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IEA Wind Task 34

Assessing Environmental Effects (WREN)

Adaptive Management White Paper

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Technical Report

Results of IEA Wind Adaptive Management White Paper

Prepared for the
International Energy Agency Wind Implementing Agreement

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Preface

The primary objective of IEA Wind Task 34 (WREN) is to facilitate international collaboration to advance the global understanding of environmental effects of offshore and land-based wind energy development. Task activities are intended to contribute to advancing the knowledge base. A key strategy to achieve this goal is the development of white papers that will examine specific wind and wildlife topics where explicit information is not readily available within the existing literature, and to focus and facilitate discussion that will advance the state of understanding of global concerns within the wind energy community. This white paper on adaptive management is the first in a series of papers to be published through IEA Wind Task 34 (WREN).

Country	Contracting Party	Active Organizations
France	Government of France	EDF Energies Nouvelles
Ireland	Sustainable Energy Authority of Ireland	BirdWatch Ireland
Netherlands	Ministry of Economic Affairs	Rijkswaterstaat – Branch Water, Traffic and Environment, Department of Water Quality and Nature Management
Norway	Norwegian Water Resources and Energy Directorate	Norwegian Institute for Nature Research
Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)	Consejo Superior de Investigaciones Cientificas (CSIC)
Sweden	Swedish Energy Agency	Vindval; Swedish Energy Agency
Switzerland	Swiss Federal Office of Energy	Nateco AG; Swiss Federal Office of Energy
United Kingdom	Offshore Renewable Energy Catapult	Marine Scotland Science
United States	U.S. Department of Energy	National Renewable Energy Laboratory (OA), Pacific Northwest National Laboratory, US Department of Energy, Bureau of Ocean Energy Management; National Oceanic and Atmospheric Administration, US Fish and Wildlife Service

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Abbreviations

AM	adaptive management
BGEPA	Bald and Golden Eagle Protection Act – US
BLM	Bureau of Land Management – US
DEPONS	Disturbance Effects on the Harbour Porpoise Population in the North Sea
DOI	Department of the Interior – US
ES	Environmental Statement(s)
ESA	Endangered Species Act
EPA	Environmental Protection Agency – US
HCP	Habitat Conservation Plan
IEA	International Energy Agency
INTACT	Innovative Mitigation Tools for Avian Conflicts with Wind Turbines
ITP	Incidental Take Permit
MBTA	Migratory Bird Treaty Act
MMPA	Marine Mammal Protection Act – US
MW	megawatt(s)
NEPA	National Environmental Policy Act – US
NGO	nongovernmental organization
NRC	National Research Council
OECD	Organization for Economic Co-operation and Development
TAC	Technical Advisory Committee
UK	United Kingdom
US	United States
USFWS	United States Fish and Wildlife Service – US
WREN	Working Together to Resolve Environmental Effects of Wind Energy

Executive Summary

Adaptive management (AM) is a systematic process intended to improve policies and practices by learning from the outcome of management decisions and to reduce scientific uncertainty. While many nations are considering the use of AM for wind energy, its application in practice and in policy has been limited. Recent application of AM has led to fundamental differences in the definition of AM, its application, and the projects or planning processes to which it might be applied. This paper suggests the need for a common understanding, definition, and framework for AM and its application to wind energy. As a starting point, we discuss a definition of AM and technical guidance created by the United States (US) Department of the Interior's (DOI's) Adaptive Management Working Group referred to in this paper as DOI guidelines. The paper also examines how AM has been applied to wind energy development around the world with additional focus given to US examples. The challenges and opportunities associated with implementation of AM for wind development are addressed, management actions in nations that exhibit attributes of AM are compared, and pathways to appropriate application and potential broader use of AM are explored.

This paper is written from an international perspective and, as such, discusses the science of AM, as well as its intersection with policies and management practices that are common to most WREN (Working Together to Resolve Environmental Effects of Wind Energy) member nations. The exact effects and interactions of AM with the regulations or policies of any individual country cannot be inferred from these discussions.

There is no widely accepted international definition of AM for wind energy, but AM has been defined and broadly applied in other natural resource settings. The US DOI Adaptive Management Working Group published an Adaptive Management Technical Guide in 2007 (updated in 2009) and a follow-up Application Guide in 2012). The Technical Guide adopted the US National Research Council definition of AM and described conditions and guidelines for its implementation. Key attributes of this definition include the need for AM to pose hypothesis-based questions for data collection, to retain a level of adaptability for monitoring and management actions throughout the process based on outcomes, and to enact AM as an interactive process that provides feedback between the assessment of impacts on wildlife, wind energy project design and implementation, monitoring and evaluation of effects on wildlife, and adjustment of management requirements. While the DOI Technical Guide and Application Guide are not an expression of policy or internationally accepted standards, for the purposes of this paper they serve as important reference points to assess the application of AM in the context of wind energy.

Natural resource legislation, regulations, and guidelines for wind energy project management in some WREN member countries were found to include the explicit use of AM, while others apply some or no principles of AM. Using the DOI Technical Guide as a departure point for analysis, we found that of the 16 wind energy AM plans prepared in the US, most did not fully meet the DOI AM definition, but many contained components that partially do so. These wind energy AM plans demonstrate a high degree of variability in the processes used to make management decisions, and they rely largely on predetermined mitigation triggers and actions. Based on this limited sample, we conclude that AM is being applied largely on a project-by-project basis, rather than being strategically applied across current projects as a means of learning lessons for use in future projects. For the purposes of this paper, we examine wind energy projects of varying sizes and with a wide range in the numbers of turbines or output capacities.

US stakeholders were interviewed to determine their perceptions of the usefulness and application of AM to wind energy projects. Interviewees included representatives from federal resource management agencies; wind farm developers, owners, and operators; environmental consultants;

and nongovernmental organizations. Respondents generally acknowledged the regulatory benefits of acquiring added decision-making flexibility through AM in the face of unexpected impacts. However, they also raised concerns about the effect that AM can have on project financing, and whether its application to operational wind energy projects in the US truly embodies the AM principles. The stakeholders highlighted the confusion around a common definition and approach to applying AM, the high degree of variability among AM plans, and the lack of tools or specific guidance to direct preparation of AM plans. Suggestions for alleviating the financial stress associated with the application of AM included establishing triggers or boundaries for mitigation measures.

AM approaches should seek to leverage lessons learned from existing projects to inform future management decisions. This paper recommends that the AM guidance be improved as follows:

- Adopt a universal definition of AM that is coupled with an agreed-upon set of eligibility criteria and consistent with the regulatory context in which it is being applied.
- Optimize the spatial and temporal scales over which AM is applied for their ability to reduce scientific uncertainty. For example, while AM can be applied to a single project, more commonly AM is best applied at a larger scale (across multiple wind energy projects) to inform planning for future projects.
- Let the application of AM be guided by the need to minimize undue financial pressure on projects while ensuring that the natural resources of the nation or region are protected.
- Establish formal processes and structures within national or regional regulatory bodies to make use of environmental impact data from existing projects to generate knowledge that can be applied to the planning and management of future projects.

1. Introduction

In 2013, global renewable electricity generation accounted for almost 22% of total power generation (IEA 2015). As nations continue to deploy renewable energy technologies to supplant carbon-based energy sources it is increasingly important to develop an understanding of the technology's environmental effects. All sources of energy have impacts on the environment and an understanding of these effects is critical to helping countries make informed decisions about the relative costs and benefits of various energy solutions. The rapid and large-scale development of renewable energy, however, challenges our ability to anticipate, verify, and mitigate impacts on the environment. As climate change and associated environmental effects create an urgent need to develop relatively new renewable energy sources rapidly throughout the world, tools are needed that allow for the environmental management of wind and other development projects in the face of a degree of uncertainty about their direct environmental effects.

Adaptive management (AM) has been discussed since the 1970s as a potential decision-making process for addressing uncertainty, managing natural resources, and directing research. AM has been used for developing wind energy projects in the United States (US) and is under consideration in other countries. AM is perceived to be a topic of interest based on the promise of reducing scientific uncertainty and informing future wind energy projects and management decisions. However, AM has not been irrefutably shown to be a practical management tool because of the lack of consistency in its definition, preferred outcomes, implementation practices, and time scales of relevance. This lack of consistency has resulted in a wide range of outcomes and effectiveness for managing environmental uncertainties associated with the wind energy industry. It is important to note that striving for consistency in all aspects of AM projects may not be desirable because the relevance of AM to mitigating the environmental impacts will be specific to each individual project.

The Working Together to Resolve Environmental Effects of Wind Energy (WREN) international collaborative identified AM as a tool that has the potential to advance the wind energy industry, but acknowledged the existing confusion and inconsistencies around its application. To address this, WREN offers this white paper to better examine how AM has been used for wind energy projects, and evaluate how it may be best applied in the future. The purpose of this white paper is to explore how AM is used by the wind energy industry around the world, and to identify ways the process and its implementation may be improved upon. This paper documents the use of AM internationally, examines the challenges and opportunities associated with implementation of AM for wind energy development, compares management actions in other nations that exhibit attributes of AM, and discusses a pathway to appropriate application and broader use of AM to further the wind energy industry worldwide. Up to now, AM has primarily been implemented actively in the US; this paper will focus specifically on lessons that can be gleaned from that experience.

This paper is written from an international perspective and, as such, it discusses the science of AM, as well as its intersection with policies and management practices that are common to most nations associated with this document. The exact effects and interactions of AM with the regulations or policies of any individual country cannot be inferred from these discussions.

2. Defining Adaptive Management

To evaluate the benefits and costs that AM has brought to the development of the wind energy industry, it is important to understand the use of the term, and to assess how it has been applied across wind farms. An in-depth description of AM and its underlying principles follows, based on the US Department of the Interior Adaptive Management Working Group's Adaptive

Management Technical Guide (DOI Technical Guide)(Williams et al. 2009) and companion Application Guide (Williams and Brown 2012), collectively referred to in this paper as DOI guidelines. In addition, the principles of AM, as applied to wind energy, are discussed in relation to the *mitigation hierarchy* and the *precautionary principle*, which focus on mitigating or avoiding project-related risks or impacts (see Sections 2.2.1 and 2.2.1).

AM has been described as a systematic process intended to improve management policies and practices by learning from the outcomes of operational programs (Holling 1978). AM has been used to manage natural resources in various parts of the world to improve management decisions and address uncertainties in areas including ecosystem management (Ringold et al. 1996; Johnson 1999), the effects of commercial fishing on the marine environment (Martin and Pope 2011), and water resource management (Pahl-Wostl 2007). AM refers to a learning-based approach, or learning by doing, that leads to adaptations of management programs and practices based on what has been learned (Williams and Brown 2012; Walters and Holling 1990). The most widely accepted definition of AM comes from the US National Research Council (NRC 2004) and has been adopted and further described in the DOI Technical Guide:

> Adaptive Management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process… (NRC 2004; Williams et al. 2009).

AM can be applied at several different scales for wind energy developments, including at the project scale, where an AM approach is used to address scientific uncertainty and help inform future management decisions (e.g., implementation of mitigation measures) of an individual project, and at the planning scale, using data and outcomes from individual and multiple projects to inform future regulations and development and management decisions (Köppel et al. 2014). The data collected may be similar for assessing scientific uncertainty and informing management decisions at both scales, but the spatial and temporal extent of monitoring data collection and the analyses of the data at the two scales may differ.

AM has been described as being passive or active (Walters and Holling 1990; Murray and Marmorek 2003). Passive AM applies in situations where historical data are used to construct a single best estimate or model for response, and the decision choice is based on assuming this model is correct. Active AM applies in situations where available data are used to structure a range of alternative response models, and a management choice is made by taking into account the short-term performance and long-term value of knowing which alternative model best reflects the real world situation.

The DOI Technical Guide presents a "Problem Scoping Key for Adaptive Management" (included in Appendix A) that poses nine general questions that are intended to assist in determining whether AM is applicable in a specific management situation or for a specific project (Williams et al. 2009). According to the Key, all questions must be answered in the affirmative for AM to be considered the best approach for managing the project (Table 1).

Table 1. DOI questions to determine fitness for application of AM (Williams et al. 2009).

Question #	Question
1	Is there some kind of management decision to be made?
2	Can stakeholders be engaged?
3	Can management objective(s) be stated explicitly?
4	Is decision-making confounded by uncertainty about potential management impacts?
5	Can resource relationships and management impacts be represented in models?
6	Can monitoring be designed to inform decision-making?
7	Can progress be measured in achieving management objectives?
8	Can management actions be adjusted in response to what has been learned?
9	Does the whole process fit within the appropriate legal framework?

The definition of AM is open to interpretation, so it is important to establish clear definitions at the outset. In the context of monitoring at wind farms these discussions are likely to focus on the distinction between actions that reduce scientific uncertainty and actions that reduce impacts on wildlife and other environmental components. Data collected using appropriate techniques will support both outcomes, and both outcomes may be considered desirable, but the scope of AM as defined in this paper focuses largely on reducing scientific uncertainty in order to better inform future decisions about wind energy development. Under this definition, AM does not presuppose that improved decisions related to wind and wildlife conflicts will equate to less or more environmental risk, rather only that reduced uncertainties will lead to improved decision-making. In scenarios in which reducing wildlife impacts is the overriding priority, it may be considered appropriate to apply other management techniques, as discussed later.

Though AM can be broadly defined as a decision-making process for addressing uncertainty, several key components highlighted by Williams et al. (2009) distinguish AM from other decision-making processes and are designed to ensure successful management of complex natural resource systems. In particular, AM must be question-driven, adaptable, and consist of an iterative process.

2.1 A Question-Driven Approach

AM seeks to address scientific uncertainty and improve understanding of an environmental system using a question-driven, hypothesis-based approach. AM is not a trial-and-error process, or a management approach that randomly implements alternate decisions if desired results are not achieved. Rather, AM maintains a hypothesis-based approach to meeting objectives agreed upon by the involved parties, and it typically uses quantitative or conceptual models to test hypotheses, provide management alternatives, and predict the consequences of management decisions. Post-installation monitoring of natural resource interactions provides data used to validate the models, address scientific uncertainties, and set a baseline for the managed environmental system (NRC 2004; Williams and Brown 2012). If a question-driven approach is not taken, the data collected may have limited relevance for use in validating models or supporting AM processes. A further set of challenges relates to the suitability of the experimental design for meaningfully addressing questions that relate to the management of resources that can be addressed by a research approach, within the AM framework, and for gathering sufficient data to provide the levels of statistical power decision-makers require to implement AM.

AM objectives are critical for evaluating progress and assisting the decision-making process (Williams et al. 2009). Stakeholder engagement should play a role throughout the AM process to generate initial research questions, review monitoring results, observe outcomes of management decisions, and ensure all affected individuals and organizations support AM objectives (Williams and Brown 2012; Rogers and Biggs 1999).

2.2 Adaptability in the Face of the Uncertainty of Natural Variability

The AM process relies on maintaining a certain level of adaptability (flexibility) to ensure informed management decisions can be made in the face of uncertainty; as new information is gathered, management decisions may be amended to better accommodate the environmental system and the goals set forth by the AM process. Because of the inherent natural variability of environmental systems and the inevitable measurement errors when measuring environmental interactions, uncertainty is a key attribute that must be accommodated by natural resource management. AM principles can be used to identify and understand natural variability and provide organizations with the knowledge and information to make informed management decisions in the face of uncertainty.

2.3 An Iterative Process

AM should be thought of as an iterative cycle. As information and data are gathered over time, management approaches and decisions can be adapted to better accommodate the ecological process or system being managed, thereby leading to better understanding of the targeted ecological system and improved management decisions. A further purpose of AM relative to wind energy is to optimize the use of wind energy while maintaining environmental safeguards. In practice, AM should enable greater wind energy development if the associated environmental effects are shown to be insignificant.

AM consists of an iterative process or feedback loop of monitoring, evaluation, and management adjustments that focuses on learning about the impacts of management (Figure 1) (Williams et al. 2009). The collection of appropriate monitoring data facilitates learning and helps to inform decision-making. Well-designed management actions contribute to learning by administering interventions that determine the state of resources (Williams and Brown 2012). Figure 1 shows a single feedback loop, and is applicable for AM at the individual project level or whenever a question-driven approach is used to inform mitigation and management decisions. As discussed by the US DOI, AM also seeks to promote "double-loop learning," or institutional learning (Figure 2). Double-loop learning takes place across individual projects, promotes the use of lessons learned from current and past projects to reconsider objectives and management alternatives, and can potentially be used to inform future management decisions for other projects.

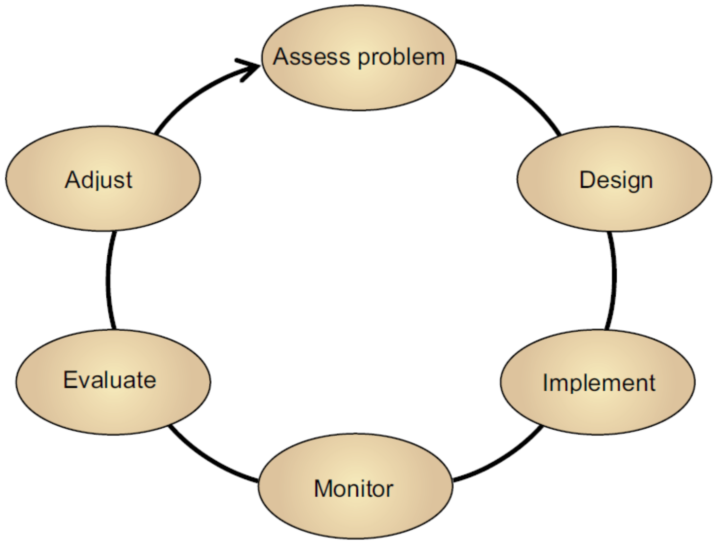

Figure 1. Iterative process (single-loop learning) of adaptive management (Williams et al. 2009).

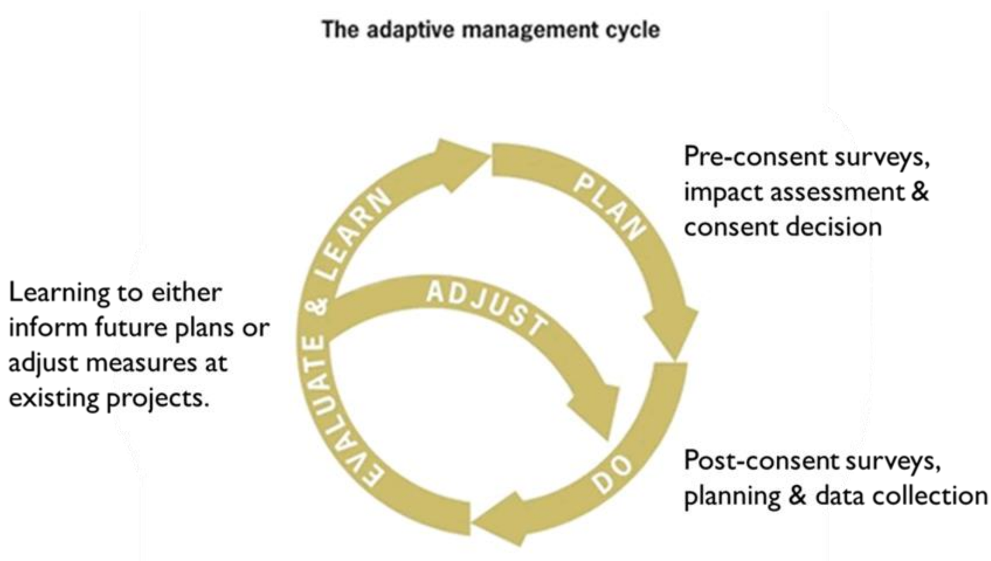

Figure 2. Double-loop or institutional learning for AM. (Drawn after *From Resilience to Transformation: The Adaptive Cycle* [2016])

2.4 Important Concepts Associated with AM

Several key concepts are critical for understanding the overarching objective of AM and how it is typically implemented.

- Scientific Uncertainty. As discussed in the US DOI Technical Guide (Williams et al. 2009), the primary objective of AM is to inform future decision-making and reduce scientific uncertainty. More specifically, the uncertainty that AM seeks to address is related to the adverse outcomes associated with the development or operation of wind energy projects;

however, AM may also be used to address the uncertainty associated with the overall effectiveness of certain mitigation measures or management decisions.

- Bounding. Bounding, or setting limits to the range of possible mitigation activities, is a concept that has been used, particularly in the US, to assure project proponents that mitigation activities will stay within an agreed-upon range of thresholds. Bounding mitigation activities provides a level of financial security for project developers by limiting the amount of mitigation that may be required, and it reassures regulators that mitigation can be required if certain thresholds are surpassed.
- Scale. The scale at which AM is implemented is an important aspect of determining how it is used and how effective it is. AM may be applied at the project scale, where collection of monitoring data using appropriate methods, metrics, and experimental design will support AM principles to reduce the scientific uncertainty of an individual project or the effectiveness of particular mitigation measures. AM may also be applied at the planning scale, where it takes place over multiple projects and may be used to collate information and monitoring data from different projects to inform the future management and permitting (consenting) of wind energy projects.

3. Wind Energy and Adaptive Management

The land-based wind energy industry has been under development since the 1980s, but the initiation of the offshore industry is more recent. The relative maturity of the land-based wind industry has led to greater certainty around environmental impacts and standardized methodologies for collection of meaningful data. Efforts by a diverse set of stakeholders over the last 20+ years have led to retirement of certain risks, prioritization of issues left to be addressed, and development of robust siting and monitoring techniques. However, as wind energy projects increase in size and are built in an ever-widening variety of environments, wind developers continue to be confronted with challenges associated with the siting and environmental permitting of projects. Offshore wind farm development also raises issues concerning the conservation status of, and potential impacts on, some marine animals, as well as the practical challenges of monitoring impacts in the marine environment. This uncertainty stems from a lack of understanding of how wind energy developments affect the surrounding environments and animals.

Although data have been collected extensively around both land-based and offshore wind energy farms, some information and data gaps remain. Offshore wind, in particular may suffer from this problem: a recent review of offshore wind farms in the United Kingdom (UK) showed that the industry appears to be “Data Rich and Information Poor” (DRIP condition). This condition implies that while a significant amount of data have been collected around wind energy projects, the data sets often lack statistical power or do not enable the ability to draw any significant conclusions about how wind energy projects affect the surrounding environment (Ward et al. 1986; MMO 2014). These data may not yield sufficient information for a number of reasons:

- The scales over which the data have been collected may not be large enough to reduce scientific uncertainty.
- The data may not been collected in a question-driven manner.
- The data utility is undermined by issues of inadequate experimental design.
- The data collection level of effort lacks statistical power to reduce scientific uncertainty or improve future management decisions.

Often it is challenging to collect sufficient data to achieve adequate statistical power, particularly for mobile marine species.

Traditionally, the wind energy industry has been managed using several approaches including the mitigation hierarchy and the precautionary principle (discussed below). In general terms, these approaches encourage project developers and regulators to avoid or mitigate project-related risks or impacts through siting and/or mitigation measures. While these approaches are built around science-driven questions and can be effective at mitigating the overall impact of a project and meeting regulatory requirements in the short term, they have limited ability to reduce scientific uncertainty or facilitate learning that can be transferred to other projects or advance the overall state of knowledge. As overarching policy frameworks, the mitigation hierarchy and the precautionary principle have not placed reduction of scientific uncertainty at their core, which sets them apart from AM approaches.

AM can add value to wind energy projects where existing levels of uncertainty hinder permitting/consenting processes, and where existing data are information poor and lack the power to drive conclusions and reduce scientific uncertainty and social concerns (nongovernmental organization [NGO] concerns). Providing a means of learning by doing and reducing scientific uncertainty is beneficial for regulators and developers because it allows project managers to more effectively apply lessons learned from previous projects to new developments, thereby potentially reducing the cost and time constraints associated with monitoring, planning, and adopting mitigation or compensation measures.

As previously noted, depending on the regulatory and policy context and the goals of a project developer and community of stakeholders, AM can be applied at two scales for wind energy projects: an individual project scale and a larger planning scale. To address scientific uncertainty and enhance the overall effectiveness of an AM process, adequate data must be collected to reveal the impact of a single wind farm or a collection of projects on a population or segment of the population of concern. Due to the spatial and temporal scale of the data needed to understand large populations over wide geographic ranges, AM applied at the planning scale may be more effective at helping project planners understand how a wind energy project might affect a population of animals by using data from multiple projects over large geographic spaces. Conversely, the application of AM at the project scale may be limited for assessing population level impacts, because project developers of single wind energy projects are unlikely to fund monitoring activities of an entire population that falls outside of the scope and range of their project, and the site-based results may have limited application to reducing uncertainty about the impacts on populations. Efforts are under way in the US and other nations to broaden data collection to encompass areas larger than a single wind farm. Monitoring at the project scale is most likely to be useful in determining collisions. AM at the project scale can also effectively address impacts and reduce scientific uncertainty, but it depends on the situation and scale at which the resource of concern occurs.

It should be acknowledged, however, that implementing AM in the wind energy industry may be a relatively costly and time-consuming process compared to monitoring at a lower level of effort, although that effort may not contribute useful information for future decision-making. AM is not the correct management approach for every wind energy project; particularly, if decreasing scientific uncertainty is not feasible within the constraints of the design of the monitoring program. It may be too expensive to successfully implement AM, and doing so may not be technically feasible. If the risk associated with reducing the scientific uncertainties of the project is above predetermined or acceptable thresholds, AM may not be the best management approach. In addition to unforeseen costs, implementing AM can instill a false sense of security for regulators, developers, conservation groups, and other stakeholders if the limited data collected are misleading and show inaccurate effects on wildlife.

AM should be strongly considered to reduce the uncertainty about wind-wildlife interactions for wind farms where it appears that risks can be managed, and where a high degree of scientific uncertainty interferes with a project's development or policy goals. Note that the use of AM will not allow development at sites where the environmental risks are deemed too high, but it can help to manage sites where wind and wildlife interactions are less well known.

3.1 Mitigation Hierarchy

The mitigation hierarchy best represents the decision process or management approach that most wind energy projects use, and consists of steps taken to systematically limit impacts or risks by taking actions to avoid, minimize, or compensate for them (Jakle 2012; Kiesecker et al. 2010; May 2016; Business and Biodiversity Offsets Programme 2015). The avoidance or minimization of impacts is the primary focus of the mitigation hierarchy and is aided by innovative technological advances and best management practices (May et al. 2015; Marques et al. 2014). When applied to wind energy projects, the mitigation hierarchy involves avoiding impacts on wildlife through detailed siting techniques; minimizing or reducing impacts through mitigation measures such as temporary curtailment of turbine operation; and if outstanding impacts remain, offsetting them through compensatory mechanisms and restoration (Figure 2) (Jakle 2012).

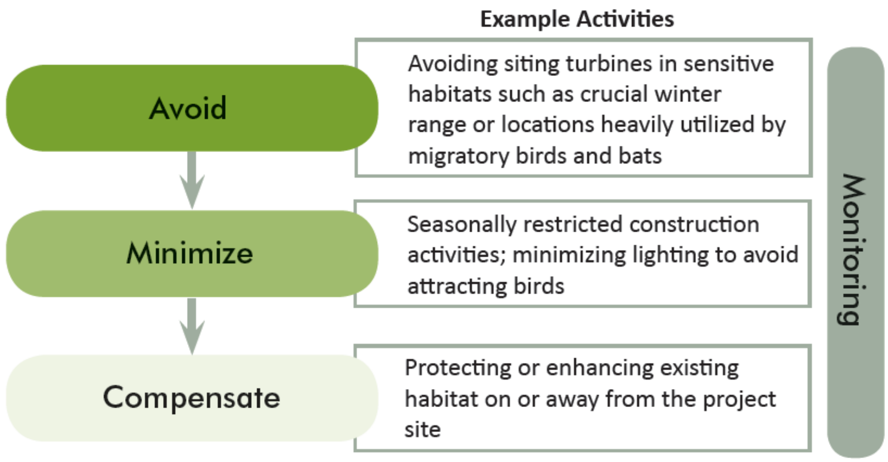

Figure 3. The mitigation hierarchy. The hierarchy is generally defined as avoiding impacts when possible, minimizing remaining impacts, and compensating for unavoidable impacts (Jakle 2012).

The application of the mitigation hierarchy provides developers with a framework for minimizing and mitigating potential risks associated with wind energy, allowing them to pursue a wider selection of potential project sites and to build larger and more profitable projects (May 2016). Compensatory mitigation measures can be carried out by replacing or restoring habitat either onsite or offsite; purchasing credits through conservation banks to compensate for unavoidable impacts; paying in-lieu of fees to government agencies or non-profits that may be used to engage in restoration or conservation activities to offset the project's impacts; or taking other actions deemed to be ecologically beneficial, including legal taking of certain species (Jakle 2012; May 2016; Marques et al. 2014). Replacing or restoring habitat is a viable mitigation for land-based wind energy losses; however, mitigation that directly affects species of concern, particularly offshore, is much more difficult.

Some form of the mitigation hierarchy is commonly used to manage wind energy projects around the world, but there is scant evidence that it is considered legally binding in jurisdictions engaged in wind energy development. The mitigation hierarchy provides developers with a prescribed approach for addressing environmental impacts and uncertainties associated with developing wind energy projects. The mitigation hierarchy has been criticized for its lack of consistency and science-based methods for determining appropriate levels of compensation and other thresholds at all levels of the hierarchy. The mitigation hierarchy does not include any evaluation of the level of effort required at each step in the process of mitigation (Darbi 2010; Darbi and Tausch 2015; Gardner et al. 2009; Cole 2011).

The overall responsibility for funding and supporting activities associated with the mitigation hierarchy typically falls on the project developer, which mirrors a process known as the "polluter pays principle" (Tobey and H. Smets 1996). The polluter pays principle, as adopted by most Organization for Economic Co-operation and Development (OECD) and European Community countries (OECD 1992) and used extensively in US law (Cordato 2001), states that the project developer, or polluter, is responsible for the planning, costs, and implementation of measures to address environmental impacts associated with a project. This principle is widely used for wind energy projects and other developments where mitigation may be required.

3.2 Precautionary Principle

When significant scientific uncertainty or perceived risk exists around development of a wind energy project, a precautionary approach—often referred to as applying the precautionary principle—may be taken. This approach is considered the "no regrets" or "better safe than sorry" principle; it can be interpreted to mean that when a specific development or management action is surrounded by significant uncertainty and a potential negative outcome could occur, measures should be taken to avoid the negative outcome, often by proceeding very cautiously or not pursuing the project at all (Raffensperger and Tickner 1999; Kriebel et al. 2001).

Wind energy facilities and associated infrastructure, such as access roads, meteorological towers, transmission lines, power substations, and operational activities, can affect wildlife directly through habitat loss and turbine collisions, and indirectly through habitat displacement, disturbance, or barrier effects (Jakle 2012; Kuvleksy et al. 2010; May 2015). In light of these potential impacts, the precautionary principle has often been applied to permitting and siting processes to reduce environmental risk. The precautionary principle is one of the most conservative approaches for addressing uncertainty and avoiding risk, and can be represented within any of the three levels of the mitigation hierarchy if environmental risks are too high and must be avoided to some extent (Figure 3).

It can be argued that this approach has resulted in responsible development of wind energy with limited environmental impacts, and that it provides regulators and project developers with more confidence that unwanted interactions and negative effects associated with installing and operating wind energy facilities will be avoided. However, compared to any other management approach the precautionary principle will either prevent a project from going forward, or may lead to increased avoidance, mitigation, and/or compensation throughout the life of a project, and it is improbable that such a risk-averse approach will facilitate the reduction of scientific uncertainty or inform future decision-making. A further criticism is that using precautionary assumptions within a modeling process to assess a project's impacts can reach excessively precautionary conclusions that may have very limited value for decision-makers to apply lessons learned to future projects.

4. International Use of Adaptive Management

Applicable laws, regulations, and guidelines that relate to AM were gathered from the WREN member countries and others including Germany, Ireland, the Netherlands, Norway, Portugal, Switzerland, the UK, and the US (Table 2). The use of AM principles for wind energy projects in the WREN countries ranges from relatively frequent use in regulatory processes to no formal recognition or application of AM. To better illustrate how AM principles have been used for wind energy projects outside of the US, case studies or examples from Norway, Portugal, Germany, Spain, Switzerland, and the UK are described below. Key themes or topics from these case studies, and communication with the other WREN members, are used to further explore how AM and its principles are applied to wind energy projects internationally, and to determine the relationship between these examples and the AM guidelines, as defined by the US DOI.

Table 2. Summary of the use of adaptive management among a subset of International Energy Agency Wind WREN nations.

Country	Status and Use	Legislation	Regulations Guidelines	Guidelines
Germany	No formal use; however conceptual attributes of AM are currently used to address wind/wildlife impacts.	No laws specific to AM; several natural resource protection laws provide a basis for wind/wildlife impact limits.	No formal regulations.	Resource agency guidelines contain adaptive attributes but do not suggest how to use AM.
The Netherlands	No formal use; however conceptual attributes of AM are currently used to address wind/wildlife impacts.	No laws specific to AM.	No formal regulations.	Round 3 for offshore wind development is using AM principles and moving closer to formalizing AM for wind energy projects.
Norway	No formal or informal use.	No laws specific to AM.	No formal regulations.	
Portugal	No formal use; however conceptual attributes of AM are currently used to address wind/wildlife impacts.	No laws specific to AM.	No formal regulations.	
Switzerland	No formal use; however conceptual attributes of AM are currently used to address wind/wildlife impacts.	No laws specific to AM.	No formal regulations.	
United Kingdom	While the term AM has no formal status, attributes of the policy concept are widely recognized as having utility and are often incorporated into conditions attached to consent decisions.	No laws specific to AM; the conceptual attributes of AM are currently used to address wind/wildlife impacts.	No formal regulations.	Resource agency guidelines contain adaptive attributes but do not suggest how to use AM.
United States	AM has been used for wind/wildlife impacts although it is not required; recent application aided by federal guidance documentation.	A portion of the Clean Water Act (section 404) requires developers to produce AM plans for wetland mitigation, but no laws are specific to wind energy AM.	No formal regulations.	Guidelines specific to developing AM plans have been published by natural resource agencies.
Spain	No formal use; however conceptual attributes of AM are currently used to address wind/wildlife impacts.	No laws specific to AM.	No formal regulations.	

4.1 International AM Case Studies

WREN members contributed information about and examples of how AM principles have been instituted to effectively manage wind energy projects in their respective nations. The following sections summarize several European examples or case studies from Norway, Portugal, Germany, Switzerland, the UK, and Spain.

4.1.1 Portugal

No specific regulatory approaches, policies, or guidance documentation in place in Portugal apply to AM. However, a good example of the principles of AM can be found at the Candeeiros wind farm located in the central portion of the country. The Portuguese refer to it as an iterative approach to post-construction bird mortality monitoring. After 3 years of post-construction bird monitoring, the common kestrel (*Falco tinnunculus*) emerged as the species most commonly killed at the wind farm. As a result, the monitoring program was changed in order to study the kestrel population and evaluate the significance of the wind farm impact on this species. Although the common kestrel is not an endangered species in Portugal, the impact of the wind farm on the local population was considered significant and this led to the development of a site-specific mitigation program (onsite minimization and offset/compensation). The environmental authorities and the wind developer concurred that this was the best solution for reducing kestrel mortality at the wind farm. The mitigation plan included planting native shrubs, enhancing habitat and scrub areas away from turbines, and promoting extensive livestock grazing away from the turbines to enhance habitat heterogeneity. The implementation of the mitigation program started in 2013 and will continue until 2016. Monitoring of the kestrel population and carcass surveys have continued in order to evaluate the success of the mitigation measures.

4.1.2 Norway

In Norway, a number of laws, regulations, and guidance are related to the protection of biodiversity and concern the development of renewable energy and other development (May et al. 2012); however, none of them explicitly requires AM. Wind farm licenses may include specific terms and regulations to avoid damage to wildlife. The Nature Diversity Act could provide the legal mechanism for AM practices, because the precautionary and polluter pays principles are well established in the Act. However, in practice these principles are not enforced for wind energy and wildlife interactions due to the limited influence of the Environmental Agency in the consenting process. In addition, there is a continuous tension between authorities and industry about who should be held responsible for financing monitoring and research of environmental impacts from wind energy developments. There also is pressure to minimize the total project costs in favor of profitability, which can act to compromise environmental considerations.

Although AM is currently not implemented in Norway, the renewable energy company Statkraft co-financed extensive research and monitoring at the Smøla wind farm (2006–2016). This effort included testing of mitigation measures in response to an official complaint from the Bern Convention to the Norwegian government concerning conflicts with white-tailed eagles (*Haliaeetus albicilla*). Although no mitigation measures have been demonstrated to reduce collision risk, the investment has contributed to reducing the scientific uncertainty pertaining to both the extent of the impacts and effectiveness of mitigation measures. Between 2012 and 2016, a research and development project titled “Innovative Mitigation Tools for Avian Conflicts with Wind Turbines” (INTACT, www.nina.no/Forskning/Prosjekter/INTACT) tested several mitigation measures in situ at the Smøla wind farm. Prior to this project, a literature review was conducted to assess the expected efficacy of various proposed post-construction measures to reduce wind-turbine–induced avian mortality with regard to audible, optical, and biomechanical constraints and options (May et al. 2015). The INTACT project tested the efficacy of contrast-painting one of three rotor blades to increase its visibility to birds, and contrast-painting of tower bases to reduce tower collisions of ptarmigan. A geographic information system micro-siting tool was developed to delineate areas with thermal and orographic updrafts as well as leading lines in the landscape. A pilot study was executed to verify whether nocturnal birds respond to ultraviolet lights. Finally, an operational mitigation model was developed aimed at identifying hazardous periods and turbines with increased bird collision risk.

4.1.3 Netherlands

There are no formal regulations for the use of AM for wind energy projects in the Netherlands. Legislative difficulties in adjusting permits after they have been issued renders use of AM within projects (single-loop learning) generally impossible. However, AM principles have been used to adjust mandatory monitoring programs within projects for offshore wind farms. The offshore wind farm Luchterduinen includes intensive and regular contact between the competent authority and the wind developer to assess whether adjustment of the monitoring program is needed, based on monitoring results and information from other sources that have become available during the project. Examples of major adjustments that have been made to the program include the addition of research on bats using bat detectors (which was not included in the monitoring program because the occurrence of bats at sea was largely unknown); participation in the Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS) project to develop an individual-based model of the effects of underwater piling sound on harbor porpoise (in place of the originally planned aerial surveys); and adjustments to research on the effects of underwater piling sound on fish juveniles and larvae. These and other more minor adjustments to the monitoring program have led to a much more effective program than that originally scoped.

The use of AM principles among multiple offshore Dutch wind farms is becoming more common (double-loop learning). Currently, a third round of offshore wind farms is being planned in the Netherlands; each round builds on the knowledge acquired in the previous rounds to improve conditions and decrease constraints for offshore wind energy projects. A new policy system was implemented for the third round; it improves the chance of implementing AM by tasking the government to select possible areas for offshore wind energy development, carrying out all preliminary environmental assessments, implementing monitoring and research programs that will validate assumptions made in these assessments, and overseeing research into issues of financial importance to wind developers such as wind resource characterization, bathymetry, and sea bed characteristics. Under this scheme, the government will draft decisions for each proposed wind farm site including all conditions and constraints for the development of a wind farm.

The third round consists of 10 planned offshore wind farms of 350–380 MW each. Wind farm site decisions will be drafted in five phases, one phase per two wind farms. Knowledge gathered during one phase will be applied in the next in an AM process. However, this process is new and just beginning to unfold, making it difficult to assess the extent to which AM will actually be applied. An evaluation at the end of 5 years will provide better insight into the questions about the use and efficacy of AM.

4.1.4 Germany

While AM is not required and no formal regulations outline how it should be used for wind energy projects in Germany, AM principles have been applied to several different projects. For example, the Ellern wind farm in Germany’s southwest Rhineland-Palatinate attempted to mitigate the collision mortality of bats by curtailing turbine operation at wind speeds below 6 m/s from April to October. The mitigation was required locally, specified in the wind farm permit, and based on federal state guidelines. Data were collected during the first year of operation through carcass surveys and nacelle monitoring. After 1 year of operation, the monitoring data were compared with thresholds set by a group of stakeholders, including nature conservation organizations and the project proponent, and the curtailment methods were altered to ensure that the thresholds were met. Monitoring was only required for the first 2 years of wind farm operation and subsequent adaptations to the monitoring plan are not intended.

Another wind farm located in North-Rhine Westphalia uses the cultivation of nearby farmland to trigger turbine shutdowns to avoid collisions with red kites (*Milvus Milvus*). Shutdowns are required by permit under certain circumstances: during daytime periods if red kites nest within a 0.5 km radius of the turbines; and for three days after cultivation activities. If monitoring of the surrounding area finds no nesting red kites within the minimum distance for four consecutive days, the measures are no longer required. Similar procedures have been adopted by nearby wind farms, where daytime turbine shutdown during harvesting is triggered by the first collision incident, but no wind farm specifically identifies these procedures as AM.

4.1.5 Switzerland

Similar to many other European countries, AM is not mentioned in Swiss legislation, and there is no corresponding translation or specific term for the concept in the national languages. Only recently have AM principles for wind energy projects been recognized as a means of improving upon the interpretation of impact assessments and management of bats around wind energy projects (Swiss Federal Office of Energy 2015).

The Gries wind farm, planned to be the highest-altitude wind farm in Europe, has one pilot turbine that has been in operation since 2012. Three additional turbines are planned, but their potential impacts on migrating bat and bird species is considered to be highly uncertain. As a condition of the construction permit, a curtailment plan will be implemented to mitigate the project's impact on bats. Bat activity will be monitored around the wind energy project for 3 years during spring, summer, and autumn; the resulting data will be assessed on a yearly basis in order to optimize the curtailment algorithm. Any operating adjustments will need approval by an operations commission consisting of stakeholders, the wind farm developers, an independent bat expert, and cantonal (local government) representatives. After 12 years of operation, the commission will reassess the project's operating concept.

4.1.6 United Kingdom

AM principles are used to manage wind energy and other renewable energy projects in the UK, but the term has no formal status in UK law, policy, or guidance. At a strategic level in Scotland, which now has more than 150 operational wind farms, the Scottish Windfarm Bird Steering Group has been formed to examine the relationship between bird populations and wind farms, and to act as a platform for dialog between the renewables industry, conservation organizations, and government on these issues. The Group has devised a program of research aimed at reducing scientific uncertainties and improving future decision-making.

In a recent land-based example, at a 50 MW land-based wind energy project in the UK developed in moorland habitat over 10 years ago, collision risk models were developed that suggested the farm could pose a risk for hen harriers (*Circus cyaneus*). Monitoring was carried out to determine how to most effectively manage heather moorland habitat to benefit the hen harrier through rotational burning, drain-blocking, etc. The monitoring results inform annual decisions about how to best manage the moorland habitat, which in return offsets the collision risk for hen harriers. Understanding of the extent to which these activities benefit the species has improved over time.

Offshore, a number of wind farms have been consented in recent years in Scottish waters, but construction has not yet started. Assessments of the potential impacts of wind farms on the marine environment are being used to develop a question-led approach to monitoring that will be able to reduce scientific uncertainties associated with future decision-making. For example, modeling of collision and displacement effects on a range of seabird species including auks and gulls is forming the basis of monitoring that is capable of improving confidence in the predictability of seabird behavior in response to operational turbines. Data collection is generally undertaken by consultants acting on behalf of the developers, and the monitoring plans are agreed upon by regional advisory groups with representation from statutory advisors and nongovernmental bodies. There are no pre-established requirements for projects to adjust their management approach on the basis of monitoring results. Data collection activities serve as a means of validating that the effects associated with the consented wind farm are acceptable, and the results contribute to a double feedback loop that facilitates learning for future offshore wind developments.

A recent decision was made to limit the size of a planned offshore wind farm in the Thames estuary (London array – http://www.londonarray.com/project/london-array-to-stay-at-630mw/). This came about because of a requirement that the developer demonstrate that any change caused by the additional turbines to the habitat of the red throated divers (*Gavia stellate*) that overwinter in this part of the Thames Estuary does not compromise its status as a designated environmental Special Protection Area. The application of an AM approach may help to avoid limitations to planned developments in the future.

4.1.7 Spain

Currently, AM has not been required in Spain but in cases with a special relevance, environmental regulators, wind energy companies, and researchers may create these agreements to achieve a good outcome.

Wind farms located in La Janda (Cádiz, south of Spain) provide an example related to having found large numbers of dead birds due to blade collision. After several meetings, researchers proposed a novel method for reducing avian mortality; it consists of monitoring bird flight in the field, especially the flight of the more affected species such as the Griffon vulture (*Gyps fulvus*). When the wind farm operators detect a dangerous situation, they can stop the relevant turbines and restart them after the birds have left the area. Training was provided to operators to ensure accurate detection of collisions, while the area was surveyed for bird carcasses. Daily monitoring for collisions was carried out from early morning through late in the evening.

The agreement reached by all parties was as follows: wind energy companies paid for the system; researchers carried out the data analysis and interpretation; and environmental agencies awaited the results before taking more punitive measures. After 2 years, results showed a 50% decrease in mortality and a reduction in energy production of approximately 0.7% per year (de Lucas et al. 2012). Since then, this monitoring method has continued and bird mortality rates continue to decrease.

4.2 Overview of Case Studies

The six international AM case studies from Norway, Portugal, Germany, Switzerland, the UK, and Spain provide examples of the application of some AM principles. Most of these case studies take an approach that is closer to that of the mitigation hierarchy than AM, because most of them are focused on implementing monitoring and mitigation measures to reduce project impacts on a specific bird or bat species. However, the terrestrial wind farm example in the UK, the Gries wind farm in Switzerland, and the Ellern wind farm in Germany provide excellent examples of how the AM principle of learning by doing can be integrated into a mitigation hierarchy approach to better inform how future mitigation measures may be improved. The offshore wind farm example from the UK is the closest example to a true AM approach as defined by the US DOI; it illustrates the application of double-loop learning to use stakeholder input, learning by doing, and lessons learned from individual projects to inform future offshore wind project planning and management decisions.

The remainder of this section discusses several key themes or topic areas that were highlighted during communication with WREN members about AM and how AM principles are used or perceived to be used in the WREN member nations.

4.3 Use and Implementation of Adaptive Management

Many of the WREN or other European countries do not commonly use the term “adaptive management” in practice or as part of their regulatory/legal framework. A more commonly used term—risk-based management—is defined as any approach that seeks to inform decision-making through an understanding of the scientific uncertainties and associated consequences in terms of the likelihood and magnitude of impact. Under some programs, AM is the adoption of a risk-based approach to reducing scientific uncertainty (Le Lièvre et al. 2016). However, several European countries have applied principles of AM to wind energy projects, in practice or in guidance documents, even when those practices have not been referred to as AM. The US and the UK do not have regulatory requirements for the use of AM, but resource agencies provide policy guidance on using AM for wind energy development (USFWS 2012; Strickland et al. 2011). Germany, the Netherlands, and Portugal have no formal guidance, but some of the attributes of AM, including the implementation of monitoring programs and the continual adjustment and improvement of practices, are prevalent for existing wind farms. Norway has no formal regulations related to the use of AM, but AM principles have been proposed for wind energy projects.

When applying AM to wind farms, it is important to recognize that these developments are first and foremost commercial activities. Taking the opportunity to consider wind farms as experiments in reducing scientific uncertainties associated with wind and wildlife interactions will come second in importance and may introduce practical obstacles. For example, conducting an experiment over large spatial and temporal scales will entail collating data from multiple wind farms that may not be collected with the same experimental designs. These challenges and tensions need to be openly acknowledged and reconciled through effective planning.

One of the more significant challenges to fully implementing AM, as voiced by European WREN members, is the inability to curtail or alter project operations, which results in lost revenues, once a formal contract or agreement has been signed between the project developer and the regulatory bodies. Once a contract has been signed, the project developers may be legally entitled to receive the agreed-upon revenue. If a wind energy project is using an AM approach, and mitigation is required to better understand how a certain species may interact with the project, the project developer must be compensated for any revenue that is lost due to the curtailment of activities. In such cases, curtailment is used to mean the voluntary decrease in wind energy production for any reason, although the meaning may differ somewhat among nations. Wind energy developers in the US are not legally entitled to a specified level of revenue, and if a project has deleterious effects on wildlife, regulators may require any necessary level of mitigation or curtailment, as allowed by law.

Other challenges discussed among the WREN member nations concern the costs associated with implementing AM, including the potential for decreased electrical generation, and the ongoing costs of monitoring. In Europe, the polluter pays principle is often used to support mitigation and curtailment activities; however, developers are not always willing to absorb mitigation costs that were unforeseen during the project development and financing stages. Additionally, in the US and the UK, efforts to prescribe mitigation measures, and therefore reduce financial uncertainty up front, can be self-defeating if the mitigation actions are inflexible and potentially add significant cost to the project without reducing scientific uncertainty.

5. Adaptive Management and Wind Energy in the US

A number of statutes exist for protecting natural resources under US federal law.[1] Wind farm owners and operators must abide by this diverse set of laws and regulations. As a result, monitoring plans are often developed to meet a number of statutory and regulatory requirements, and none of these laws explicitly require AM practices as part of species/population management. Selection and implementation of AM practices are at the discretion of each jurisdictional agency, and are typically outlined and discussed in their associated guidance documents, which come in the form of conservation or AM plans (USFWS 2012, 2013; BLM 2010). Because AM has only recently become part of these wind energy management approaches, few existing wind energy projects have formal AM plans or principles, such as those described in the UK example, in their conservation plans.

A review of 16 plans governing wind facilities was conducted to identify how AM and its underlying principles have been applied to the wind industry so far, and whether these examples resemble the US DOI AM guidelines. A list of the projects, the date the plan was written, the location and size of the project, the motivation for the plan, and the species of concern can be found in Appendix B. Almost all of the plans have a specific focus on federally protected species, such as those protected under the Endangered Species Act (ESA), Migratory Bird Treaty Act (MBTA), and the Bald and Golden Eagle Protection Act (BGEPA).

To supplement the information gathered from the review of the US wind energy AM plans, a series of semi-structured interviews were conducted with wind energy stakeholders in the US. Interviewees included wind developers, NGO representatives, owner/operators, environmental consultants, and regulatory agencies.

The following section discusses AM practices and overarching themes found in each of the plans, as well as key takeaway messages from the interviews. A considerable amount of variability exists among the different plans such as the definition of AM and the overall perspective of the role AM should play in wind energy. Mitigation plays different roles in each of the plans, because some define predetermined limits or boundaries for mitigation, while others discuss a more flexible approach such that predetermined mitigation limits or tiers are not established. Only a few plans consist of AM principles or approaches that are similar to those discussed in the US DOI guidelines. Each plan was measured against the nine questions (Table 1) or criteria outlined by the US DOI to determine whether AM is appropriate for a specific management situation.

5.1 Prescriptive Adaptive Management

Several of the conservation plans reviewed are fairly detailed and contain explicit sections outlining prescribed mitigation actions as a result of specific environmental monitoring results and/or key species mortality events, or triggers. These approaches often set predetermined tiers for monitoring and mitigation thresholds, such as those that adhere to the US Fish and Wildlife Service (USFWS) Land-based Wind Energy Guidelines and the USFWS Eagle Conservation Plan Guidance (USFWS 2012, 2013). This tiered approach may provide more certainty for project developers and regulators earlier in the process. It may limit the overall flexibility of AM as discussed in the US DOI guidelines, and could be seen as limiting the ability to fully learn from

[1] Endangered Species Act (ESA), Migratory Bird Treaty Act (MBTA), Bald and Golden Eagle Protection Act (BGEPA), and Marine Mammal Protection Act (MMPA) (Offshore Wind only)

the results of management decisions. Using this prescribed approach also makes it more difficult to follow a hypothesis-driven approach to monitoring.

Alternatively, several of the plans listed in Appendix B do not contain predetermined mitigation limits or boundaries but rather they outline a more flexible approach. These plans generally defer to resource agencies or Technical Advisory Committees (TACs) to determine mitigation actions and address potential mortalities. Even though the Grand Prairie Wind Farm plan (Stantec 2014) follows the USFWS Land-based Wind Energy Guidelines and contains a tiered structure, the plan outlines a more flexible AM approach that relies on a set of triggers or mass mortality events to restart consultation with federal and state authorities concerning the possibility of amending avoidance and minimization plans. The only offshore wind project reviewed, the Cape Wind project off Massachusetts, also uses AM principles to ensure the best available science and technologies are used to monitor and potentially mitigate the project impact on the environment. Such plans may require frequent coordination between project developers, regulators, and TACs. A process such as this will likely promote additional iterations between the project stakeholders, which can help maintain flexibility as the project progresses. It is important to note that Cape Wind is the only offshore wind project discussed in this section; because it was the first proposed offshore wind project in the U.S., an AM approach was used to address the greater uncertainty at the project outset.

5.2 Role of Mitigation in AM Plans

The reviewed US wind energy AM plans, many of which take the form of bird or bat conservation plans, reference a variety of mitigation tools for addressing environmental uncertainty and the unique characteristics of each project. The vast majority of the plans discuss some sort of mitigation trigger that consists of a mortality threshold that is established in the respective conservation plans and can be either arbitrarily defined or based on population models. Curtailment—the most frequently referenced mitigation response in the plans—consists of feathering turbine blades at certain cut-in speeds to reduce impacts on bird and bat species, or limiting the operation of individual turbines or an entire wind farm over periods of time, such as during key migration periods. Plans adhering to the USFWS Land-based Wind Energy Guidelines and the USFWS Eagle Conservation Plan Guidance outline tiers for monitoring and mitigation triggered by specific eagle mortalities, and the corresponding curtailment responses required (USFWS 2012, 2013). In certain cases, such as projects where golden eagle (*Aquila chrysaetos*) fatality is a significant concern, project developers have agreed to curtail turbine operation any time an eagle is in the vicinity of the project site and is considered at risk of collision (Ocotillo Wind 2012). Further study of the efficacy of curtailment to protect eagles is under study at several wind farm locations in the US.

Several plans propose compensatory mitigation actions if required mitigation and conservation measures do not remove or adequately address the potential for take. Compensatory mitigation strategies include power pole retrofitting to prevent eagles from landing on electrical infrastructure to reduce risk of electrocution (Cole and Dahl 2013), essential species habitat conservation, and roadside carcass removal to prevent scavenging activities in the vicinity of vehicular traffic. Plans also propose making monetary investments in permanent conservation easements and purchasing critical habitat areas prior to construction (Criterion Power Partners 2014). Only a few compensatory mitigation options appear in plans because the number of acceptable options is limited. It is unclear whether these measures have been effective as mitigation tools.

While curtailment and compensatory mitigation may be applied to certain AM approaches, the processes described in many of these plans more closely resemble the mitigation hierarchy than the US DOI guidelines definition of AM. The mitigation hierarchy can serve an important role for projects that feature high environmental or financial risks. It has a strong emphasis on the use of common methods and metrics (Strickland et al. 2011), but lacks emphasis on double-loop learning and the question-driven approach of AM needed to promote learning from the results of management decisions and inform future wind energy projects.

5.3 US DOI AM Criteria

The DOI AM scoping questions listed in Table 1 were applied as criteria to each of the 16 wind energy plans to evaluate whether the management processes and approaches described could be considered AM under the DOI Technical Guide definition. While a total of seven plans outline an AM process that fits the DOI criteria, several factors made it particularly difficult to confidently determine whether certain criteria were applicable. The DOI criteria are very broad, making it difficult to determine whether the criteria are applicable or relevant for specific projects, and several of the AM plans examined were written for projects that have not yet been constructed and lack the specificity needed to fully understand whether they represent AM as defined by the DOI criteria. While the US DOI criteria may be broad and challenging to apply to specific plans, they provide a baseline understanding of AM and can assist wind energy stakeholders in understanding the concept of AM and implementing it in the future.

5.4 Applying AM – Stakeholders' Perspective

Interviewees included four representatives from wind energy development companies, four environmental consultants, three government regulators, and one NGO staff member. Interviewees were asked to describe:

- their involvement in wind projects that include AM plans;
- their experience with outcomes, costs, efficacies, successes, and challenges using AM; and
- whether they could provide documentation of AM plans and/or data on the outcomes of AM.

Overall, many of the key themes and messages obtained from the interviews agreed with those gleaned from the wind energy plans. Interviewees noted considerable variability among AM plans, which is likely due to the lack of consensus around AM as a concept and practice, as well as the limited tools available for its efficient implementation. The stakeholders also discussed differences in the risk culture among wind farm developers as a factor that can promote variable application of AM. That is, the risk tolerance of an organization partially determines whether the developer will agree to meet certain AM requirements, particularly if a monitoring or mitigation action may appear to be expensive or when no upper limits for costs are set.

The interview process confirmed that various definitions of AM are in use. Some stakeholders conceived of AM at wind farms as a set of tiered, pre-agreed-upon management actions triggered when environmental impacts surpass certain levels. Others explicitly stated that such a construct is not truly AM, and argued that true AM should be hypothesis-based. Similarly, interviewees had a variety of perspectives on the value of AM. Some stated that the adaptability of AM makes it extremely useful, and others claimed it is a "toolbox without tools" because of the lack of guidance for AM plan formats and implementation procedures.

Financial risk was a commonly discussed topic. AM promotes flexibility to develop projects in the face of environmental uncertainty, but can also create challenges for financing due to the potential open-endedness of AM plans and the additional financial uncertainty this creates. Bounding of mitigation, or setting predetermined mitigation triggers, was mentioned as one way to alleviate some of the uncertainty associated with AM. As a result, potential investors may gain a better understanding of the risks, likelihood, and magnitude of the consequences of applying AM. Some stakeholders also noted that the open-ended nature of AM could be construed to imply that all future changes will result in additional mitigation to reduce impacts, regardless of the cost. This would lead to the conclusion that definitive limits need to be set, such as acceptable levels of take for certain species at wind farms, to ensure that the cost of reducing impacts does not outweigh the benefits produced.

It is important to note that the information from the interviews represents a very small sample of stakeholders from the US, and may be biased toward the groups represented.

6. Discussion – DOI Guidelines and Application of AM to Individual Wind Projects

An evaluation of existing US wind energy conservation plans, and the application of AM to wind energy projects worldwide, makes it apparent that few examples discussed in this white paper fully meet the criteria for AM as laid out in the DOI guidelines. Most examples appear to follow the principles of passive, rather than active, AM (Walters and Holling 1990; Murray and Marmorek 2003).

To systematically decrease scientific uncertainty about wind energy project and wildlife interactions, it will be necessary to reconsider the design of monitoring studies at wind energy sites if data collected are to meaningfully reduce scientific uncertainty such that the data can inform future management decisions at both the project and planning scales. A necessary first step is to move toward a common definition and application of AM to effectively reduce scientific uncertainty and inform future management decisions. The overall scale at which AM is applied to wind energy projects and the industry as a whole should be strongly considered. Studies undertaken at larger spatial scales, or data accumulated from multiple projects, are more likely to correspond closely to a species with a large population range and are therefore likely to be more effective at reducing uncertainties. Sampling efforts at smaller scales are less likely to measure changes in populations, whether or not those changes are due to the presence of the wind farm. However, as demonstrated by evaluating the DOI criteria against existing wind energy plans and projects, AM may be applied at an individual project scale under certain conditions, for example, if the home range of a species is largely confined to the project site.

The following sections discuss the lessons learned by evaluating AM practices for individual wind energy projects within the US and internationally, the outcomes measured against the DOI AM criteria and definition, the role of AM in relation to regulatory processes, and areas where AM plans for individual wind projects can inform collective AM for use in future planning of wind energy projects.

6.1 Consistency and Implementation

The existence of several definitions of AM further complicates the overall understanding of this decision-making process in the wind energy context. As demonstrated by the review of conservation plans from US-based wind energy projects and the application of AM internationally, the overall approach and implementation of AM for wind energy projects can vary greatly. One of the underlying reasons for this is probably associated with differences in the definitions of AM.

Within the US, no federal or state regulations require wind energy projects to use AM, and there is no single definition of AM that is accepted and used by all wind energy projects. No laws or regulations require AM in any of the other countries evaluated. Several natural resource agencies within the US have recently produced guidelines for AM, or rules that invoke the principles of the concept (BLM 2010; Williams et al. 2009; USFWS 2013). However, relatively few projects have instituted these guidelines because AM is still a relatively new concept to the wind energy industry, and developers have not been required to use it. Existing AM guidelines vary in the degree of prescription of specific actions, the amount of stakeholder involvement and representation within the AM process, and how monitoring and mitigation triggers are developed. In the UK, practitioners of AM are most likely to use the US DOI guidelines, although one could argue that the Survey, Deploy, and Monitor policy in Scotland promotes an AM approach. None of the other WREN member countries other than the US have formal guidance.

While complying with all national and international regulatory requirements for wind farms, there appear to be opportunities for implementing aspects of AM within existing legal structures and practices. For example, European directives that require preparation of environmental impact assessments for wind energy developments typically follow a principle of "predict-mitigate-implement" for potential wind/wildlife interactions. By encouraging the application of AM principles, while continuing to comply with all applicable regulations, the assessments could be moved toward a "predict-mitigate-implement-monitor-adapt" model that is likely to improve decision-making and ultimately create more effective ecosystem management.

Also, in keeping with the regulatory requirements of many nations, the broad principles of AM require the engagement of stakeholders. Successful AM programs will of necessity involve active information sharing about scientific questions, potential effects of the development, planned monitoring to decrease uncertainty, and possible mitigation actions if effects are detected. Examples such as the US National Environmental Protection Act (NEPA 1969) require stakeholder engagement. Adding the principles of AM could further increase the sense of openness and legitimacy for the process, and potentially result in better support for monitoring efforts.

The US DOI provides general criteria as part of its guidance for defining AM and under what conditions it may be applied. It is not straightforward to use these criteria to ensure a management approach will result in effective AM for wind energy. These criteria or nine questions (Table 1) require elaboration and greater specificity for implementation of AM for the benefit of wind energy projects. Implementation guidance for AM associated with individual projects or to benefit future planning for wind energy would benefit from including the following topics:

- the need to develop an AM process from the ground up to meet the specific needs of the location, farm layout, and wildlife in the region, including hypotheses-based questions to guide monitoring activities that will facilitate learning and help to reduce scientific uncertainty;
- the importance of establishing the spatial and temporal scale over which monitoring and data collection should occur, based on the resources of concern and questions to be asked;
- a process for identifying acceptable tolerance levels for monitoring data and potential mitigation triggers;
- a process for engaging stakeholders in decision-making and information sharing;
- guidance for integrating or closely connecting AM processes with required environmental assessments (such as Strategic Environmental Assessments in Europe or Programmatic Environmental Impacts Statements in the US); and
- efforts to determine whether mechanisms can be created that address financial risk, limits, and uncertainties that come about as a result of AM.[2]

[2] As discussed above, this is a particularly challenging issue that may be a sticking point for achieving widespread implementation of AM.

More specific guidance could be particularly beneficial for project developers and regulators who choose to use AM but remain unsure of specific implementation practices. Due to the variety of environmental uncertainties and options for policy and site management responses that exist for wind energy, implementation guidelines for wind energy use AM may be most effective if they are written to allow for a range of monitoring decisions and responses to policies and management of projects.

The overall responsibilities and costs associated with implementing AM and its monitoring activities are typically passed on to the project developer, similar to the polluter pays principle. However, as discussed in Section 4.0, project developers in many European countries may be compensated for part or all of any revenue lost (below an agreed-upon level) due to unforeseen curtailment or mitigation activities. Due to this complexity, the overall responsibility of who should be required to support and pay for AM may need to be addressed on a case-by-case basis.

6.2 Monitoring to Support AM

Monitoring data that have been collected using consistent and rigorous methods and that are fit for the intended purpose are the cornerstone of ensuring that AM processes can be applied successfully. Most developers are required to collect baseline data for the area around a proposed wind farm to understand which wildlife populations and habitats might be at risk, and to collect data on wildlife interactions with wind farm infrastructure after its construction. In many cases these data were collected with specific uses in mind, making it difficult to evaluate the effect of wind farm operations on wildlife, particularly at the population level or beyond the scale of any one project. This situation, sometimes referred to as DRIP (data rich and information poor) and originally cited by Ward et al. (1986), results when monitoring activities are not well-defined or lack a hypothesis-driven question. By initiating an AM process with one or more scientifically valid questions, monitoring programs can yield data that are useful in determining the effects of wind farms on wildlife and can assist in reducing scientific uncertainty, provided the data are collected in an appropriate manner. Collection of the data should not require that the overall level of effort be increased but rather that the data collection be thoughtful and aimed at important questions, resulting in a better outcome while not increasing costs to the developer. Such plans will need to take into account an understanding of species' behavior and relationship to wind turbines in order to produce meaningful data. For example, pre-construction monitoring may help predict raptor risk from turbines, but the relationship between pre-construction activity levels and post-construction bat mortality levels, has yet to be ascertained.

In addition to defining data collection efforts that meet specific questions and reduce scientific uncertainty at the level of a single wind farm, it is important that the data be consistent among wind farms and be collected using standardized methods, in order to group data together for analysis over a region. Such standardization can facilitate the effective application of AM at the larger planning level. Although there will be differences in wildlife species, wind speeds, terrain, and operational modes among wind farms in different countries and regions, agreement should be sought within functional groupings of wind farms to enable the data to be used for meta-analysis. Although collecting compatible data across wind farms may be burdensome for developers, an attempt to collect comparable data can assist with future planning and siting of installations. Efforts to develop standard practices and guidance for US land-based wind farms may serve as good models for such efforts.[3]

[3] Example guidance documents include the Land-based Wind Energy Guidelines (USFWS 2012), the USFWS Eagle Conservation Plan Guidance Appendix C (USFWS 2013), and the National Wind

Whether an AM process is aimed at the project or larger planning scale, monitoring of wind farms and wildlife should be carried out at the appropriate temporal and spatial scale to fit potential interactions. For example, monitoring for wind farm effects on populations of migratory species must take into account the broad spatial scale over which the species travels to ensure that the effects of the wind farm are separated from any other potential effects; in addition, sampling should be concentrated during the migratory season. Carrying out large spatial and temporal scale monitoring programs is inherently difficult and expensive.

Although data collected to reduce scientific uncertainty and answer specific questions will form the basis for applying AM approaches at the project and planning level, there will also be an ongoing need for strategic research studies of wind energy project interactions with wildlife. By concentrating data collection efforts on turbine interactions with species for which little information is known or for which the conservation status has changed, research studies can help answer questions about the mechanisms of harm, suggest effective mitigation strategies, further reduce scientific uncertainty, and perhaps decrease overall monitoring needs at wind farms.

6.3 Adaptive Management vs. Mitigation Hierarchy

Conservation plans associated with US wind energy projects are usually driven by the need to abide by statutory and regulatory guidance related to numerous environmental laws, resulting in variability among these plans. Additionally, the relatively recent focus on including AM in monitoring plans, has further contributed to variability in these plans, because a standard plan or best practice has yet to be firmly established. Several of the plans adopt a flexible AM process, while others are more prescriptive and provide a tiered approach to monitoring and mitigation. The latter approach provides developers with certainty about the costs of implementing AM, but unless the study design is fit for its purpose there is a risk that the outcome will not reduce scientific uncertainty or facilitate learning. In addition, where tiered approaches primarily focus on reducing impacts by monitoring, minimizing, mitigating, and compensating for the effects of wind energy projects, the study design may be less able to detect changes due to the presence of wind farms and therefore may lack the ability to reduce uncertainty about the mechanisms of the effects. The prescriptive mitigation approach leans toward the overall objective of reducing impacts at each step, which more closely resembles the approach of the mitigation hierarchy than the DOI's definition of AM.

The mitigation hierarchy is focused on a tiered approach to mitigating activities to reduce impacts, and if necessary, compensatory actions may be required if impacts are not adequately reduced. This process works well for reducing impacts, but it does not necessarily facilitate learning as emphasized by AM principles. For example, developers may eventually be required to curtail operation if endangered albatross are found near an offshore wind energy project area. While protecting the bird, this curtailment will limit the ability to reduce scientific uncertainty about the behavior of large soaring seabirds near operational turbines, and it will potentially place a financial burden on the project. The mitigation hierarchy, as demonstrated in this example, will enable mitigation activities to prevent the taking of an endangered albatross and avoid regulatory concerns, but can make it difficult to create a learning scenario for the project, thereby resulting in the potential for a continuation of curtailment activities throughout the life of the project. Conversely, AM seeks to better understand the risks and uncertainty associated with such an interaction through an iterative process of monitoring and informed management decisions.

Coordinating Collaborative's Comprehensive Guide to Studying Wind Energy/Wildlife Interactions (Strickland et al. 2011).

Striking the appropriate balance between mitigating and compensating for potential impacts versus detecting change is a dilemma with which regulators and industry must concern themselves if they are to develop AM approaches that meaningfully reduce scientific uncertainty.

From a theoretical perspective, AM is a logical approach for a wind energy project seeking to better understand environmental uncertainties and risks. However, as discussed below, drawbacks associated with AM can include increased financial risks if the level of monitoring and the management response under an AM plan are unclear or unbounded. Furthermore, as seen in the US plans reviewed in Section 5.0, in certain situations limited data are available and highly protected avian and bat species are present, or the potential level of impact is relatively high, resulting in management strategies that place protection of wildlife interests above the goal of reducing scientific uncertainty about the impacts. For these situations, application of the mitigation hierarchy, within the bounds of existing laws, will be more appropriate for limiting the risk of mortality of a protected species and the associated regulatory consequences.

6.4 Scale of Implementation

As AM is considered for future wind energy projects, the spatial scale at which it is applied should be considered to optimally address or reduce scientific uncertainty. Almost all AM examples reviewed and discussed in this white paper seek to apply AM at an individual project scale. AM that is applied at the project scale may be relatively less successful at reducing scientific uncertainty, The ability to reduce certainty may be further compromised by the substantial emphasis on reducing impacts at the project scale, as opposed to gathering data to inform a hypothesis. Equally important, the fact that some of these projects have not yet been built and the AM plans have not been implemented renders the evidence of AM inconclusive. In situations where the mitigation hierarchy is used to minimize potential impacts, such as projects at risk of causing unacceptable impacts on protected or endangered species, an AM process may be inappropriate or its utility may be limited to steps farther down the mitigation hierarchy to help inform future management decisions. In other words, AM processes may be more useful in determining scientific uncertainty about the efficacy of mitigation or compensation measures rather than scientific uncertainty about the mechanisms of effects causing impacts, in the absence of mitigation or compensation. In practice, as mitigation activities are carried out, an AM approach could be used to evaluate the effectiveness of the mitigation actions, learn from these experiences, and reduce overall scientific uncertainty by informing more effective mitigation for use in future management decisions. A similar approach can be taken over longer periods of time with compensatory mitigation. While this learning-based approach sounds simple, it does not appear to be frequently used, as evidenced by the US plans examined. As data are collected, an AM process nested within each level of the mitigation hierarchy may allow developers and regulators to learn from their management actions, thereby informing future wind energy developments. Note that this is only possible if data and knowledge are shared and published.

While AM can be an effective approach for informing mitigation measures and future management decisions, as well as for reducing scientific uncertainty for individual projects, the spatial and temporal scale of the monitoring data collected can be important in determining the success of the AM process. Answering questions and testing hypotheses about the impact on individual animals at a single wind energy project is complicated by the large spatial and temporal scales that encompass a species' ecological processes. These scales potentially require large amounts of data to be collected over a long period of time within larger geographic areas, as well as the use of each wind energy project as independent points, rather than randomly selected samples. Depending on the project, species of concern, and resources allocated to monitoring, it can be challenging to collect an adequate amount of data to meet statistical power requirements that enable conclusions to be reached with confidence. It is essential that the experiment conducted to examine wind and wildlife interactions be designed at the most relevant spatial and temporal scales. For many wind/wildlife research questions the most appropriate spatial and temporal scales may be considerably larger than individual wind farms or short time periods after the onset of operation. For example, understanding displacement rates of moorland bird species over time has been most appropriately addressed through meta-analysis of multiple wind farms (Pearce-Higgins et al. 2012). There are likely to be persistent challenges to implementing AM at larger spatial and temporal scales that are not derived from scientific concerns but rather from practical limits to data collection and the associated costs.

The temporal and spatial scale at which learning is applied under AM is another important consideration. AM can be applied through the use of double-loop learning or institutional learning (Figure 2), as discussed in Section 1.0. Double-loop learning (as opposed to single feedback loop learning; Figure 1) applies the lessons learned from other projects to inform future management decisions. While this approach to AM was not seen in any of the US wind farm AM examples reviewed, it holds the potential to be particularly useful if AM is used to allow data collected and lessons learned to be transferred to other projects. The purpose of implementing AM at a project is to reduce scientific uncertainty for future projects and not to change management of the project where monitoring is undertaken. Learning outcomes achieved through this approach could have greater overall benefits in terms of protecting wildlife, improving future decision-making, and supporting the further development of the industry.

6.5 Financial Risks and Mitigation Limits

As highlighted by many of the US and international stakeholders, AM can lead to unwanted financial risk for a wind energy project. Additional mitigation measures can lead to a decrease in electrical generation in conflict with Power Purchase Agreements, and monitoring requirements that are poorly defined initially could become progressively more intensive during plan implementation, thereby leading to more unforeseen project costs. Additional monitoring requirements may include pre-installation assessments and post-installation monitoring that could continue for an undefined period of years.

Collaboratively setting mitigation boundaries or limits has been shown to help mitigate financial uncertainties. Bounding of mitigation involves a negotiation between regulators and project proponents to identify an impact level at which mitigation becomes necessary. Examples of these boundaries can be seen in both US and UK wind energy projects, and they result in a more certain approach to mitigation. Projects that did not follow a prescribed approach tended to rely on resource agencies or TACs to establish monitoring and mitigation levels and triggers.

Setting mitigation boundaries and limits appears to be a viable approach to reducing financial uncertainties within an AM process; however, prescribing these mitigation activities before fully understanding the associated uncertainties and risks may reduce opportunities for adjusting monitoring and mitigation strategies as more information and data become available. This approach also reduces opportunities to learn from mitigation and conservation activities, which could lead back into an endless cycle of mitigation and financial burden for developers of future projects. Several of the stakeholders interviewed noted that prescribed tiers serve more as suggestions, and ultimately provide the regulators and developers with a starting point for setting mitigation triggers for protected species. Developers and their financial backers are interested in the most precise tiers possible to increase the certainty of financial return and to decrease financial risks.

Setting mitigation boundaries also can provide regulators with a level of certainty that protection of species and habitats will be maintained and impacts will not be exceeded. However, no mitigation boundaries are absolute; if impacts were found to exceed boundaries, the boundaries could be redrawn or reopened, which may undermine their ability to provide certainty to developers.

As AM is used for future wind energy projects, appropriate mitigation boundaries should be considered that address both financial risk and the risk to wildlife without undermining the core purpose of AM, which is to reduce scientific uncertainty. For each project for which AM is used, the goals should be clearly defined, methods for learning identified, and criteria for effectiveness stipulated.

7. Conclusion and Recommendations

The formal application of AM to wind farm regulation is relatively new. As a result, wind developers and regulators are just beginning to identify the most effective ways in which to balance the strengths and challenges associated with its application. The US DOI guidelines provide an explanation of AM and how its underlying principles may be applied to reducing the scientific uncertainty associated with management of natural resource issues, but consistent application of AM in the context of wind energy regulation does not exist. Little evidence can be gathered at this point to assess the best characteristics and attributes of successful AM plans, because this practice has only recently been implemented for the wind energy industry. This white paper highlights several areas of potential concern and possible improvement.

First, more specific guidelines or good practices should be created for developing and implementing AM plans for the wind energy industry. As demonstrated by the US plans, interviews, and the application of AM internationally, several definitions and approaches exist. One of the main takeaways from interviewing stakeholders was that there are considerable challenges to applying a concept that does not have a common theoretical foundation agreed upon by practitioners. By providing specific guidelines for how best to implement AM, increased understanding and support for the approach could be achieved. While it is important to keep AM implementation guidelines at a level suitable for accommodating particular characteristics of individual projects, consistency is needed to allow for comparison between projects and approaches. Only then can key characteristics and attributes that might make the AM process successful be identified. This should include guidance that AM plans be as detailed as possible. While all wind energy installations must meet regulatory requirements, AM plans should not be perceived to consist of a loose approach to learning by doing, nor allow opportunities for regulators to exercise additional discretion.

Second, well-defined data collection efforts are necessary to answer specific hypothesis-driven questions about interactions between wind energy projects and wildlife. By collecting and aggregating data across wind farms in a consistent manner, the overall scientific uncertainty about these interactions can be reduced and future wind farm development better informed, without significantly increasing financial burdens on developers and wind farm operators of individual projects. Mechanisms of potential harm for wildlife can be best elucidated through strategic research studies that can point toward effective and cost-efficient mitigation measures, and potentially decrease overall monitoring needs in the future.

Third, establishing an AM process that provides increased financial certainty is important for project developers and financiers to feel comfortable with implementing an AM process. As seen in several of the existing AM plans and discussed by the US stakeholders, several processes have established tiers, limits, or boundaries for AM activities to minimize financial risk. While these mitigation limits and prescribed approaches to AM can be beneficial for minimizing financial risk to a certain extent, they may limit the overall flexibility of the AM process, hampering the project's ability to address future unforeseen issues. Developing appropriate mechanisms and approaches for minimizing the financial risk associated with AM will be critical as more projects begin to rely on AM to address environmental uncertainties.

Finally, the scale at which AM is implemented in the wind energy industry is an important consideration for determining its overall effectiveness. While it is evident that AM is being applied at an individual project level, challenges associated with measuring change over the spatial and temporal scale of the resource of concern may limit the ability of an individual project to meaningfully reduce scientific uncertainty and facilitate an iterative learning process. To be most effective, the implementation of AM should be considered at a larger spatial and temporal scale than individual projects. The larger spatial and temporal scale of data collection and analysis may consist of a combination of research data collection at the ecosystem scale and data collection at individual wind farms.

Expansion of AM to inform future wind energy planning and siting may appear to impose an increased financial burden on wind developers. Coordination of monitoring methods and practices to ensure that comparable data are collected across the range for species of concern may prove difficult and expensive. Innovative funding mechanisms for carrying out good monitoring practices and ensuring that data analysis is rigorous and consistent are likely needed. Ideas that might provide starting points include the possibility of creating an AM bank that could combine contributions from various sources to carry out AM research in broad support of improved decision-making for wind farm planning. Key support of an AM bank might include developer contributions, public funding to assist with monitoring in association with existing wind farms, and a means of spreading costs across beneficiaries and stakeholders in wind energy.

From the outset, these AM approaches should seek to leverage lessons learned from existing projects to inform management decisions. By building on these results, the application of AM to future projects will potentially be more effective than current approaches. Although none of the AM examples evaluated in this white paper implemented AM at this larger planning scale, the lessons learned from examples at smaller scales should be used to develop processes and approaches that optimize the use of AM at the most appropriate scale. Applying AM to wind energy projects at a larger spatial and temporal scale is anticipated to enable regulators, developers, and researchers to gain a better understanding of what AM approaches will be most successful, and to more effectively address environmental uncertainties in the future, in support of an expanding wind energy industry.

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Appendix A – United States Department of Interior's Adaptive Management Guidelines

Problem-Scoping Key for Adaptive Management

The following key can help in dissecting a particular management problem and determining whether adaptive management is an appropriate approach to decision making. If the answer to any question in the key is negative, then an approach other than adaptive management is likely to be more appropriate.

1. Is some kind of management decision to be made?
   (see Sections 1.1, 2.1, 2.3, 3.1, and 5.5)
   No – decision analysis and monitoring are unnecessary when no decision options exist.
   Yes – go to step 2.

2. Can stakeholders be engaged?
   (see Sections 1.1, 1.2, 2.1, 3.1, and 4.2)
   No – without active stakeholder involvement an adaptive management process is unlikely to be effective.
   Yes – go to step 3.

3. Can management objective(s) be stated explicitly?
   (see Sections 1.2, 2.1, 2.2, 2.3, 3.1, 4.2 and 5.1)
   No – adaptive management is not possible if objectives are not identified.
   Yes – go to step 4.

4. Is decision making confounded by uncertainty about potential management impacts?
   (see Sections 1.1, 1.2, 2.1, 3.1, 4.1, 4.2 and 5.2)
   No – in the absence of uncertainty adaptive management is not needed.
   Yes – go to step 5.

5. Can resource relationships and management impacts be represented in models?
   (see Sections 1.2, 3.1, 4.2, and 5.1)
   No – adaptive management cannot proceed without the predictions generated by models.
   Yes – go to step 6.

6. Can monitoring be designed to inform decision making?
   (see Sections 2.1, 2.3, 3.1, and 4.2)
   No – in the absence of targeted monitoring it is not possible to reduce uncertainty and improve management.
   Yes – go to step 7.

7. Can progress be measured in achieving management objectives?
   (see Sections 1.1, 3.1, 4.1, and 4.2)
   No – adaptive management is not feasible if progress in understanding and improving management is unrecognizable.
   Yes – go to step 8.

8. Can management actions be adjusted in response to what has been learned?
   (see Sections 1.2, 2.1, 3.1, 4.1, 4.2, 5.3, and 5.4)
   No – adaptive management is not possible without the flexibility to adjust management strategies.
   Yes – go to step 9.

9. Does the whole process fit within the appropriate legal framework?
   (see Sections 2.3, 2.4, 3.2, 4.1, and 4.2)
   No – adaptive management should not proceed absent full compliance with the relevant laws, regulations, and authorities.
   Yes – all of the basic conditions are met, and adaptive management is appropriate for this problem.

(From: Williams et al. 2009)

Appendix B – Summary of Wind Development Project Plans with Adaptive Management Components

Project Name	Location	Species of Concern	Report Name	Motivation for Report/Regulation Referenced	Date
Alta East	Kern County, California	Golden Eagle	Conservation Plan for the Avoidance and Minimization of Potential Impacts to Golden Eagles	NEPA, ESA, BGEPA BLM Instructional Memo (IM) 2010-156, USFWS Draft Eagle Conservation Plan Guidance	March 2012
Beech Ridge Wind	Greenbrier and Nicholas Counties, West Virginia	Indiana bat, Virginia big-eared bat	Habitat Conservation Plan (HCP)/ Research, Monitoring, and Adaptive Management Plan	ESA – Incidental Take Permit in accordance with a settlement agreement from a lawsuit, NEPA, MBTA, BGEPA	August 2013
Cape Wind	Nantucket Sound, Massachusetts	Roseate tern, Piping Plover and other avian species, bats	Avian and Bat Monitoring Plan	ESA, MBTA	August 2012
Criterion Wind Farm	Western Maryland	22 Rare, Threatened and Endangered Birds listed in Garrett County, MD and other eagles	DRAFT Avian Protection Plan	NEPA, BGEPA, MBTA, Maryland Nongame and Endangered Species Conservation Act	March 2012
Criterion Wind Farm	Western Maryland	Indiana bat	Indiana Bat HCP - ITP	Incidental Take Permit Application (lawsuit driven)	January 2014
Echanis Wind	Princeton, Oregon	Golden Eagle, Migratory Birds, and Bats	Eagle Conservation Plan and Bird and Bat Conservation Strategy	Plan was written for issuance of BLM ROD on the ROW BLM IM 2010-156	November 2011
Grand Prairie Wind Farm	Holt County, Nebraska	Whooping crane, birds and bats	Bird and Bat Conservation Strategy	MBTA, BGEPA, ESA, Nebraska Regulations	May 2014
Ocotillo Express Wind Energy	Ocotillo, California	Golden Eagles	Golden Eagle Conservation Plan for the	Draft Eagle Conservation Plan Guidance	February 2012

Project Name	Location	Species of Concern	Report Name	Motivation for Report/Regulation Referenced	Date
Facility			Ocotillo Wind Energy Facility		
Ocotillo Express Wind Energy Facility	Ocotillo, California	Avian and bat species	Avian and Bat Protection Plan for the Ocotillo Wind Energy Facility	USFWS Interim Guidelines for the Development of a Project-Specific Avian and Bat Protection Plan for Wind Energy Facilities (2010) California Energy Commission Guidelines BLM IM 2010-156	February 2012
Shiloh IV Wind Project	Northern California	Bald and Golden Eagles	Eagle Conservation Plan	BGEPA	June 2014
Spring Valley Wind Farm	Nevada	Eagle, bird and bat species	Avian and Bat Protection Plan	ESA, MBTA, BGEPA, BLM IM, 2010-156	2010
Tule Wind Project / Reduced Ridgeline Project	San Diego County, California	Golden Eagle, birds, bats	Project-Specific Avian and Bat Protection Plan for the Tule Reduced Ridgeline Wind Project	USFWS Land-based Wind Energy Guidelines	March 2013
Shaffer Mountain	Somerset and Bedford Counties, Pennsylvania	Indiana bat	Biological Opinion; Effects of the Shaffer Mountain Wind Farm on the Indiana Bat	Clean Water Act, Endangered Species Act	2011
Mohave County Wind Farm	Arizona	Golden Eagles	Eagle Conservation Plan and Bird Conservation Strategy	BLM IM, 2010-156, MBTA, BGEPA, USFWS Land-based Wind Energy Guidelines	2012
Searchlight Wind Energy	Clark County, Nevada	Golden Eagle, birds, bats	Bird and Bat Conservation Strategy	ESA, MBTA, BGEPA, Nevada State Codes BLM IM, 2010-156, USFWS Land-based Wind Energy Guidelines	2012
Buckeye Wind	Champaign County, Ohio	Indiana bat	Habitat Conservation Plan	ESA	March 2013

Project Name	Location	Species of Concern	Report Name	Motivation for Report/Regulation Referenced	Date
BLM = Bureau of Land Management; BGEPA = Bald and Golden Eagle Protection Act; ESA = Endangered Species Act; IM = Instruction Memoranda; ITP = Incidental Take Permit; MBTA = Migratory Bird Treaty Act; ROD = Record of Decision; ROW = Right of Way; USFWS = US Fish and Wildlife Service.					