihood of the outcomes identified
- Ambiguity, where the outcomes cannot be closely characterized because they cannot be imagined or because such characterization depends upon the perspective of the observer
- Ignorance, where neither likelihood estimates nor well-characterized outcomes enjoy sufficient credibility to guide policy or to motivate action

Risk Partitioning in the Energy/Climate Dilemma

These components of what is commonly called "risk" can be organized into a full-spectrum risk space (Awerbuch et al., 2006), as shown in Figure 14-1. In particular, policymakers would gain insight if the larger energy/climate problem were partitioned into the categories shown in Figure 14-1. The following four examples—energy efficiency, oil peaking, terrorist attack, and climate change—demonstrate how risk partitioning can be done and suggest how two policy tools—scenario analysis and real options analysis—can illuminate the full implications of unknowable futures.

Investing in Energy Efficiency: A Case of Risk

Public policies can apply two basic levers to increase the efficiency with which energy is converted into products and services—influencing the cost of energy and regulating its use. With regard to cost, a complex web of subsidies and taxes, many in conflict with one another, influence the cost of energy at the point of use. Nevertheless, specialists in the field understand these complexities well and are quite capable of estimating the value of the energy saved at any cost level. Even when new regulations, like the Corporate Average Fuel Economy (CAFE) standards imposed by the Energy Policy and Conservation Act of 1975, required changes in energy-using products, the competitors quickly adjusted to the new rules of competition. Once the new rules become apparent, analysts can estimate their impact reasonably well.

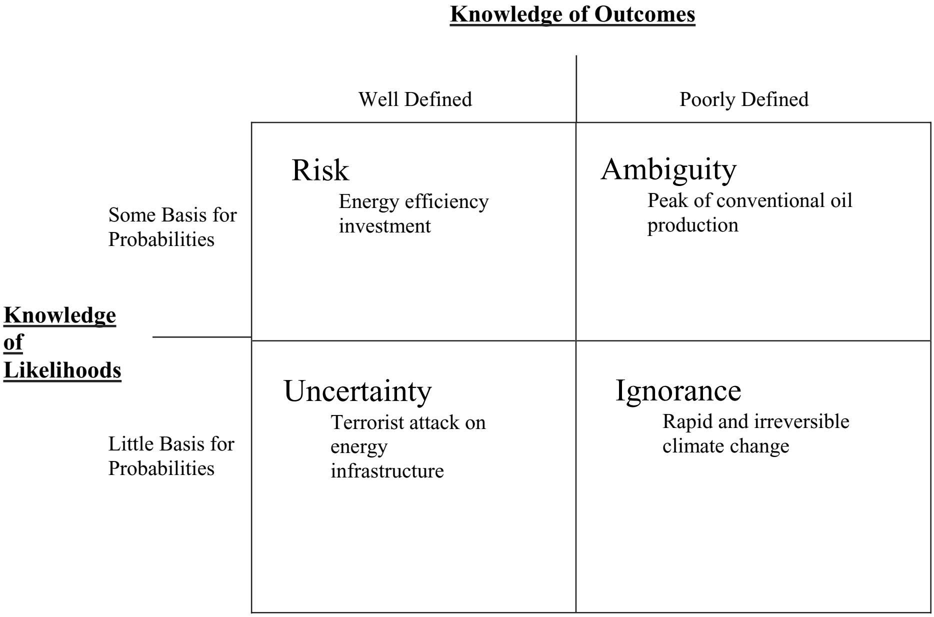

FIGURE 14-1. Knowledge about likelihoods and outcomes. *Source:* Awerbuch et al., 2006.

Thus, investors in energy efficiency, either public or private, can reasonably understand the consequences of their investments and the likelihood that they will achieve the desired returns, and decision makers can find reasonable estimates of the effects of alternative policies on the use of energy (CBO, 2004). For these reasons, this component of the larger energy/climate problem generally falls within the "Risk" quadrant of Figure 14-1. Here, the unknowables do not inhibit action, and policies ensure the clarity that allows the private economy to accommodate the public's goals most efficiently.

Other energy/climate issues are not so conveniently arranged. Either the consequences of alternative actions are poorly characterized or the likelihood of game-changing events cannot be estimated, or both. These issues fall into the less certain quadrants of the full-spectrum risk space defined in Figure 14-1—ambiguity, uncertainty, and ignorance.

Oil Peaking: A Case of Ambiguity

Ambiguity characterizes the northeast quadrant of the risk space shown in Figure 14-1. Issues falling into this quadrant generally have sufficient evidence for most observers to form opinions regarding the likelihood of events, but views diverge wildly regarding their consequences. Thus, a primary objective of policies under ambiguity is to better characterize the economic and environmental consequences of events that can be reasonably foreseen.

Consider, for example, the peaking of conventional world oil production, now predicted by most analysts. About 72 million barrels per day (MMbpd) of conventional oil were pumped out of the ground in 2004, according to the United States (U.S.) Energy Information Administration (EIA). World oil supply, which adds to conventional production, liquids produced from solid hydrocarbons, natural gas plant liquids, other hydrogen and hydrocarbons for refinery feedstocks, and refinery processing gain, was estimated at 84 MMbpd (EIA, 2005). If the current limit to conventional production capacity really is only 10 percent above that, then a peaking of conventional world oil would seem quite near. Indeed, the durability with which price exceeds marginal production cost, apparent in late 2005 prices above $60 per barrel, suggests that financial markets include production limitations, together with disruption risk, in the price calculus.

Other analysts, however, foresee world production capacity in the range of 100 to 120 MMbpd, achievable with investments in new production technologies likely to come online in the next few years (*The Economist*, 2005). Thus, much disagreement remains concerning the timing of the transition from increasing to declining conventional production. But most geologists seem to have reached sufficient consensus that a peaking point exists and that reasonably available signposts—discovery rates for new fields, or projections of petroleum demand, for example—can guide the astute observer in estimating its timing, even if approximately. Thus, the likelihood dimension of the risk space can be estimated.

In contrast, views of the possible consequences of a downturn in conventional production vary sharply with the perspective of the observer. On the one hand, geologists and those holding a science-based perspective tend to view the coming peak as catastrophic (see the Hirsch chapter in this book). They warn that the downturn will be steeper than many realize and that unconventional production of liquid fuels could arrive too late and in insufficient quantity to make a difference. Consequently, this school of thought foresees sharply curtailed economic activity, especially in demand-inelastic sectors like transportation. Some analysts of more apocalyptic persuasion imagine worldwide economic collapse.

On the other hand, many economists imagine a smoother transition as fuel price increases motivate unconventional sources of hydrocarbons—chiefly coal, shale, and tar sands—to replace the conventional. Indeed, the excess of price over the production cost of oil when prices are above $60 per barrel suggests an ample incentive to produce liquid fuels from tar sands, estimated to cost between $30 and $40 per barrel. At worst, this would mitigate the fall-off of conventional oil production, and at best it might provide for continued growth in liquid fuels consumption. However, this cheerful view requires two assumptions:

- An acceptable way can be found to sequester the massive amounts of carbon dioxide that would be released from unconventional hydrocarbon feedstocks or that carbon dioxide release ultimately proves to be less of a concern than economic downturn.
- Sufficient and timely investment in unconventional hydrocarbon sources will be forthcoming in response to the price signals.

Thus, the estimated consequences of the inevitable peak in production of conventional oil depends closely on the point of view of the observer. This has significant implications in the energy/climate policy debate. For energy/climate issues that fall within the Ambiguity quadrant of Figure 14-1, energy policy should assume primary responsibility for relieving the unknowns that inhibit action. In the case of oil peaking, several elements of a transition policy emerge as essential to move this issue into the Risk quadrant, where private investment can more confidently provide public service:

- Cost and Feasibility of Carbon Capture and Sequestration (CCS): Boundaries around the cost to capture and permanently sequester the carbon emissions from unconventional fuel production would enable private investors to place more intelligent "bets" on these resources. This implies an acceleration of CCS demonstrations with the technologies currently in the mainstream—storing carbon dioxide in underground formations.
- Licensing and Regulating Carbon Repositories: Cost is only one dimension of the uncertainties surrounding CCS. The other is regulatory uncertainty. Any carbon repository will surely require some kind of license and receive regulatory scrutiny, thus adding the politics of regulation to the list of hazards facing potential investors. Early policy attention to the conditions for public acceptability and oversight might forestall the protracted legal warfare that made the introduction of nuclear power so painful for its proponents.
- Precompetitive Research and Development: Informed by attention to public requirements like CCS, precompetitive research can lower the risk of investment in unconventional fuel production once its results become widely available.
- Risk Sharing for Early Production: The intent of public policies should not be the removal of all risk—indeed, risk taking is the societal function of private capital. Rather, risk sharing would seek to remove the prospect that catastrophic events outside the scope of private markets will emerge to upset the business case for investment. The Price-Anderson Act, for example, accomplished this, although imperfectly, by placing a cap on liability for accidents at nuclear power plants. Similarly, policy might help move the unconventional production of motor fuels to the Risk quadrant, where private investment can marshal the resources and the skills.

Oil Disruption: A Case of Uncertainty

The world's largest oil processing facility, Saudi Arabia's Abqaiq complex, sits about 24 miles north of the Gulf of Bahrain. The flow of petroleum through Abqaiq is comparable to the entire U.S. production in 2004 of around eight million barrels per day. The entire petroleum output from the southern oil fields in Saudi Arabia flows through this facility to the loading terminals at Ju'aymah and Ras Tanura. The consequences of a successful terrorist attack on any of these facilities can be understood with grim certitude. The likelihood of such an event, however, remains obscure, so the issue of oil disruption must reside in the "Uncertainty" quadrant of Figure 14-1.

On the one hand, many analysts argue that our current understanding of the terrorist threat makes the likelihood of successful disruption remote. This thinking emphasizes the strength of the Saudi security forces and notes that they are composed exclusively of ethnic Saudis, all of the Sunni persuasion. A gloomier outlook notes that Saudi Sunnis also perpetrated the September 11 terrorist attacks on New York and Washington, D.C. Other observers accuse the House of Saud of buying temporary political stability and security by providing financial support to terrorist groups, an arrangement unlikely to prove either stable or secure over the longer term (Baer, 2003).

Better intelligence would, of course, help matters, but past surprises, from the 1941 attack on Pearl Harbor to the 2005 destruction caused by Hurricane Katrina, suggest that plenty of information is often available before the disaster—the difficulty lies in its interpretation and acceptance. To the extent that this remains true, preparations for rapid response are the strongest policies to prevent future energy supply disruptions. Some specific energy policies would emphasize the following:

- Building a much stronger strategic petroleum reserve, perhaps as much as two billion barrels
- Diversifying and dispersing the sources of petroleum, including the expansion of unconventional production
- Eliminating petroleum use from its most demand-inelastic sector—transportation—over the long term

Rapid and Irreversible Climate Change: A Case of Ignorance

Climate change could occur too rapidly for effective adjustment. Such an event would create winners as well as losers, but the latter would probably outnumber the former and would include the poorest people around the globe, always the most vulnerable to environmental catastrophe.

This gloomy prospect, however, has not yet motivated effective policies. Some critics quite correctly note that the scientific case for causation has not been made and that much ignorance surrounds global climate change phenomena (Schlesinger, 2005). They contend that the prospective benefits of protecting against a vaguely specified disaster far in the future must be weighed against the certain costs that would be borne today.

The Ignorance quadrant of the larger risk space tends to dominate much of the landscape in energy/climate policy. The most obvious response would be to accelerate research on climate change in order to expand understanding of the underlying physical phenomena. But until sufficient learning can be accumulated, decisions will still be made—or not made, which amounts to the same thing. The quality of decision making for issues in which ignorance dominates the risk space can be improved through the use of two planning tools commonly employed by industry but neglected or misapplied by the federal government: scenario planning and real options analysis, discussed in the sections that follow.

Scenario Planning

Some federal agencies, notably the U.S. Department of Energy (DOE), use scenarios for planning, but they do not use them as well as they might. The difficulty springs from an excessive emphasis on price, especially the price of oil. Typically, scenarios are built around a set of production and consumption assumptions that yield a base case, with high-price cases and low-price cases on either side (EIA, 2005). Quite properly, these are not offered as forecasts but rather as plausible market outcomes in the future. Nevertheless, the focus remains on the price trajectories and not on the primary forces that drive these outcomes. Those driving forces that are not closely connected to price thereby suffer neglect. An alternative approach to scenario planning, commonly practiced in industry, could raise the quality of the policy debate by building the analysis around those primary forces (Bodde et al., 2005).

The Practice of Planning

Scenarios are stories about the future, a way to understand the impact of conditions that, while perfectly plausible, might never come to pass. Most importantly for policies aimed at an unknowable future, they are not stories about the policies themselves but rather about the context in which those measures dwell. Thus, scenarios, properly done, focus on the external world and the implications of alternative futures for the policies being considered. They offer decision makers and policy analysts a systematic way to ask, "What would we do if . . . ?" and hence provide unique value in managing the Ignorance quadrant of risk space. In effect, scenarios create an intellectual wind tunnel in which new policies and program concepts can be inexpensively tested. For example, Shell Oil, one of the pioneers of scenario analysis, used the method to avoid strategic surprise when prices on the world oil market collapsed to the $10 per barrel range in the 1990s, an event previously held to be unthinkable.

A large literature has grown up around constructing scenarios and using them effectively, though the practice remains more art than science (Schwartz, 1996; van der Heijden, 2002). Here, it suffices to note the common principles that underlie scenario applications, especially in cases where mission and necessity force energy planners to operate in the Ignorance sector of risk space. These principles include the following:

- Operational relevance: Good answers only follow good questions. Thus, scenarios must be built around a key policy issue for which some decision is imminent. A single focusing question should address this decision directly and ask the implications of strategic actions or portfolios of actions that might be taken.
- Causal forces: The scenario planning team must identify the forces operating in the external environment that will most strongly influence the outcome of policy decisions made now. The range of plausible effects of these causal forces then defines the scope of the scenarios. Here the analysis must capture the unpredictable, those forces firmly within the domain of uncertainty, ambiguity, and especially ignorance.
- A learning platform: The chief value of scenarios derives from making them, not from having them. Properly done, a scenario analysis becomes a platform through which organizations and their policy analysts learn about their external environment and the connections between that environment and the prospects for the success of the proposed actions. The very act of constructing the scenarios serves to communicate the policy process throughout the organization that builds them. Thus, the process itself can help build an operational consensus and clarify areas of policy disagreement, where those exist. This means that scenario planning must become a team sport played with intramural talent for its learning value to be fully realized.
- Continuity: Scenario planning only offers value as an ongoing way of mapping how actions that can be taken now ramify into an unknowable future. It does not work well as a one-off activity. It might be more accurate to rename the process "scenario thinking." The scenarios must be updated and revised as the passage of time reveals more about once-obscure events.
- Organizing observations: Scenarios provide a framework for organizing perceptions of unforeseeable events. The future itself will unfold eventually, and scenario analysis can provide signposts to sharpen our ability to discern the emerging patterns of events before they are fully developed. Current knowledge must be scanned for clues to the future and the scenarios frequently updated to account for real observations.

Scenario Principles in Action: A Brief Example

The scenario matrix shown in Figure 14-2 offers an example to illustrate the scenario method and the principles just sketched. It focuses on this question: What policies could be implemented within the next ten years to accelerate the transition of the automobile away from petroleum dependence? Even at this high, strategic level, the focal question still requires a key assumption: that constraints on the supply of conventional petroleum make this transition something that should be accelerated. More tightly focused questions could also be posed, but these would also require more assumptions. The constraints arising from climate change appear as one of the variables in the analysis.

Thus, scenario analysis requires considerable judgment to pose a question sufficiently focused that it illuminates meaningful distinctions among policy choices, yet broad enough to encompass the key issues. There is no formula for striking the proper balance, but if analysts and decision makers take the time to thoughtfully debate alternative framings of the issues, then those efforts will probably meet success. Two primary forces in the external environment will influence the answers to this question within the ten-year event horizon:

- Limits on carbon emissions imposed by climate change concerns. These could vary from strong constraints, the upper half of the policy framework of Figure 14-2, to essentially no constraints, in the lower quadrants. Thus, carbon constraints, or their absence, form the vertical axis.
- Constraints on the supply of conventional petroleum. These range from disruptive interventions, perhaps by terrorists, on the right side of

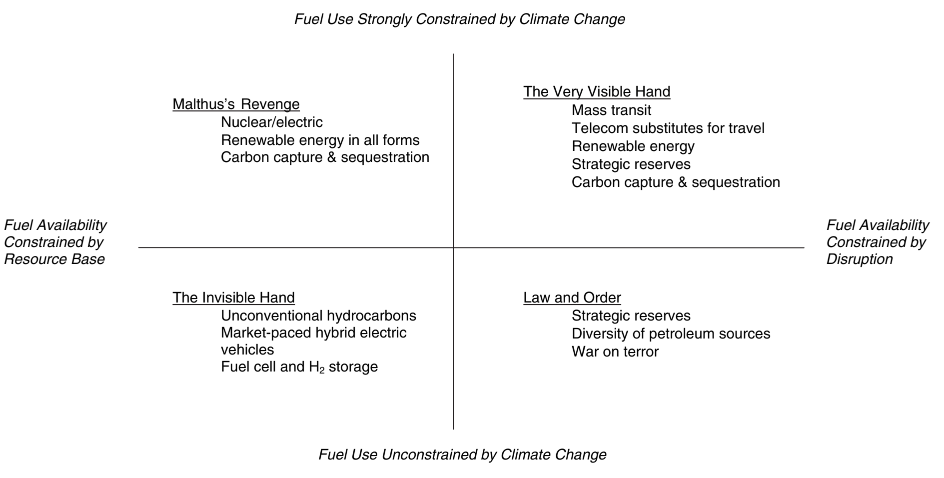

FIGURE 14-2. A policy matrix for the auto transition.

Figure 14-2 to simple resource inadequacy on the left. This builds the horizontal axis.

Taken as the axes of the matrix in Figure 14-2, these forces define a set of four distinct event patterns and capture much of the ambiguity, uncertainty, and ignorance of the risk space of Figure 14-1. Of course, more could be imagined, and "wild card" scenarios are frequently used to capture the impact of occurrences that might be unlikely but would have a severe impact if they did occur.

The essential characteristics of the four scenarios would then be set out as stories about the future, each one labeled with a characteristic name. These stories must be plausible and hold a reasonable prospect of occurring, even though many will not be congenial to the personal wishes of the analyst. In practice, the scenario stories often run several pages in length, but here a simple summary will suffice.

The scenario in the upper left corner of Figure 14-2, "Malthus's Revenge," is an unhappy world. Severe concerns with climate change mean that the atmosphere can no longer be used as a carbon sink. At the same time, resource constraints on conventional petroleum raise the cost of motor fuels and industrial petroleum to levels that cause a global recession. The policies with greatest leverage here would include the following:

- Carbon capture and sequestration (CCS). If this can be done satisfactorily, then the entire hydrocarbon resource base would be open to relieve the resource constraints on conventional fuels.
- Expanded renewable energy use for producing hydrogen or electricity. This important set of technologies provides a partial hedge against the failure of CCS.
- Increased reliance on nuclear energy for producing hydrogen or electricity—also a hedge.

Diagonally across the matrix, the lower right quadrant frames a scenario called "Law and Order." Here, chronic supply disruption, rather than resource depletion, motivates the transition in the auto sector. Environmental considerations do not inhibit petroleum use, either because of offsetting climatic events or simply because concern for the economy has trumped concern for the environment. In this world, CCS offers little value—a striking contrast to the high value of the technology in "Malthus's Revenge" scenario. Renewable energy must compete in the marketplace, but nuclear power remains inhibited by concerns with terrorism and rogue states. The policy options offering traction in such a world include a large strategic petroleum reserve, perhaps on the order of 2 billion barrels, and the capacity to use it as an effective price and supply shock absorber. Other options are diversification of conventional oil supply into politically stable regions and antiterrorist campaigns.

The lower left quadrant shows the "Invisible Hand" scenario. In this world, as in "Law and Order," concern with climate change does not drive policy. Therefore, carbon release does not constrain the search for unconventional hydrocarbon feedstocks, and the use of these hydrocarbon fuels enables a smooth transition away from conventional petroleum.

Early evidence of the feasibility of CCS offers much less value in the "Invisible Hand" scenario because carbon release is not an issue. Renewable and nuclear energy enter the market, but only as their cost competitiveness allows. Hybrid electric vehicles enter the market in proportion to the services they offer—onboard electronic capabilities, improved torque at each wheel, and so forth.

In the "Invisible Hand" scenario, research to improve the competitive status of fuel cells and onboard hydrogen storage might find a higher payoff than in, say, "Malthus's Revenge." This is because the desperate circumstances of the "Malthus's Revenge" scenario would encourage storing hydrogen onboard vehicles in pressurized tanks and burning it in internal combustion engines—both bringing enormous efficiency losses. By contrast, the hydrogen vehicles under the "Invisible Hand" scenario must compete in the marketplace with hybrid electric vehicles on the basis of consumer services. Publicly funded research would be the only way to accelerate that.

Finally, the upper right quadrant shows the "Very Visible Hand" scenario. Public needs drive this scenario, in contrast with the market orientation of the "Invisible Hand." Though conventional petroleum resources remain available, concerns with global climate change and terrorism sharply inhibit their use. As in the "Malthus's Revenge" scenario, early resolution of the questions surrounding CCS offer extraordinary policy value. Renewable energy would be encouraged by policy fiat, though nuclear would remain constrained by terrorist fears, thus removing an important hedge against the failure of CCS. Alternative hedges, such as mass transit and reduced vehicle travel, would rise in importance, and policies to encourage them would find value.

In sum, scenarios provide a systematic way to test how policy alternatives would work under sharply varied, but equally plausible, circumstances. In general, two kinds of policy options emerge: those that are robust across two or more scenarios, like CCS in the preceding example, and those that provide an essential hedge against disaster in one scenario, like nuclear energy or diversification of conventional petroleum supply. A well-balanced policy portfolio would include both kinds of options.

Real Options Analysis

In contrast with scenarios, real options analysis finds its intellectual roots in trading financial options, and hence the method has retained a reputation as a quantitative tool. Like scenario planning, its chief value lies in the thought process, not the numbers. Applied to policy decisions, this concept of options analysis seeks to estimate the value of creating a new "real option": the technological or political capacity to do something that cannot now be done, like permanently and safely disposing of the carbon wastes generated in the manufacture of hydrogen. The knowledge created by the research becomes the real equivalent to a financial call option—the ability, but not the requirement, to invest. Negative results matter, too, and much value can be derived from learning that a desired goal cannot be achieved within reasonable boundaries of cost, time, and public acceptability.

The option value of the knowledge gained from research will vary with future circumstances. In a world characterized by abundant renewable or nuclear energy, for example, an option to dispose of the carbon from fossil-based hydrogen production would add little value. On the other hand, learning sooner rather than later that such disposal is not achievable would have great value, as it would lend urgency to the development of nuclear and renewable alternatives. Thus, real options analysis can help decision makers balance their bets placed throughout the energy portfolio.

In addition to balancing the strategic portfolio, real options analysis offers insights to the managers of individual programs. Take, for example, FutureGen, a $1 billion project, initiated by the DOE with the support of industrial partners, to build and operate a zero carbon emission, coal-fueled power plant. The project bundles two important, but separable, objectives. First, FutureGen seeks to demonstrate that useful energy products—such as electric energy, hydrogen, and process heat—can be produced reliably and economically from the gasification of coal. Second, it would achieve zero carbon emissions by capturing the carbon dioxide effluent and permanently sequestering it from the biosphere in some geologic formation, such as depleted oil and gas reservoirs, unmineable coal seams, deep saline aquifers, or basalt formations. These reservoirs would require monitoring for an extended period to verify that the carbon dioxide did indeed remain in place.

Importantly for policy, these two chief benefits of the FutureGen project are quite separable. The DOE can demonstrate the option of geological sequestration without producing the energy products simply by purchasing the carbon dioxide from conventional power plants or even in industrial gas markets and then pumping it underground. Similarly, the department can demonstrate the chemical refinery approach to processing coal without attempting to dispose of its byproducts. Thus, each of these project components carries a distinct option value that does not depend on the other component—either the value of having the capability or the value of knowing that it cannot be achieved and that something else must be substituted.

As the FutureGen demonstration is currently managed, reliable knowledge about carbon storage must await both the completion and operation of the power plant and the protracted period of monitoring. The high option value of this knowledge would imply that the DOE should consider a separate and early effort in carbon storage. A real option analysis, once accomplished, might lead the DOE to hold that same opinion.

Taking Thought

Though this uncertain world might not be arranged as conveniently as humans might like, neither is it arranged as perversely as we might fear. Putting on a clean shirt does not always attract the soup-of-the-day, even though it might seem to. By taking thought about a future characterized by uncertainty, ambiguity, and ignorance, those charged with policy leadership can place more intelligent bets about the future and, in doing so, better persuade those charged with political leadership of the actions required.

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