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Subcontract Report
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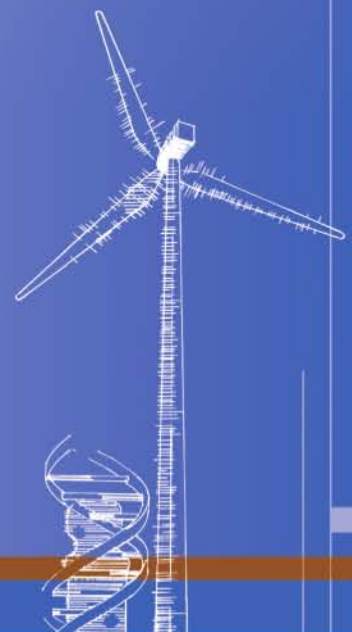

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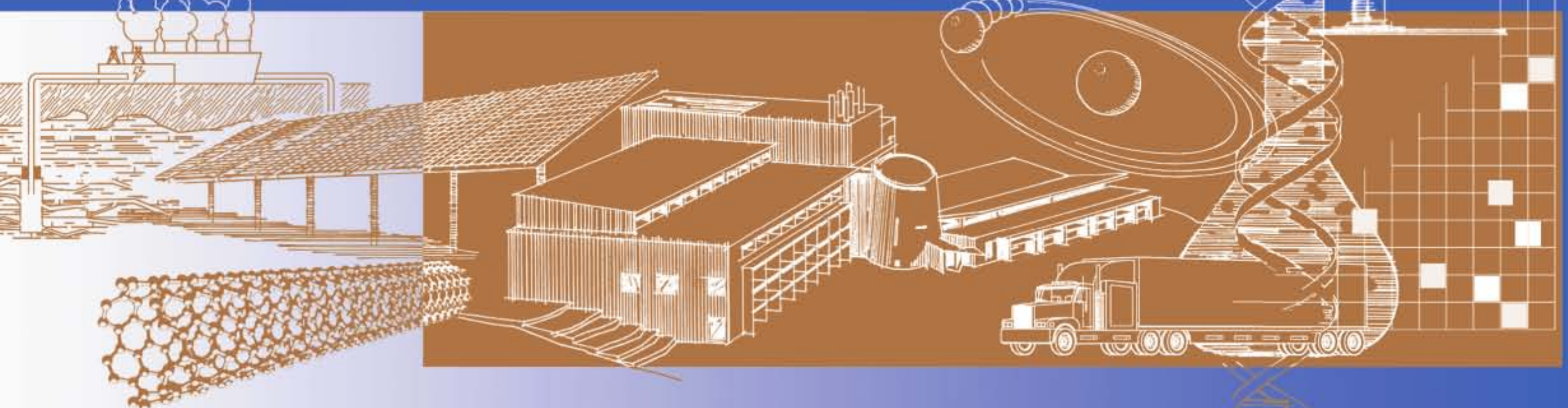

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NREL Technical Monitor: Kathleen O'Dell

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National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
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List of Acronyms

CEQ	Council on Environmental Quality
CO_2	Carbon Dioxide
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FWS	U.S. Fish & Wildlife Service
MBTA	Migratory Bird Treaty Act
NEPA	National Environmental Policy Act
NO_x	Nitrogen Oxide
NRC	National Research Council
NREL	National Renewable Energy Laboratory
NWCC	National Wind Coordinating Collaborative

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Introduction

Assessing the potential environmental and human effects of deploying renewable energy on private and public lands, along our coasts, on the Outer Continental Shelf (OCS), and in the Great Lakes requires a new way of evaluating potential environmental and human impacts. Deployment of renewables requires, I will argue, a framework risk paradigm that underpins effective future siting decisions and public policies.

Risk assessment is not a new ingredient to decision making. It has been widely applied throughout the federal government and corporate sectors, though not yet for renewable energy except within specific sectoral impact areas, such as bird and bat collisions. Developing and applying an integrated risk assessment framework that assesses and compares energy-related risks and benefits are critically needed to make good decisions in a timely way under conditions of significant uncertainty. Of course, risk assessment by itself does not include all the elements needed for complex decisions. However, it provides one body of information and analysis essential for complex decision making. Throughout this paper, we discuss "risk-informed" rather than "risk-based" decision making. Accordingly, we recognize that no generic number exists as the "answer" for setting standards or interpreting regulations on any sector. Risk assessment provides valuable information, but the decision process always reflects "value" considerations that are embedded in the political arena (NRC 2009b). Other issues beyond environmental and human risks—such as financial risks, workforce training and education, federal R&D policies supporting new technology developments, and transmission infrastructure—also must be considered in making decisions.

Evaluating potential risks and making energy decisions requires a sustained program of assessment and research that collects relevant data for each sectoral risk, whether on land or in the sea. (See diagram below for the sectoral risks, e.g., mammal migrations, habitat fragmentation, safety within shipping lanes, and visual effects.) Data collection alone, however, will not lead to better decision making. Arriving at a broad and integrated risk profile of environmental and human effects requires an approach that accounts for the scientific evidence, compares other energy supply options and benefits, and considers stakeholder and public concerns.

Every potential wind energy site has a unique set of potential risks (e.g., navigation may be the principal problem at one offshore wind site, community concerns and tourism impacts at another, and land or marine use conflicts at others). Thus, analysis is needed across risks and sites to discover the principal problem areas or where the benefits may be. An integrated framework also seeks transparency of the major "tradeoffs" of siting decisions for a renewable technology or some other energy supply option.

Proceeding in this direction can be complicated, given that the current regulatory framework for assessing risks and permitting varies across localities and states—although this may be a challenge that all energy supply options face rather than a wind-specific one. The current approach for evaluating potential impacts of wind energy facilities still focuses on sector-by-sector assessments, sometimes with an environmental impact statement or environmental assessment [required under the National Environmental Policy Act (NEPA) for federal lands or laws] and/or a permit application prepared by a government agency and/or a private developer.

Government-sponsored risk research often is designed around perceived “barriers” to wind developments that arise from new problems or piecemeal concerns. One example is radar interference. Federal agencies responsible for hazard assessment of wind developments related to radar performance could employ risk reduction strategies for upgraded software and hardware systems. This approach balances the risks and benefits within the broader context of national security and clean energy deployments. Also decisions about radar interference research would be made in relation to other sector risks.

Perceptions of significant risks also relate to important, but narrow, agency regulatory missions, such as the Migratory Bird Treaty Act (MBTA), in which even one death from a bird collision is forbidden by statute. This risk approach seeks to sensitize agencies, whether local or national, to the advantages of an integrated knowledge base for different approaches to decision making.

The integrated knowledge base includes the major ecological, human health, and socioeconomic risks. It does not attempt to embrace all matters of risk specifically, nor does it treat all issues relevant to decision making. Nonetheless, it provides an integrated view of the major body of environmental, health, and community risks that are critical to any energy facility siting or deployment initiative.

The issue of how to integrate risk assessment into a broader decision-making process is captured in Figure 1. The figure takes into account “non-risk” considerations, such as utility decision making and state renewable portfolio policies.

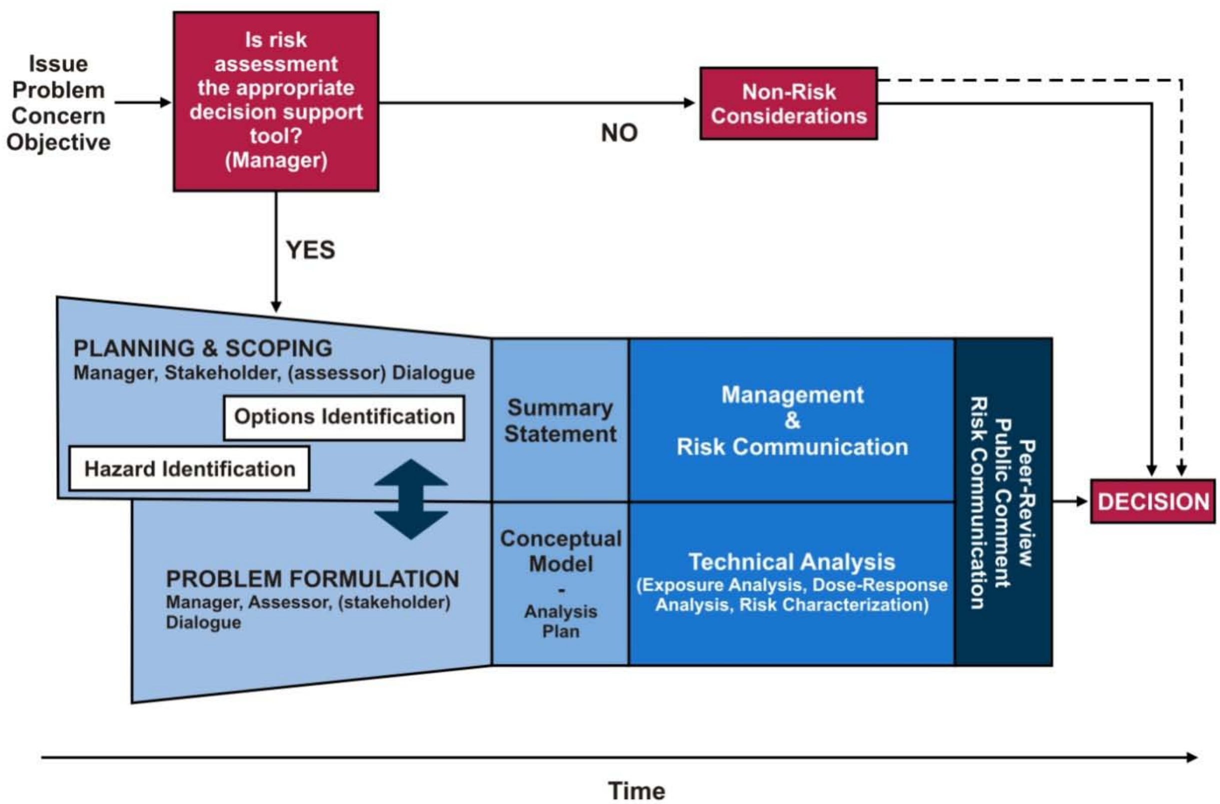

Figure 1. The formative stages of risk-assessment design
Source: Adapted from NRC 2009c:73

The site-, sector-, or project-specific risk analyses are central to a better understanding of risk, but again, they do not serve the decision maker well. The decision maker needs to understand the broad spectrum of risks and benefits across all potential sites to make sound decisions. The proposed framework can be applied at different scales of problems and addresses issues that decision makers face at national and regional sites.

In addition, weighing the size or significance of the risk allows a more objective assessment of whether the tools, methods, and metrics are appropriate to assess the level of risk and make comparisons among energy facility choices. Of course, there are a wide variety of tools and methods, and each sector needs a specific set of analytical tools to address the specific questions related to different sector risks. In some cases, the tools may be more cumbersome or precise given the level of the defined risk and its "impacts" on the human and physical environments. Although the dataset or the analyses may be incomplete and uncertainties are still apparent, expert judgments can assist in determining the adequacy of our knowledge base and the research gaps that exist. An important revelation in the risk field is that further research does not always reduce uncertainty (e.g., National Research Council (NRC) 2005, especially Chapter 4). Therefore, this analytical framework can help an agency or industry group decide where to invest scarce resources to fill knowledge gaps in areas where risk reductions are possible and cost-effective.

In other cases, adaptive management strategies may be employed along with a precise monitoring program. Adaptive management is more than a slogan about postponing difficult decisions related to environmental risks. As Kai Lee, a noted voice in environmental management issues, aptly said, "adaptive management [is] treating economic uses of nature as experiments, so that we may learn efficiently from experience." He continued: "adaptive management is an approach to natural resource policy that embodies a simple imperative: policies are experiments: *learn from them*…. Adaptive management takes uncertainty seriously, treating human interventions in natural systems as experimental probes" (Lee 1993:8-9).

Agencies, organizations, and developers are quick to suggest employing adaptive management strategies for risk and uncertainty associated with wind projects on land and at sea, but institutionalizing adaptive management strategies is a more complex challenge than is typically discussed in renewable energy circles. It involves openly acknowledging mistakes that will inevitably be made, creating institutions that can incorporate lessons learned, and encouraging bold leadership that can admit these mistakes and take a new path (Holling 1978, Walters 1986). It is not clear whether institutions responsible for wind energy decisions—on the local, state, or national levels—are prepared for these challenges. Pathways of "social learning" require a combination of adaptive management and political change that demands debates by, and commitments from, institutions unaccustomed to these circumstances, transparency, and openness.

Although the lifecycle footprints of renewable energy deployment are small today, large-scale deployments are planned on land and in the ocean over the next decade within North America, Asia, and Europe. Now is the time to construct an integrated risk framework that systematically and comprehensively evaluates the range of adverse risks and impacts and compares them with those of other energy supply options. A central principle of such an integrated risk framework is that risks (sector effects) must be compared with each other to develop a transparent evaluation of temporal and spatial impacts on a site or a region and national effects on this and future generations. An evaluation of only one sector separated from other potential problem areas leads to a skewed and incomplete understanding of significant risks, encourages an approach of "subsystem dominance," and dangerously risks a reactive, "risk du jour" approach. (This is an approach that involves responding to risk events as they happen or as they delay individual project developments.)

The lesson is simple. Risk assessment must not make assumptions about what the risk of concern will be at any site or future time. It must follow a strategy that allows work on any particular risk to proceed in a framework in which our understanding of the panoply of risks and uncertainties, and the needed knowledge base, always moves forward.

Nuclear power provides a compelling historical example of how not to do risk analysis. Although it was widely recognized that nuclear plants, like wind plants, entailed a range of site-specific risks, the assumption was made in the late 1960s and 1970s that reactor accidents were the risks of concern and should be the focus of attention. A systematic approach to risk was not taken because it was assumed that we knew the main risk problem. As a result, nuclear waste disposal was neglected, and it contributed significantly to the reason nuclear plants have not been built over the past 30 years. Clearly, we can take valuable lessons from other experiences (NRC 2008a:167).

The major risk in each case is context-driven; it will typically differ from site to site, and a sound risk framework is needed to ensure that an integrated risk knowledge base can be drawn on by developers, state officials, and local officials. This, of course, in no way prevents or discourages a vigorous research program on any particular risk. It simply ensures that any particular risk is always put into a local context and addressed within the context of other risks and benefits.

An integrated risk framework also contributes to effective siting strategies, which are based on avoiding irreducible risks, mitigating those that can be avoided or reduced, and employing cost-effective, adaptive management practices wherever possible. While the nation moves forward in deploying renewable energy, lessons learned and new data will trigger new problems and new solutions to the potential impacts on our communities, landscapes, and the marine environment. Therefore, an important theme lies in understanding that exhaustive studies are not necessary for identifying the most significant risks. Often, more data uncover new problems rather than resolving uncertainties. In the risk analysis world, the focus is on decisions, not the pursuit of perfect knowledge.

An integrated risk framework is discussed and presented graphically in this paper. It identifies the specific analytical steps needed for a systematic and complete assessment and explains how these activities can provide the knowledge base to inform better decision making, effective management approaches, and smarter siting strategies. In the Department of Energy's report *20% Wind Energy by 2030*, a risk framework was identified as a needed step to scale up deployments to gigawatt-scale levels (DOE 2008: 114). The report called for a more systematic approach to environmental risks than the current piecemeal approach, which does not systematically evaluate risks and benefits. This framework can be employed across all renewable energy sources, not just wind energy.

A risk perspective is a major asset for the renewable energy community. It not only addresses important aspects of the broader energy portfolio debate but also can show whether renewable technologies, compared with conventional energy options, are more benign energy sources in terms of health and environmental risks and offer more positive effects on climate change and national security.

Risk Assessment Is Not a New Invention

Risk assessment and integrated risk frameworks are not new inventions for decision makers. Since the publication of the National Research Council's "Red Book" in 1983, they have been widely applied to a range of environmental and health issues within federal and state agencies and in many global corporations. They provide a well-established set of tools and methods that comprise an integrated analytical approach for assessing potential problems and decision making related to technology deployments (NRC 1983). Risk assessments can also provide a focal point for cooperation among local communities and state and federal government agencies. Further, they can build the knowledge base and approaches for determining how safe is "safe enough" and what major tradeoffs exist among different technology and policy choices. In the wind case, the primary question has often been "How many bird and bat fatalities are tolerable?" (See the case study highlighted in Section 3.2, below). Other important questions are "What level of landscape impacts to habitats on land and at sea are tolerable?" and "How should wind energy risks and benefits be balanced with climate change benefits?"

Well executed, risk assessments also can identify major divergences between public perceptions and concerns and expert judgments. There is a wealth of literature on risk paradigms (NRC 1996, NRC 2005, Gregory 2003) and ecological risk assessments and their application to an array of health threats and environmental problems (NRC 2008b). Indeed, the recent NRC (2009c) review of risk assessment practices lists 53 reports by the Environmental Protection Agency (EPA) on risk assessment. In addition, risk analyses have been applied to a variety of industrial sectors and regulatory agencies, including:

- Nuclear power and the nuclear fuel cycle (e.g., deterministic and probabilistic risk and human mortality analyses)
- The EPA and its regulation of the chemical and heavy metals industries (e.g., carcinogenic effects and exposure assessments)
- The Food and Drug Administration (e.g., food safety threshold analyses)
- The Bureau of Reclamation (e.g., dam failure and societal risk assessments)
- The Federal Aviation Administration (e.g., deterministic and probabilistic risk assessments).

The EPA Ecological Risk Assessment Guidelines (1998) were developed to help guide EPA scientists in assessing ecological risks to the environment from chemicals and other agents. In addition, the guidelines inform EPA decision makers and the public about procedures. The EPA published an initial set of five risk assessment guidelines (relating to cancer, mutagenic effects, developmental effects, exposure assessment, and chemical mixtures) in 1986, as recommended by the National Academy of Sciences. In addition to publishing these guidelines, the EPA continues to develop new guidelines as experience and scientific understanding evolve. A 2008 NRC report (NRC 2008a) summarized the guidelines' origin quite clearly by stating that "the premise central to EPA risk assessment practices can be found in enabling legislation for its four major programs: air and radiation, water, solid waste and emergency response, and prevention, pesticides and toxic substances." It stemmed from the science-based regulatory actions from environmental legislation of the 1970s, although the term *risk assessment* was not incorporated into the statutes (Risk analysis emerged in the late '70s and '80s). As yet, studies have not explored energy choices, although the guidelines and methods are clearly relevant to assessment and decision making in the wind case.

According to the EPA (1992), "Ecological risk assessment evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors." Also: "It is a flexible process for organizing and analyzing data, information, assumptions, and uncertainties to evaluate the likelihood of adverse ecological effects. Ecological risk assessment provides a critical element for environmental decision making by giving risk managers an approach for considering available scientific information along with the other factors they need to consider (e.g., social, legal, political, or economic) risks in selecting a course of action" (EPA 1998). Risk assessment is not intended, it should be noted, to cover the array of risks that any energy option entails.

For example, the EPA conducts ecological risk assessments to evaluate the adverse effects of human activities and pollutants on the plants and animals that make up ecosystems. The ecological risk assessments provide a way to develop, organize, and present scientific information so that it is relevant to environmental decisions. These decisions may include the regulation of hazardous waste sites, industrial chemicals, and pesticides. When conducted for a particular place (such as a watershed), an ecological risk assessment can identify vulnerable and valued resources, prioritize data collection activity, and link human activities with their potential ecological effects. The limitation of an ecological risk assessment is that it is a partial assessment of a complex set of risks—such as risks to economic health and social systems—beyond ecology. As a partial assessment of risk (e.g., for species-specific exposure), its value is incomplete until the results are "integrated" with other risk assessments and results.

Wildlife issues have been the focus of risk research in the wind community since the Altamont Pass controversy of the 1990s (See NREL 2009). Nuclear and other toxic materials are absent in the deployment and operation of wind turbine technology. However, due to some evidence of risk to birds, specifically raptor species and habitat fragmentation, there have been recent attempts to apply ecological risk principles to the wind energy.

Around 2004, the possibility of applying risk analysis to the wind energy area was discussed within the National Wind Coordinating Collaborative (NWCC). This DOE-funded, consensus-based collaborative was established in 1994 originally to address the biological debate about the Altamont Pass raptor kills in California. A subcommittee was formed to discuss the relevance of risk assessment to the wind industry, and a white paper on ecological risk assessment was drafted, although it did not include risks to social systems (Efroymson 2007). At that time, a decision on the application of risk analysis was deferred for further conversation among the members, and the group decided ultimately to focus more narrowly on wildlife-related risks at the site level. Other NWCC workshops were held, but they continued to focus on the wildlife sector. For example, the purpose of the Probability of Impacts Workshop in November 2007 was "to assess strengths and weaknesses of current methods to assess wildlife impacts at individual sites." In 2010, the NWCC wildlife workgroup updated its measures and metrics document, which addresses how to collect wildlife and habitat baseline and monitoring data for an individual site. The revised document incorporates ecological risk assessment principles for land-based pre- and post-construction site surveys.

Alternative activities, led by NREL through a subcontract with Energetics, focused on a broader approach toward a better understanding of the application of risk principles. A workshop was held in October 2007 with the nationally-recognized risk expert Robin Gregory, who introduced the principles of risk assessment and structured decision making (SDM). This was followed by one lecture to the Fish and Wildlife Advisory Committee on how SDM might support decision making for wildlife guidelines. These activities led to the preparation of this paper (See Appendix A).

DOE stakeholder efforts have advanced understanding of the extent of wildlife risks from land-based wind deployments. However, an inherent weakness exists in the preoccupation of the research to arrive at a "tolerable number" for wildlife risks. As previously discussed, this goal cannot be resolved with more data collection since it lacks political dimension and values that are essential for decision making.

Similar results are expected from the Department of Interior's (DOI's) Federal Advisory Committee of the Fish and Wildlife Service (FWS). The FWS Wind Turbine Guidelines Advisory Committee was formed on Oct. 24, 2007. Then Secretary of the Interior Dirk Kempthorne appointed 22 committee members, representing a broad array of constituencies from wildlife biologists to wind developers. The scope and objective of the committee, as outlined in its charter (FWS 2009), are to provide advice and recommendations to the Secretary on developing effective measures to avoid or minimize impacts to wildlife and their habitats related to land-based wind energy facilities. After two years of deliberation, the committee developed a set of policy recommendations and voluntary guidelines for wind siting and operations to assess, avoid, minimize, and mitigate the potential impacts to wildlife and habitat from wind power development. The crux of the recommended guidelines is a tiered approach—a decision framework for collecting information in increasing detail to evaluate risk and make siting and operational decisions.

As the Federal Advisory Committee moves forward, its challenge lies in incorporating science-based decisions on risks while avoiding the political realities of clean energy deployments, climate change, and siting strategies. The recommended guidelines may fail to define how decisions will be made by developers or FWS field staff. Further, the premise of the document is to facilitate FWS staff and developers' decisions on site suitability. However, the document does not provide a complete risk assessment methodology because it only addresses the wildlife sector—only one of the sector risks—and does not identify the broader scope of risks or provide risk comparisons. So although DOI was given the responsibility to develop guidelines for siting wind energy, its mission does not cover the wider array of issues needed to make siting or deployment decisions.

The outcome of this committee work resulted in a document that attempts to guide developers and FWS staff on a path to avoiding, minimizing, and mitigating effects from wind facilities on wildlife but falls short on providing a consistent risk-based methodology for proceeding. Finally, as the scope of the FWS is limited to wildlife protection, it is unlikely that this agency is capable of producing a comprehensive analysis of site suitability that addresses the full range of risk issues that may be present. Moreover, FWS is hamstrung by the MBTA regulations that do not allow any "takes" of migratory birds (Lilley & Firestone 2008)—a further barrier to the possibility of integrated decision making from this committee.

A Description of the Integrated Risk Framework

An integrated risk framework is, at base, a logic structure that sets the stage for assessing a spectrum of potential areas of risk associated with deploying renewable energy facilities across the national landscape. Risk assessment informs decision making but does not in itself provide the sole basis for making decisions. Such decisions always involve a range of issues—such as siting strategies, technology developments, and industry workforce needs—that may be important. Beyond technical issues, the "values" placed on wildlife and habitat are complex issues that must be assessed across an array of stakeholders and communities. It is not a step-by-step process, and it does not reflect a linear scientific process for solving a problem. It is instead a set of interactive logical steps that allow for feedback loops. In fact, the interactive nature of this framework shows that stakeholder involvement and public perception are critical at every stage of assessment, deliberation, decision making, and implementation, as a number of National Research Council reports, particularly *Understanding Risk* (NRC 1996), have made clear. To this end, I propose an integrated framework, a graphic description of which is shown in Figure 2. The framework may be applied to evaluating the siting of all land-based and marine renewable energy options, although the sectoral impacts will, of course, vary depending on the specific technology deployed, the specific site considered, the scale of the deployment, and the stakeholder concerns at particular locations. The framework may also support a proactive approach to the complex issues related to siting new energy supplies as well as transmission lines. Of course, no risk assessment would include a detailed analysis of every box in the diagram, but the diagram does provide a systematic framework for the range of questions or potential concerns arising from siting decisions across the country.

An integrated risk framework provides federal, state, and local decision makers and their stakeholders a common ground for analyzing and managing risks and devising public policies and effective siting strategies. This approach is a "big picture" analysis of how the various scientific and analytical pieces fit together at any site or region—or indeed, at the national policy level—and how the potential environmental and social effects in one area compare with those at other sites and with different technologies. It provides a potentially powerful means of collecting and conducting research on many disparate impacts or sectoral areas and for comparing risks that seem quite different. By integrating fragmented research components, decision makers and stakeholders are better able to evaluate site decisions within a broad analytical context—reflecting the complex risk challenges in transforming our nation's energy supplies to a low-carbon portfolio operating on a smart grid. In addition, given the significant uncertainties surrounding many environmental and health problems, comparing the risks helps prioritize which uncertainties require most urgent attention and resources and how scarce dollars to support needed research can best be allocated.

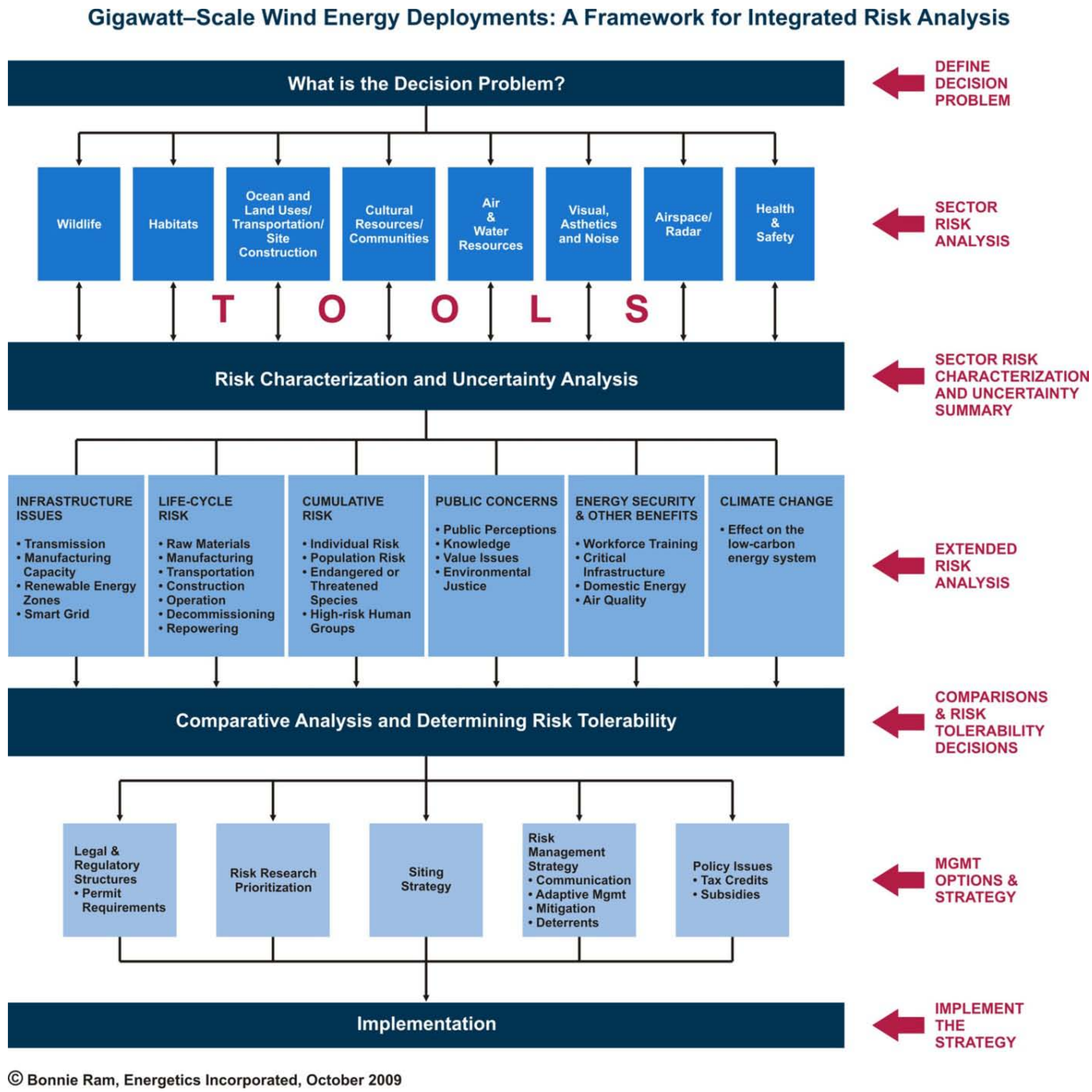

Figure 2. A framework for integrated risk analysis: Gigawatt-scale wind energy deployments

An integrated risk framework can provide a comprehensive approach to renewable energy testing and deployments. In addition, it can assist states and local communities in moving toward an integrated "measure" of impacts and judge their degree of severity and likelihood rather than unduly focusing on what may be the most obvious and contentious impact of today. Without an integrated approach, we are susceptible to "risk du jour" thinking because of legal or regulatory drivers (e.g., MBTA), the experience at the last site of deployment (e.g., radar interference), or the complexities of protecting endangered species (e.g., Indiana Bats, Whopping Cranes). All of these issues trigger sensitivities within the communities that are responsible for managing these risks, but it is a reactive approach—which we argue is the current approach. It allocates resources in a piecemeal fashion that does not reflect the actual level of ecological or human risks. Our nation has invested millions of dollars in studying potential risks. These studies have substantially enlarged our knowledge base of some land-based sector risks, (e.g., bird and bat collisions, radar interference, and property values) while uncertainty analyses and comparative frameworks have been neglected. Without these additional analyses, we will not be able to produce any measurable probability of endangerment. Moreover, we may not be investing in understanding risks that will become the showstoppers of tomorrow (e.g., visual effects on the seascapes and landscapes).

Our experience tells us that "obvious" impacts of today at particular sites may not actually be, and often are not, the showstoppers of tomorrow. How does the nation move toward a more systematic assessment and integrated measure of risks that also allows a comparison of risks from present and future uses of our public lands, the Great Lakes, and our coasts? How shall we learn from the probabilities of consequences at widely separated sites and diverse marine and land environments? An integrated risk framework can indicate the areas of significant effects (both adverse and beneficial), the principal uncertainties that surround them, and the major knowledge gaps that need to be filled (Morgan & Henrion 1990). It provides a systematic and generic approach to comparing risks, assessing priorities, and formulating management strategies rather than reacting to what hits us on the head or what a special interest group finds resonates with their constituency.

What Is the Decision Problem?

The first step in developing an integrated risk framework is to define the decision problem. In the wind energy case, the decision problem is multi-layered with an overriding decision (i.e., how to effectively site gigawatt-scale land-based and offshore wind energy across our nation while minimizing and, wherever possible, avoiding environmental and social impacts). It is important to recognize that a decision problem should be defined before specific tools to measure potential risks are applied and before it is determined how the risk assessment will be framed and scoped. In some cases, the tools for measuring probability and consequences may not need to assess a problem more precisely if this level of detail is not necessary.

It is beyond the scope of this paper to frame a possible decision problem that may focus on global decisions regarding which energy supply choices need to be built where and with what level of risks and benefits—a potential challenge for international organizations. The decision problem we are posing would focus on our national energy portfolio and making choices among the range of power generation facilities and transmission siting options. A regional example of a decision problem is one that analyzes the options of employing offshore wind projects that need underwater cables to connect to coastal load centers versus supplying power from land-based wind projects using overland transmission lines in the Midwest and the Great Lakes. The final layer of decision making may focus on a specific siting choice at one location or multiple locations. The framework can also inform a series of other critical decisions, such as deciding whether a particular risk level is "tolerable," whether public concerns can be mitigated in a cost-effective manner, and whether an adaptive management strategy is appropriate.

Sector Risk Analysis

The concept shows important linkages between the specific sectoral environmental and socio-economic effects of deployment, leading to a summary risk characterization and uncertainty analysis (see Section 3.3, below). The list of sectoral areas shown in Figure 2 is comprehensive but not exhaustive, and it may be expanded to reflect specific priorities of a state or a region or a community making decisions about energy choices. Some states may add in coastal zone management issues, for example, as a separate sectoral evaluation to address marine renewable conflicts with other uses of the coastal environment, such as fishing or tourism. The sectoral risk analysis initially involves desktop studies and/or field surveys to gather evidence on each of these potential effects. Even at a first survey of sectoral risk, areas of particular concern may become apparent, whereas others may be expected to involve only minimal risk. To develop an integrated risk framework, of course, research may be needed in all of these areas to understand the sectoral impacts of deploying the technologies, to compare the seriousness of the risks, and to assess related uncertainties.

At any point in time, the knowledge base of any sectoral risk, particularly at a given site, will be incomplete, uncertain, and need further research. The wildlife issues are good examples of the types of issues that require sustained research to clarify the significance of the risk and the development of appropriate tools and metrics for enlarging the knowledge base. A balanced approach to risk will reveal other sectors that need similar examination and application of tools to contribute to a broader knowledge base, whether at the site, regional, or national level.

The first review of sector assessment using this process may reveal showstoppers or areas in which risk tradeoffs may be required to meet broader decision goals and societal objectives, such as climate change mitigation strategies, new transmission lines, or national energy security. (This is shown in the extended risk row in the diagram. Section 3.4 details these risks.) The underlying objective is to arrive at an initial balanced assessment of potential problems or risks by summarizing risk characterization and uncertainty analysis. As the integrated risk framework shows, focusing on one potential impact (or engaging in "subsystem dominance," which in the technical language of systems analysis is making one subsystem the whole system) while neglecting other risks carries the danger of inaccurate findings and poor decisions. For example, sound judgments cannot be made on site suitability based on any single sector (e.g., habitat fragmentation) alone. A judgment can only be made on whether the site is "suitable" in regard to that specific issue. Such an approach runs the risk of the "risk du jour" problem that has ambushed other energy areas, such as hydroelectric power, which for years focused on fish-friendly turbines while neglecting and underestimating the broader ecological and social risks and benefits.

Each sectoral analysis has its own set of tools and methods that are applied to assess potential effects. For each sector, the probability and magnitude of potential consequences, as well as associated uncertainties, must be identified and assessed. Therefore, each sector will have a range of specific tools that are developed and/or refined over time to attain "better measurements" or temporal and spatial analyses for study results. There may be hundreds of tools available for any specific sector. Visibility and aesthetic issues, for example, require quite different approaches from assessing risk to birds and wildlife. Peer-reviewed measures and metrics for each sectoral analysis are thus essential and are part of an ongoing assessment process.

The uncertainty levels that surround these sectoral assessments need to be examined and related to the seriousness of the risk and the value to decision makers (not only scientists) of improved information and more complete data. Here, value-of-information approaches, in which the contribution of further data to decreasing uncertainty is assessed, may be helpful. Where data is inadequate, expert elicitation (in which experts provide subjective estimates of risk and probabilities) may be needed to help fill the gaps. To date, the wind community has not applied these techniques. Such assessment, however, needs to be conducted using state-of-the-art elicitation methods, such as those pioneered at Carnegie Mellon University (Morgan et al 2001).

The best example of risk characterization with a variety of tools in the wind area, to date, has been extensive work focused on measuring the impacts of bird and bat collisions, but the wind community has yet to determine the probability and magnitude of these potential consequences at a particular site or across the nation. Meta-analyses indicate that between two and three birds per turbine per year is the current estimated risk. For the Mid-Atlantic region, NRC has estimated that wind poses a risk to 0.003% of all birds affected. (See Lilley & Firestone 2008, NWCC 2004, and NRC 2007). Fifteen years of federal and private research and debate has substantially enlarged our knowledge about these risks, but at the same time, the wind community is uncertain about "biological significance" and potential population impacts. Ultimately, the communities, special interests, and politicians must navigate the uncompromising MBTA regulations, in which one migratory bird kill is unacceptable for potential listed species such as the sage grouse and endangered species such as the whopping crane. Clearly, more precise tools or science alone cannot resolve these uncertainties or determine acceptable risk levels.

Some states, however, are moving forward with pre- and post-construction protocols for monitoring bird and bat collisions as well as curtailment policies prior to the initiation of careful uncertainty analysis related to "risk tolerability." Curtailment involves the shut-down of the turbines during low-wind nights when higher incidences of bat kills have been documented. The hypothesis has been made that turbine shut-downs during low-wind periods reduce mortality without a "significant" reduction in power generation or revenue in certain geographic areas (Arnett et al 2009, Baerwald et al 2009). But nagging risk questions as to whether such curtailment is justifiable in risk and economic terms, particularly as compared with the environmental effects of other energy sources or the risk of reduction of species from climate change, persist. Comparing the environmental risks of wind with other energy supply options is essential in reaching judgments about risk "tolerability" and invoking the "precautionary principle." It should be noted that some biologists and decision makers believe that curtailment policies are a good example of how to apply the precautionary principle to the wind case. On the other hand, one could argue that the risks of not deploying wind and opting for traditional fuel supplies also should be evaluated.

Why have the scientific and permitting communities not been able to agree on the risk characterization of this sector? Are more precise and costly pre- and post-construction surveys for estimating bird mortality essential if the level of risk has not yet been judged to dominate other potential risks (such as species loss from climate change) as well as potential benefits (Thomas 2004 and Jetz et all 2007)? Ultimately, risks from wind siting need to be compared with the benefits of wildlife that may be saved from climate change mitigation. What if wind facilities were not deployed? How shall we assess those risks of deploying less wind energy over the next decade? Moreover, the debate needs to assess relative net risk, not the significance of absolute risks, of wind in the context of other energy supply options. We have to better understand how reducing the potential local risks of wind deployments compare with the option of not deploying wind and, therefore, not reducing our carbon footprint over time.

There is a wide body of literature about science and decision making in which the application of best available tools and methods is called upon for examining risks and uncertainties to arrive at a level of confidence. All sectoral risks have different but incomplete levels of data and analyses available, and yet decisions still must be made. Uncertainties or data gaps continue to haunt decision makers in various sectoral areas. The lack of data, variability in data sets, and prevalence of uncertainties does not mean that decisions should be delayed or postponed. (More than 100 nuclear power plants were deployed before the long-term, high-level waste problem was addressed in any depth, and hundreds of hydroelectric plants were built before fish-friendly turbine innovations). As we learn from the integrated risk framework approach, decisions must be made with the best available information at the time and under conditions of continuing uncertainty. As new information continues to evolve, siting decisions are revisited and mitigation strategies and adaptive management principles are developed. Another important aspect is the “influence” of uncertainty in particular decisions, as different decision makers attach different importance to different uncertainties!

The major types of uncertainty that enter into complex decisions (Kasperson 2008) include:

- Risk uncertainty:
  Such uncertainties arise from a multitude of sources, including data inadequacies, model parameters, disagreements about the scope of consequences, the use of subjective judgment when experience is lacking, differences in perceptions of voluntary and involuntary risks, and inadequate scientific understanding. Routine, everyday risks must be compared with rare, catastrophic risks.
- Communication uncertainty:
  Uncertainties arise and abound in the various communication processes, beginning with communication from science to decision makers. But there are numerous stakeholders, each with different knowledge bases, abilities to evaluate, information needs, and opaque value systems.
- Decision options and benefits:
  Multiple options exist for any health and environmental decision. Defining and assessing these options are filled with uncertainties. The relative costs of various options must be assessed, often with questionable data provided by the entity being regulated. Benefits of different actions for health and environmental protection must be estimated and valued and sometimes compared with costs. Benefit assessments pose their own rich array of uncertainties that decision makers must grapple with.

Sector Risk Characterization and Uncertainty Summary

Arriving at risk characterization and decision making for offshore wind deployments, for example, is an ongoing scientific and collaborative process involving marine ecology, public perceptions, fishing, tourism, as well as wind turbines and foundation technologies. To date, these efforts are primarily coordinated through the NEPA process that requires the preparation of environmental impact statements (EIS) and environmental assessments that are central to evaluating sectoral risks and complying with state and federal law. Deploying wind on the Outer Continental Shelf triggers NEPA compliance and the EIS process because it is located in federal waters. In the case of the Cape Wind project in Nantucket Sound, assembled NEPA documentation totaled over 3500 pages. (Cape Wind actually prepared two EISs – one for the U.S. Army Corp of Engineers and one for the Minerals Management Service, since the federal regulatory process evolved after the passage of the Energy Policy Act of 2005). Has this outpouring of pages led to better decision making in the future and a more precise measure of potential risks from offshore deployments? The NEPA procedures, though supporting an important level of public involvement and agency coordination, are not sufficient for formulating integrated risk management strategies because there is no cross-sector measure of probability, magnitude, or comparison of these risks with other sectoral risks (such as visual effects or community impacts), to say nothing about uncertainty assessment in Nantucket Sound. In addition, the Cape Wind example highlights another aspect of risk analysis which is how to manage low level risks (consequences) that are "amplified" by specific values and interests of vocal minorities and the media. .

Usage of the proposed analytical processes and risk measurements has the potential to contribute to a more balanced and systematic approach to gigawatt scale deployments of wind siting at local, regional, or national levels. At best, a business-as-usual approach may replicate protracted permitting processes that delay any near term climate change mitigation strategies. Another phenomenon within sector-specific risk assessments is that any area of impact may become more important than another at different sites at any point in time. There are a variety of reasons, however, why this may not reflect the "actual risk" or impact. Two reasons are noted below:

- Agency priority: An agency mandate or regulatory requirement can skew assessment of risk because a particular species or plant may be defined "endangered" under the law and the agency mission requires its protection. Protection under the law is central to how we evaluate whether a species is important, but this species may not be significant in relation to renewable energy deployments over time and space or to the overall risks at a particular site. This has the danger of skewing the overall approach to risk and what is regarded as the most important issue to be addressed (sometimes called "subsystem dominance," as mentioned previously).
- Uncertainty: Given the limited level of deployments at this stage on land and in the water, and the limited and uneven sectoral knowledge base, there are many unknowns and deep questions about baseline data and the range of risks in the future. These "uncertainties" can create a false sense of high risk that may or may not actually exist across sites. The pre-occupation with uncertainty and what is not known can skew the potential problem areas and can create a perception of "a showstopper risk." As a recent National Research Council (2005) report makes clear, and as noted above, not all uncertainties are reducible by science. Risk management has long recognized that most decisions must be made under conditions of uncertainty.: Decisions cannot wait for perfect information and certainty. The military radar area may be a good example of such uncertainties. In this case, agencies and analysts must decide whether this is a priority risk on which to focus because the impacts are "intolerable," or that they are easily reducible with advanced technologies or software applications.

While these sectoral analyses are being assessed and further research conducted, decisions should not be delayed regarding which risks are tolerable. An integrated risk framework can help to inform "risk acceptability," or better "risk tolerability" decisions, by applying the best scientific judgment and peer reviewed tools and methods along with the incorporation of public values. Risk tolerability is an issue that can be raised but not answered by science since what is "acceptable" is not a scientific question. Inevitably, it involves the application of public values. If it were science based only, we would arrive at decisions in a more linear fashion and solve the question of "how safe is safe enough" within scientific communities. However, these decisions necessarily involve community and individual values at particular places, comparisons across other activities, and legal mandates to frame the decision broadly and logically, with sensitivity to community concerns.

"How safe is safe enough" has been one of the conundrums of environmental and health protection. It is no less an issue for renewable energy. A comparative and integrated framework for risk is needed to make judgments on risk tolerability. Deep knowledge of one or two sectoral risks, at the expense of the full range of risks, always entails the chance that the key risks of concern at the next site will be different than the last, and so strategic decisions, and not a lopsided assessment approach, are essential. Decisions about risks are always made without a full suite of data or a completed methodology. There is almost always a need for more data – the clarion call of every scientist and analyst. Risk decision making, however, must proceed while further research, deliberation, and analysis move forward. It is widely acknowledged, as in the 2008 NRC report (NRC 2008b), that critical decisions cannot be deferred because uncertainties still exist.

In summary, sectoral risks must be assessed and evaluated by their own set of peer reviewed or collaborative tools and methods, as has occurred in the wildlife area of land-based wind projects. However, individual impacts must be compared within a site or a region in order to determine overall risk tolerability across the sectors. A skewed or single-sector view of these impacts, or "subsystem dominance," carries the threat of poor or lopsided decision making. This can also result in endless studies and permit requirements that increase the cost of deployment by requiring ever more precise measurements to reduce uncertainties that cannot be fully removed.

The end product of this first stage of analysis is a sector risk assessment that also must be informed by stakeholder involvement. At the end of this, the decision problem should be well defined, the major sector risks identified, and the major tradeoffs and showstoppers apparent. The risk characterization summary gathers the evidence within and across the sector risks to compile a type of initial meta-analysis of risks. This summary identifies the significant risks, their probability and magnitude, and the base for an initial risk tolerability judgment. The analyses also highlights the probability of rare but catastrophic risks as well as potential major events or surprises possible in the wind power area.

Extended Risk Analysis

After the individual sector evaluations and their comparisons and the summary risk characterization, including major uncertainties, we move to decisions focusing on a more complex extended risk analysis. These address life cycle effects, building the necessary human and physical infrastructure (such as transmission lines), public perceptions and concerns, major benefits, and cumulative risks.

There is a need for **life cycle risk assessment** across all energy supply options in order to make clear decisions for designing the future national energy system. Such an assessment has been undertaken by the European Union (ExternE 2009) through a series of studies, but the U.S. has yet to conduct such an extensive comparative analysis. In the early 1990s, the U.S. Department of Energy combined its efforts with a similar project by the European Communities to study the major negative and positive externalities associated with the fuel cycles involved in electric power generation. This collaboration produced a multi-volume report, which chiefly focused on the byproducts of fossil fuels (Oak Ridge National Laboratory & Resources for the Future 1992). Over the last two years, research initiatives from New York State Energy Research and Development Authority (NYSERDA), universities, and the NRC (2009a) have attempted to construct comparative analysis across energy options. The NYSERDA (2009) study focused on qualitative measurements of potential wildlife impacts across all energy supplies. A lifecycle assessment of the various renewable energy options, however, never has been prepared for a future U.S. national energy portfolio. A full life cycle assessment would conduct a cradle-to-grave analysis, from securing raw materials to manufacturing components through to the recycling or disposal of components in the decommissioning phase. It is important to compare the life cycle risks of alternative energy sources with fossil fuels and nuclear power, especially since renewable energy supplies are likely to have fewer deleterious life cycle issues as compared with those alternatives.

The life cycle analysis should assess qualitatively the potential impacts at each stage of the lifecycle to arrive at relative risks (but not necessarily quantitative measurements). Again the crux of this analysis is a comparative assessment across energy supplies (as in the ExternE studies mentioned earlier) and across significant risks, such as acid deposition, mercury contamination of fish, bioaccumulation of chemicals, and contributions to climate change impacts. This analysis creates a balanced framework and underpins a national debate about potential risks and benefits of transforming the energy system that President Obama has alluded to.

Infrastructure issues include the construction of energy facilities, as well as the substations and transmission lines, that are needed to transport energy supplies to the loads in urban and rural areas across the nation. Gigawatt-scale wind energy will significantly change how the existing electricity grid operates, adding requirements for more transmission capacity, integration costs, energy storage, and reliable backup generation. As such, the challenges of integrating high levels of renewable energy into the electrical grid are an area of major focus. The Utility Wind Interest Group was organized in 1989 to address the issues surrounding the integration of wind power into utility systems. Two unprecedented challenges are at the center of this issue: the need to reliably balance electrical generation over the grid when a large portion of energy is coming from a variable power source such as wind, and the impacts of constructing the thousands of miles of transmission lines that are needed to support gigawatt scale renewable energy deployments (DOE 2008). Uncertainties remain over the most effective means to integrate variable power sources, such as wind, into the national electrical grid. A full system analysis of cycling fossil plants and smart grid systems impacts on CO_2 and NOx is needed. Current research priorities include developing advanced weather forecasting techniques in order to anticipate upcoming changes in the amount of wind energy being generated and investigating energy storage systems to capture wind energy generated at off-peak times for use later. Implementing a risk analysis of integration issues requires a team of experienced electrical systems engineers as well as risk analysts.

Beyond the technical integration uncertainties are the siting and deployment challenges of building the transmission lines needed to support gigawatt scale renewable energy deployments. Weighing the risks of transmission siting, along with the benefits of "transporting" electrons with lower carbon content, are part of an integrated risk framework. Several recent initiatives evaluating transmission siting lack an overall risk framework (e.g., Texas Clean Renewable Energy Zone [CREZ] process) or focus only on some sectoral risks (e.g., the Western Renewable Energy Zone process addresses wildlife, habitat and cultural resources).

Transitioning to a cleaner energy portfolio requires a workforce and a public that is much more conversant and comfortable with new, advanced energy technologies. A lack of human capital could limit the nation's ability to significantly increase the penetration of clean technologies. The nation's workforce development infrastructure is relatively unfamiliar with renewable energy technologies and unprepared to scale-up quality training. A gap analysis is needed along with a separate assessment of health and safety requirements to reduce the potential risks to workers and communities. Furthermore, knowledge of the technologies and tools that can help meet climate change challenges and related energy and environmental goals must permeate the nation's education system at all levels. These structural and human dimensions pose another set of risks and benefits that will need to be incorporated into this risk framework and into subsequent national energy decisions.

Analyzing cumulative effects is a challenging scientific and assessment task, primarily because of the difficulty of defining the geographic (spatial) and time (temporal) boundaries of the affected area. For example, in the NEPA regulations, cumulative impacts are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non- Federal) or person undertakes such other actions." A full cumulative assessment, of course, must address people as well as the ecosystem risks. A 2008 NRC report, as well as recent writings on vulnerability, emphasizes multiple stressors in the generation of risk (NRC 2008b). NEPA provides a framework for advancing environmental impact analysis because it addresses cumulative effects and methods for addressing coincidental effects (adverse or beneficial) on specific resources, ecosystems, and human communities including all related activities, not just the proposed project or site activity. Considering cumulative effects is also essential to developing appropriate mitigation and monitoring its effectiveness (CEQ 2005). In their environmental analyses, however, state and federal agencies routinely define the effects too narrowly (sector by sector) so that significant issues may be missed and decision makers will not be completely informed about the full consequences or risks of their projects. In most cases, therefore, NEPA stops short of a full risk analysis because it does not compare projected cumulative effects of alternatives and the ability to avoid or minimize adverse consequences. Moreover, the analysis of current and foreseeable future activities on land, in the sea and along the coasts must be developed considering stakeholder perspectives. There are some valuable analytical insights for evaluating cumulative risks, cumulative impacts and community-based risk assessments based on the recent NRC report, EPA publications, and Council on Environmental Quality guidelines (EPA 2003).

There is a rich literature about assessing and integrating public concerns into risk decision making and public policy areas (NRC 2008b, Slovic 2000, Kasemir et al 2003). The focus here highlights the importance of public involvement and agency interactions in defining the decision problem, the risk issues to be addressed, value concerns that may be important, incorporating local knowledge into the assessment, and potential social amplifications of risk that will need to be addressed (Pidgeon, Kasperson, Slovic 2005). The first step is identifying stakeholders ---who are the stakeholders and what are their concerns --- and the myriad site-specific scenarios and issues that arise. Essentially, risks associated with wind and other renewable energy are highly site-specific. They vary substantially from site to site and thus cannot be assumed to be similar across sites. The risks which will be dominant at any site cannot be assumed but must be the product of analysis and interaction with stakeholders. While bat or raptor fatalities may be the issue at one site, visibility, aesthetics, or historical properties may be the major issues at other sites. How will decision makers know what is most important to their communities? There must be a commitment to sustain the work that is underway within state and regional working groups and to apply the innovative approaches in public participation that were recently assessed by the National Research Council (NRC 2008b).

Climate change has emerged as a high priority area for national policy and for cooperation at the international level. It has been a major plank in the Obama administration, as suggested in numerous statements of the President and his appointment of a high level climate czar. The work of the Intergovernmental Panel of Climate Change (IPCC) and earlier analyses of other influential reports, such as the Millennium Ecosystem Assessment and the U.K.'s Stern Review underscore the urgency for interventions to reduce climate change over the next two decades. These reports have highlighted the risks to ecosystems and concerns with the ongoing extinction of species associated with climate change. Wind and other renewable energy sources offer important potential roles in meeting climate change goals and contribute to reducing serious further damage to ecosystems. Loss of species from climate change, for example, need to be weighed against what now appears to be relatively localized and small environmental effects from wind turbines at individual sites. Albeit greater risks to endangered species, species of concern, and critical habitat raise an important conundrum that requires open debate and decision making among stakeholders within the context of wind and other renewable energy benefits. What is needed is a comparative analysis of net losses or gains associated with particular energy generation sources. Without this analysis, an equitable evaluation of risks and benefits will be very difficult and research priorities and scarce resources cannot focus on the significant risks that have the possibility of being reduced in a cost effective way. Hopefully, the ongoing climate change analysis of the NRC, scheduled to appear in 2010, or other studies will address these issues.

Energy security is a second policy domain related to important national policy objectives. The international energy cartels and the geographic locations of energy supplies outside of our borders highlight the importance of building a diversified, domestic energy portfolio. The prospect for substantially enlarging wind energy in the U.S. carries significant value for enhancing greater political and environmental security for the nation. Again a full risk assessment considers this type of risk and the prospective gains or losses to national security which may be associated with different energy needs.

Comparative Analysis and Determining Risk Tolerability

To understand the acceptability or tolerability of risks, comparative risk assessment must be conducted. This comparison should occur on both the "intersectoral" level at a specific wind site and through a risk comparison across sectors against other energy supply options. It also should draw upon the results of an extended risk analysis because the important risks may be found in life cycle effects, cumulative risks, or public perceptions, rather than the more obvious sectoral effects. Since risks are probably never fully accepted but only tolerated to gain various benefits, we use the term "tolerability" here rather than the more common "acceptability." The potential tolerability of risks from habitat fragmentation and/or visual landscapes, for example, acknowledges that these are complex matters based on values in which people will disagree.

Once we have gauged the tolerability of risks, a sound knowledge base exists to make the decisions for risk reduction and management approaches. Then, these risks can be compared with other risks in the same option, and other energy options. to decide whether the "significant" risks can be reduced easily and at what cost (to the developer and society). Decision makers need to prepare for "unacceptable risks" that would require government actions and/or public consultations. Again, since "tolerability" is not primarily an issue for science, involvement of stakeholders is critical at this stage because tolerability requires analysis of public values.

Management Options and Strategy

Selecting a risk management strategy is essential for moving wind into a gigawatt scale capacity. These issues go beyond technological R&D challenges, but we are not yet prepared for this national shift. Since wind technology, for example, is now commercially deployed, the challenges increasingly focus on better capacity factors and lower costs. An integrated risk framework begins to grapple with this range of issues and keeps the interested parties and policy makers current with the reality on the ground and perceptions of the communities taking on the risks. An integrated risk framework is valuable not only in demarcating where major uncertainties lie but also identifies various options for risk reduction that are open to decision makers. Risk assessment provides valuable analyses and data collection for the decision maker, though the integrated risk framework is not designed to perform a multi-objective analysis required for energy supply decision making. All risks involve a chain of risk evolution (or a causal structure) consisting of the following steps shown in Figure 3:

Figure 3: Causal Chain of Risk

The causal chain begins with the societal need for energy and then a specific choice for wind energy. A risk event or a stressor affects a receptor (e.g., visual impairment, habitat loss, bat deaths, mammal migrations) and some receptors become exposed. The receptors each have a different sensitivity to the exposure (e.g., aesthetic perceptions of people or endangered species sensitivities to habitat changes). How much exposure from this risk event and the sensitivity of the receptors to the exposure determines the type and magnitude of the consequences. As noted earlier, the historical application of ecological risk assessment to wind did conduct this type of analysis through the measure of exposure and sensitivities and made a valuable contribution to our understanding (Efroymson 2007). The full consequences, the probabilities, and uncertainties, however, were not identified or estimated. Ultimately, without these analytical stages along with a comparison of energy choices, neither a final metric of risk is possible nor decisions on priority research to reduce potential risks and uncertainties.

Each stage has a probability of occurrence and level of uncertainty associated with it as well as feedback loops. Each stage also involves the possibility for management intervention to reduce the risk. A major need in management assessment is analysis of risk reduction options in terms of such criteria as cost effectiveness, impacts on industry, and equity in health and environmental protection. For many risks, there is recognition that management strategies are iterative and evolutionary. They are not made once but in sequential moves over time as risk knowledge grows and experience is accumulated with differing risk reduction interventions. This paper does not advocate one particular risk management strategy but for better analysis and strategic thinking. In some cases, decision makers will defer risk-related decisions or opt for adaptive management strategies when uncertainties are large or not easily reducible. A "mature" risk management system typically evolves over time, as various interventions are tried at different steps in the causal structure and an effective and efficient risk management approach evolves.

A risk communication program focuses on the significant risks and associated uncertainties. It should be formulated and undergo peer review, and public review in a sustained and deliberate fashion. It typically becomes integrated into a well-considered program of public engagement in the siting process. It is supported by a sustained effort of public perception research, how the public and stakeholders' views evolve over time and why. This is the basis for identifying "target" audiences, discovering the nature of their knowledge and concerns, and how to educate them. This process begins at the first stage of development and continues throughout the program. Ongoing third party evaluations inform changes in the stakeholder and management program design. Ideally, state or federal governments could lead this effort. This understanding affects the planning process and results in management adjustments to address different evolving concerns, especially as wind facilities are deployed at a faster rate. Current wind research programs focus primarily on site-to-site variations. The management plan, however, must be able to weigh regulatory requirements, mitigation strategies, public concerns and ongoing risk research and be flexible and dynamic in responding to risk information and events. This becomes the basis for informing those with a need to know of their major risks, associated uncertainties, and options for risk reduction. Public involvement in a risk communication strategy and program, developed with leading national experts should incorporate (Kasperson 2008):

- An identification of stakeholders and those at potential risk who need information
- An assessment of the stakeholder's needs which the communication program will seek to address
- Strategies for two-way communication with these stakeholder groups
- An ongoing evaluation of program effectiveness and needed strategy changes. This includes learning from experience as events occur and communication changes are suggested

- Creating links between communications and actions people can take
- Evaluating the resulting outcomes of the process with consideration of cost and time

A particularly valuable contribution of an integrated risk framework outlined in this paper is to shape smart **siting strategies** that would be designed to take advantage of where the renewable resources exist to minimize potential risks (and particularly those related to community concern) to various stakeholders (e.g., risk perception), and to select management approaches that mitigate potential risks in a cost-effective and publicly supported ways. This is a structure and process with the potential to avoid risks and stave off unnecessary conflicts. It must be recognized that social trust may be in short supply and that strategies to build that trust are an important part of a risk communication program.

Where the wind is blowing is essential information, but there is a range of potential environmental and human risks that need to be considered for smart siting strategies. From the integrated risk analysis outlined above, a sound knowledge should be in hand of what the major risks are, where the important uncertainties lie and an understanding of who the major stakeholders are along with the nature and basis of their concerns. This knowledge provides a valuable base for choosing sites with good wind resources and potential links to the grid, but also avoids significant risks and public conflicts. Siting strategies should proceed in a way that engages potential host and adjacent communities that may be impacted at early stages, emphasizes communication and transparency, and responds to local concerns. A siting strategy should emphasize process rather than a checklist and should seek a collaborative approach with state and local officials and other stakeholders as well. The goal should be to build strong local support that addresses local concerns, to shape siting to enlarge project benefits while reducing risks, and to build trust and confidence among those who ultimately bear the risks and adverse impacts.

As yet, siting consideration in wind energy development has largely centered on technical issues concerning the areas of substantial wind resource availability and the potential for connection to the energy grid. Moving from the current 1-2% of the energy supply to a 20% share by 2030 requires a broader, more robust approach to wind plant siting. Fortunately, the nation has extensive experience with siting controversial facilities, including many (e.g., nuclear plants, liquefied natural gas (LNG) terminals, and increasingly, fossil fuel plants). The superfund program and experience with radioactive waste facility siting provides additional experience on which wind energy can build. What is needed is an inventory of potential sites for electric utilities across the U.S. that accounts for the range of factors in siting success. This includes potential environmental issues such as bird and bat collisions, but also issues of public concerns and acceptance, visibility and aesthetics, and conflicts with recreation and tourism. In short, development of siting strategies must go beyond narrow technical appraisals to include more collaborative approaches with potential host states and communities. Well developed risk communication and stakeholder involvement programs are essential so that a synopsis on the process of site identification, assessment and selection will be a *sine qua non* for smart siting of the next generation of renewable energy facilities. Fortunately, a large body of analysis drawing on previous siting experience in the U.S. and abroad exists to guide the formulation of "smart" siting strategies (Kunreuther, Fitzgerald & Aarts 1993, Shaw 1996, Lesbiril 1998, and Broholm & Lofstedt 2004).

Complete information and certainty does not exist for any environmental, health, or risk problem. Therefore, a major need in any area of technology deployment, including renewable energy, is risk research prioritization to best fill gaps in the knowledge base or to understand more adequately the uncertainties that surround the risk problem at stake. While expanding the knowledge base and filling existing gaps are major *raison d'être* for science, available funds are always scarcer than the interesting scientific problems. Therefore, prioritizing risk research is a continuing challenge in almost all technology development areas, including renewable energy. Yet, a risk prioritization program makes the most efficient use of scarce research dollars. Considerations include:

- How much can the risk be reduced through further research and in what timeframe?
- How deep are the uncertainties? – do they arise from data needs, a modeling problem, or do we basically not have a scientific understanding of the risk phenomena?
- Most importantly, how do the uncertainties interact with the profile of the risk – where will progress or reducing uncertainties most contribute to reducing overall risk?

A hard-nosed approach to setting research priorities is needed – it is not what fascinates scientists but it makes for a robust knowledge base for decision makers. Risk research priorities need to be driven by management decisions that must be made now and in the future, in order to implement a sound and sustainable energy future for the nation. In May 2009, the DOE wind program announced a list of grants focusing on "environmental impacts," and all 12 projects related to birds or bats (DOE 2009). Federal research priorities have focused to date on the impacts of wind development on wildlife and on radar systems for military and aviation applications. These priorities have arisen reactively and retrospectively, in the sense that they were identified as issues to consider only after projects had been halted at substantial cost to stakeholders. Moving to an approach that addresses siting risks in a comprehensive and prospective way could enable federal agencies to avoid these costly surprises.

Minerals Management Service, on the other hand, approached offshore wind research priorities in a more systematic way. First they initiated a Programmatic Environmental Impact Statement for their alternative energy program, as required by NEPA (drawbacks in the NEPA process for risk decision making was addressed earlier). They also commissioned a synthesis of studies in Europe related to offshore wind projects, a valuable step in a developing a baseline knowledge of this wind area. Later, a workshop was organized with experts and stakeholders to list their top issues and rank priority concerns without a risk-based framework. This led the agency to fund several projects, including surveys related to coastal avian migrations, electromagnetic impacts, and visual impacts to historic properties. It is not clear whether these studies were based upon a risk framework and/or address the most significant risk from offshore deployments.

It may be useful to consider an early example to establish program priorities in a systematic way. In the late 1980s, EPA's Science Advisory Board went through an exercise to rank risks that EPA was confronting in its various programs. The Board first considered how the Agency's experts ranked the various risks that the Agency was facing in terms of their health, safety and environmental importance. It then reviewed how the public ranked these various problems. Then, it compared these two rankings with how the Agency budget allocations correlated with public concerns more than with the assessment of its own experts. This, of course, raised many questions as to how allocation priorities were being made and what drives the decision and the priority-setting process (EPA 1990).

Research priorities in the renewable energy area need to stake out a different approach to setting research priorities, beyond the core technology R&D areas that have been DOE's traditional focus. A balance is needed using the following principles:

- Balancing goals and knowledge needed by various decision makers and stakeholders
- Cost-effectiveness and the likelihood of greatest reduction of risk, given large uncertainties
- Investment in decisions with short-term payoffs vs. high-risk/high-gain longer term research

Following decisions based on comparative analysis of different energy sources and their tolerable risks, the legal and regulatory structures should reflect these decisions. The legal structure should establish priorities in order to create the climate for changing our energy portfolio. The current legal system was not prepared for the leap into offshore renewable energy, although the Energy Policy Act of 2005 required new federal rules within one year. In April 2009, new regulations were published for managing wind and water power technologies on the OCS (MMS 2009). This almost four year delay in finalizing these regulatory structures further postponed the planning process for offshore wind technologies. This is occurring amidst the recent push by East Coast and Great Lakes states to deploy offshore wind. Given the shift in the national political picture with the Obama Administration, the regulatory and institutional structures would also need to evolve in order to support the build out of low-carbon technologies in consideration of climate change policies (DOI 2009). The most obvious and significant shift would stem from the move toward a carbon price with a tax or cap and trade system.

Permitting requirements for wind energy should reflect a national shift away from traditional fossil fuels as well. Currently, these wind permits are based on state rules and practices that vary across the 50 states – reflecting their individual and societal values. The expected voluntary Fish and Wildlife Guidelines for national wildlife management at wind sites mentioned previously would more clearly address the broader context, if they incorporated risk characterization, comparative principles, and climate change. These guidelines are expected to expand the requirements for wildlife and habitat surveys pre- and post-construction, however, they do not necessarily reflect the significance of the risk. The MBTA rule is a good example of a legal structure that pre-determines risk tolerability. Risk tolerability decisions, then, are in the hands of politicians and bureaucrats rather than biologists. Thus, even legal structures and rules must incorporate an integrated risk analysis in order to move toward a low-carbon portfolio that includes gigawatt-scale wind developments.

Summary

1. An integrated risk framework informs decisions, but does not provide risk tolerability answers since this "number" necessarily stems from value-based decisions that are made by public officials not scientists or industry experts.
2. Integrated risk assessment is an analytical framework to better site wind facilities, to involve the public, to reduce those uncertainties that really matter, and to avoid or reduce risks.
3. Agency-specific missions and special interest groups can and have produced skewed frameworks of assessment where one risk is assumed to be more significant on the basis of incomplete or skewed analysis. This "subsystem dominance" in assessment and management carries a high threat to a balanced assessment and sound decision making. A more integrated and systematic framework is needed.
4. Specific tools and metrics for each risk area or sector are needed, but an integrated risk framework is essential to guide the identification of tradeoffs and priorities for risk research. In particular, it can provide guidance as to how scarce research resources can best be allocated and which uncertainties are important. It is a worse error to omit a major impact than to measure an impact imprecisely (Weiner 2008).
5. Judging risk tolerability is not a scientific decision process, but one that involves political and community interests, ongoing stakeholder involvement, and comparisons among risks associated with choices among energy options.
6. Ecological risk assessment is a valuable tool for evaluating wildlife and habitat risks from renewable energy siting, but must involve a comparison with other energy options and other sectoral impacts for a fair analysis of environmental consequences. In addition, this approach needs to be extended to human systems for a systematic appraisal of risk.
7. Uncertainty analysis is essential throughout the assessment and comparison among the risks but should not become the basis either for premature risk judgments or constitute a reason for risk management inaction.
8. Stakeholder involvement is essential at all steps in the assessment and decision process, and should be supported by effective communication strategies and collaborative decision making – in short, two-way communication and decision making.
9. Identifying major uncertainties, research gaps and significant risks as well as methods for reducing uncertainties and catastrophic risks needs to be central to identifying the risk management pathway and cost effective strategies.
10. Environmental effects that involve threatened, endangered, and sensitive species and critical habitat must be incorporated into the policy framework and risk research agenda as well as through appropriate legal instruments.
11. Scoping the elements of adaptive management and enforceable principles are central to a successful risk management strategy. As yet, it is unclear which principles may apply, but this is an area where technology design and smart siting, for example, may benefit from experience and social learning.

12. Risk management implementation has multiple objectives in a multi-faceted process that occurs in specific institutional arrangements, and social contexts, and requires sustained public involvement and collaboration with affected communities.

In conclusion, the purpose of an integrated risk framework is to identify and assess the major risks, avian, habitat, and human effects associated with a new technology or human activity in terms of potential impacts on human health and well-being and the environment. Done properly, it is systematic, rigorous, and comprehensive. It should be conducted in such a way that the potential risks of new or ongoing developments are considered and compared with each other. An advantage of a sound risk assessment framework is that very different risks can be compared with each other, can inform a prospective decision maker of concerns, and addresses the development of a new technology or facility. Such an assessment considers the probability of events or negative occurrences and their likely consequences.. A wide range of established methods are available for such assessments, ranging from technology assessment to exposure analysis, response relations, animal studies, public perception research, and consequence assessments.

Each risk typically entails some special methods and tools, such as assessing migration patterns or avoidance behavior of birds or using videos and photos for visibility concerns. Many of the methods are well-established and tested, but often not yet applied in a systematic way to particular issues or arenas. Risk assessment should include uncertainty analysis, since risks, unlike impacts, always refer to future states of existence and are, therefore, always subject to changing circumstances and animal and human behaviors. A thorough uncertainty analysis is an indispensable part of a sound risk assessment. Consideration of what can be done about the risk, whether mitigation, acceptance, or adaptation. Providing a well documented analysis of the options for risk research priorities, critical uncertainty analysis, risk management options, and communication strategies should be part of an integrated assessment and management risk framework.

Next Steps

This paper is only the beginning in a needed program of risk research for wind energy development in the U.S. Other important studies need to follow including these suggested next steps:

- Establish a federal and state working group with experienced risk experts to steer future research and development of risk analyses related to wind energy.
- Develop a proposed pathway for realizing the industry objective set forth in the DOE report *20% Wind Energy by 2030* drawing upon the integrated risk framework as appropriate along with various other policy considerations
- Apply the framework to a well-developed, site specific case of wind (land-based or offshore) where substantial data already exists. This analysis would result in a risk and uncertainty characterization and a proposed risk management strategy at the site level. This will demonstrate how the integrated risk framework can inform decision making at the site and multi-site level. The site studies should involve a comparison of sites, such as a small island, a large state on the coast, the Great Plains, and an offshore location.

- Prepare a white paper on siting strategies for wind energy where risk will be an important consideration, but other factors will enter into the discussion as well (e.g., public perceptions and community concerns, collaborative approaches with relevant stakeholders).
- Design a case study focused on the Public Utility Commission perspective as they make important decisions on wind integration to the electric grid. Are they making decisions well? What data is used to make these decisions? What are the descriptive versus prescriptive aspects of their decisions and their regulatory constraints?

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Appendix A: White Paper Peer Reviewers and Peer Review Workshop Agenda

Name	Title	Organization
Peer Reviewers		
Robin Cantor	Principal	Exponent
Mary English (provided comments via e-mail)	Research Leader	University of Tennessee
Roger Kasperson	Research Professor and Distinguished Scientist	Clark University and Stockholm Environment Institute Board
Willett Kempton	Professor, Marine Policy	University of Delaware
Robin Gregory	Senior Researcher	Decision Research
Warner North	President and Principal Scientist	NorthWorks Inc. and Consulting Professor at Stanford University
Invited Observers to White Paper Peer Review Workshop		
Mark Sinclair	Vice President	Clean Energy Group
Dave Stout	Chief, Division of Habitat and Resource Conservation	U.S. Fish and Wildlife Service

Government and Laboratory Sponsors		
Bob Thresher	Research Fellow; fmr. Director, National Wind Technology Center	National Renewable Energy Laboratory
Karin Sinclair	Senior Project Leader, National Wind Technology Center	National Renewable Energy Laboratory
Steve Lindenberg (provided comments via e-mail)	Senior Advisor, Renewable Energy	U.S. Department of Energy
Patrick Gilman	Presidential Management Fellow	U.S. Department of Energy

White Paper Peer Review Meeting -- AGENDA

An Integrated Risk Framework for Gigawatt-Scale Deployments of Renewable Energy: The Wind Energy Case Study

June 25, 2009
10:00 a.m. – 4:00 p.m. (ET)
Location: Energetics Incorporated
901 D Street, SW, Washington, DC 20024

Overall Purpose:

1. Introduce risk thinking and risk-informed decision making into the renewable energy debates, particularly relating to wind energy deployments in the U.S.

9:30 – 10:00	*Breakfast*
10:00 – 10:10	Welcome and Purpose of the Meeting , Bonnie Ram, Energetics Incorporated
10:10 – 10:30	Introductions
10:30 – 11:30	Peer Reviewers' Comments on the White Paper
11:30 – noon	Facilitated Discussion, Bonnie Ram
12:00 – 12:15	Observers' Comments
12:15 – 12:30	Summary Findings for White Paper Revisions, Bonnie Ram
12:30 – 1:30	*Lunch in Conference Room*
1:30 – 2:45	Facilitated Discussion of Possible Next Steps: 1. Establish a working group to steer future research and development of risk analyses related to wind energy. 2. Develop a proposed pathway for realizing the industry objective set forth in the *20% Wind Energy by 2030* document. 3. Apply the framework to a well-developed, site specific wind case study (land-based or offshore) demonstrating how the framework can inform decision making at the site and multi-site levels. 4. Prepare a white paper on siting strategies for wind energy.
2:45 – 3:00	*Break*
3:00 – 3:30	U.S. Department of Energy Thoughts, Steve Lindenberg and Patrick Gilman
3:30 – 4:00	Wrap-up and Final Thoughts, Bonnie Ram
4:00	*Adjourn*

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14. ABSTRACT *(Maximum 200 Words)*
Assessing the potential environmental and human effects of deploying renewable energy on private and public lands, along our coasts, on the Outer Continental Shelf (OCS), and in the Great Lakes requires a new way of evaluating potential environmental and human impacts. The author argues that deployment of renewables requires a framework risk paradigm that underpins effective future siting decisions and public policies.

15. SUBJECT TERMS
renewable energy; integrated risk framework; deployment of renewables; risk paradigm; wind energy; siting decisions

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