Technology Acceptance Workshop: Meeting Proceedings

Workshop: April 20-29, 2022

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REWI Proceedings:

Technology Acceptance Workshop: Proceedings

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The Renewable Energy Wildlife Institute (REWI, formerly the American Wind Wildlife Institute) is an independent, nonprofit 501(c)3 organization that advances scientific research and collaboration to better understand renewable energy's risks to wildlife and related natural resources and develop solutions. Built on a strong partnership of leaders, REWI works collaboratively with the wind and solar power industries, conservation and science organizations, and wildlife management agencies to facilitate timely and responsible development of renewable energy while protecting wildlife and wildlife habitat.

The Consensus Building Institute (CBI), founded in 1993, is a nonprofit organization, which facilitates complex problem-solving processes for state and federal agencies, nonprofits, businesses, and international development agencies around the world. CBI has worked on wildlife and wind energy development issues since 2012.

The National Renewable Energy Laboratory (NREL), with campuses located in Colorado, Washington, D.C., and Alaska, is the United States' primary laboratory for renewable energy and energy efficiency research and development. NREL is operated by the Alliance for Sustainable Energy LLC on behalf of the U.S. Department of Energy. The lab's mission is to advance the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provide knowledge to integrate and optimize energy systems. To accomplish these goals, the lab's researchers explore new and better ways to harness renewable power sources—including geothermal, solar, water, and wind—as well as to build more sustainable buildings, transportation, energy storage, grid infrastructure, and more. NREL's research groups tap into the lab's more than 40 years of experience to design, evaluate, validate, and demonstrate novel marine and wind energy technologies while mitigating potential environmental risks.

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Contents

Glossary/Terms

Acceptance: Broadly defined; agreement among stakeholders that a technology is effective and can be deployed commercially specific definitions of or metrics for acceptance may vary between stakeholders.

BGEPA: Bald and Golden Eagle Protection Act

Blanket curtailment: Feathering wind turbine blades below a designated wind speed to slow the rotational speed of the blades to reduce wildlife collisions. This is defined by a range of dates, times, and wind speeds (e.g., 5.0 meters per second between sunset to sunrise from 15 July through 31 October). Curtailment results in a loss of energy production, which varies based on the timing and wind speed factors implemented.

BWEC: Bat and Wind Energy Cooperative

DOE: U.S. Department of Energy

Effectiveness: The performance of the technology as it relates to the intended monitoring or minimization purpose (i.e., does it meet expectations for recording/collecting data or conservation value?).

Ensonify: To fill with sound; see ultrasonic deterrent (below)

ESA: Endangered Species Act

Functionality: The performance of the technology as it relates to operation, maintenance, communication, data storage, and weatherization.

HCP: Habitat Conservation Plan

Integration: Incorporating the technology with the wind turbine or wind energy facilities, which includes the location of the technology on or off the wind turbine, safety, power requirements, and cybersecurity implications.

ITP: Incidental take permit

MBTA: Migratory Bird Treaty Act

Risk monitoring/minimization technology: Technologies designed to monitor wildlife activity, detect wildlife/wind turbine collisions, or minimize risk of collisions. Referred to as "technologies" throughout these proceedings.

RSA: Rotor swept area: The area around a wind turbine occupied by the blades; the area where collisions between wildlife and turbine blades may occur.

SCADA: Supervisory control and data acquisition: The software system that operates and controls a wind energy facility.

Smart curtailment: A broad term for a curtailment strategy using additional variables (e.g., temperature or bat activity) and intended to reduce power loss associated with stoppage of wind turbine operation while maintaining the impact reduction benefits compared to blanket curtailment.

Take: The ESA defines "take" as: to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct. 16 U.S. C. 1542(b). For the purposes of these proceedings, "take" refers to unintentional fatalities that occur when an animal collides with a wind turbine.

Ultrasonic deterrent: A technology that emits ultrasound (>20 kilohertz) in the range of frequencies used by bats to echolocate, which is intended to deter bats or encourage them to avoid the ensonified area.

WETO: Wind Energy Technologies Office, within the U.S. Department of Energy

USFWS: United States Fish and Wildlife Service

1. Abstract

The Renewable Energy Wildlife Institute and the National Renewable Energy Laboratory convened a virtual workshop facilitated by the Consensus Building Institute in April 2022 to identify recommendations on how to accelerate the rate of research and development, evaluation, and adoption of technologies for monitoring or minimizing wildlife impacts from wind energy. The workshop drew on expertise from stakeholder groups including technology developers, federal agencies, conservation nonprofits, and the wind industry. Over the course of four sessions, participants discussed incentives and barriers to technology development beginning with early field testing and validation, through full-scale experimental deployment, and finally broad-scale acceptance and commercial deployment.

Take-home messages from the workshop:

1. There is a lack of consensus for criteria to determine the effectiveness of a technology, particularly in late stages of development.
2. There are widespread views in how stakeholders define “acceptance,” and lack of clarity around which stakeholder group(s) are responsible for defining and facilitating “acceptance” of technologies.
3. The legal framework surrounding wind/wildlife issues is complex; we lack a clearly defined path for the acceptance and application of technologies under existing conservation laws.
4. The primary current regulatory driver of technology is based on endangered species, not large-scale multispecies conservation, which leads to necessary but insufficient focus on a few species, rare events, and the particular and specific requirements and constraints of the Endangered Species Act.
5. The successful integration and reliable operation of a technology into an operating wind energy facility presents myriad and complex challenges (e.g., engineering, biological, logistics, cybersecurity, seasonality, regulatory, etc.), and relies on close interdisciplinary collaboration.
6. Early engagement with wind turbine manufacturers and wind energy operators may facilitate technology development and integration.
7. Public and private funding are critical for developing and testing cost-effective technologies. However, each funding source can present challenges relative to administrative and program management activities, or public accessibility.
8. Workshop participants proposed recommendations to facilitate the timely development and acceptance of technologies, including modifications to the regulatory framework, increasing collaboration between stakeholders, and pursuing funding for research and development.

2. A Note from the Organizers on “Acceptance”

Broadly defined, “technology acceptance" indicates that a technology has been shown to be effective, and that it may be commercially deployed to help a wind energy facility meet its conservation and energy production goals. Though technology acceptance is the topic of this workshop, it became clear during the workshop that there is no consensus among wind/wildlife stakeholders on a specific definition or metrics for acceptance, nor which stakeholders have the responsibility to formally accept technologies for commercial deployment. Perspectives on what acceptance should mean in practice varies widely among stakeholders, even within stakeholder groups.

The organizers of this workshop propose that “acceptance” of a technology should include the following characteristics:

- Consensus among stakeholders, particularly regulatory agencies and wind energy developers, regarding the effectiveness of a technology. Without a reasonable-to-high probability of acceptance by permitting agencies, any technology, however advanced, has limited market appeal.
- A standard for integration and functionality that accounts for installation, cybersecurity, and maintenance concerns of wind turbine manufacturers and wind energy facility operators.
- A reasonable existing or potential market demand for the technology sufficient in scale to facilitate the technology’s advancement.
- A clear regulatory pathway to use technology to inform take estimates of target species.
- Deployment of the technology that results in reduced costs for monitoring and/or minimization over the life of the project.

Note that while the term “acceptance” is used frequently by presenters throughout these proceedings, the individual speakers’ perspective of the term may not match the proposed definition above.

3. Purpose

Organizers:

- **Dr. Taber Allison** – Renewable Energy Wildlife Institute (REWI)
- **Patrick Field** – Consensus Building Institute (CBI)
- **Dr. Cris Hein** – National Renewable Energy Laboratory (NREL)

The organizers convened a virtual workshop held in four remote sessions over a 3-day period in April 2022. The overall purpose of the workshop was to identify recommendations on how to accelerate the rate of research and development, evaluation, and adoption of technologies for monitoring or minimizing wildlife impacts from wind energy.

The invited participants represented a cross section of wind-wildlife and technology stakeholders. These proceedings reflect the discussion among workshop participants and provide recommendations to further the workshop's goals of enabling more rapid development and acceptance of these technologies by developers and regulators.

The workshop was organized around the assumed flow of technology development from initial testing to validation and acceptance. Sessions focused on the stages of development and included case studies presented by technology developers and panels of technology users followed by discussion and breakout groups.

To set the stage for the workshop, the organizers presented a flow diagram of the research and development process by stages, beginning with bench testing and culminating in the acceptance of successful technologies. Throughout the workshop, the group discussed these stages, with respect to challenges, costs, criteria for advancing from one stage to the next, and the decision makers who provide input toward stage advancement (Figure 1).

For the purposes of this workshop, "risk monitoring and minimization technologies" (hereafter "technologies") include a suite of technologies designed to better understand wildlife interactions with wind turbines (e.g., strike detectors, thermal camera systems), and risk minimization technologies (e.g., smart curtailment strategies, deterrents, and modifications to turbine texture or color).

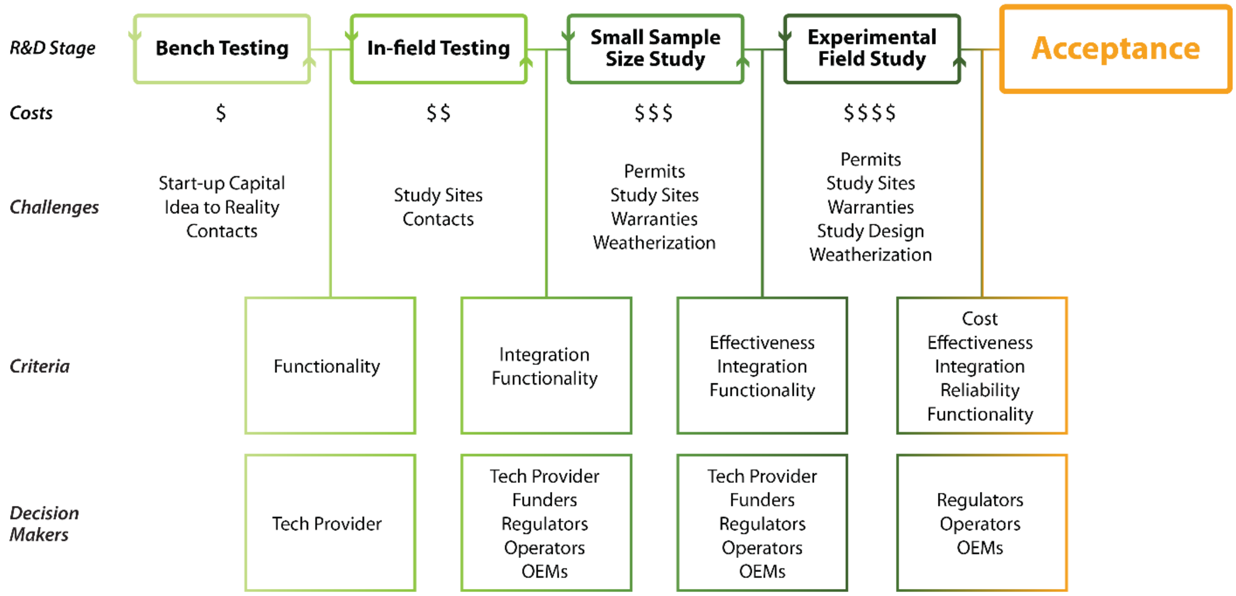

Figure 1. Stages of risk monitoring and minimization technology development and associated challenges, costs, criteria for success, and important decision makers at each stage.

To better understand what participants hoped to gain from the workshop, each shared their expectations, which are summarized below:

- Research and recent advancements:
  - Learn about recent advancements in technology development.
  - Share experiences with prior research on technologies.
  - Learn about current challenges and opportunities related to monitoring and impact minimization.
  - Find ways to use technology to reduce uncertainty.
  - Discuss ways to reduce the cost of technology development and use.
  - Develop a collaborative approach to assess which technologies to invest in
- Integration at operating wind energy facilities:
  - Discuss engineering challenges of integrating technologies on wind turbines, within a wind energy facility, or with the supervisory control and data acquisition (SCADA) system.
  - Discuss how existing technologies may be applied in the offshore environment.
  - Discuss implementation of technology solutions in harsh/challenging environments.
- Strategies to advance and implement technologies:
  - Define criteria or performance standards needed to come to a consensus around acceptance so that effective technologies may be adopted on a wide scale.
  - Consider the level of validation that is needed to move from stage to stage.
  - Understand perspectives of various stakeholder groups regarding criteria for advancement, efficacy, and acceptance of technologies.
  - Evaluate the risks associated with adoption and implementation of technologies.
  - Clarify the U.S. Fish and Wildlife Service's (USFWS's) position about incorporating technology into permits.

4. What Drives Technology Development for Conservation and the Environment?

Speakers:

- **Nick Johnson** – National Renewable Energy Laboratory (NREL)
- **Ben Cowan** – Locke Lord, LLC

Integrating technologies with wind turbines requires careful logistical and legal consideration prior to installation and use. Technology providers need to coordinate with several stakeholders to ensure the technology meets safety standards, protects against cyber-attacks, and is acceptable by the regulatory agencies. Below is a summary of these challenges.

4.1 Challenges of Wildlife Technology Integration – Nick Johnson

In many cases, technologies will be integrated into an existing fleet and wind turbines will be retrofitted with new systems after deployment. After-market retrofits are challenging to integrate into an operating facility as they may interfere with performance, reliability, maintenance, warranties, communications, security, or safety.

Performance Challenges

For any technology that triggers curtailment, there is concern that it could cause the wind energy facility to fall short of grid requirements or power purchase agreements. After-market technologies that are integrated into the turbine blade (e.g., blade-mounted deterrents or painting blades a dark color) could negatively affect the aerodynamic performance of the turbines.

Reliability and Maintenance Challenges

Some devices or strategies may compromise the life expectancy of wind turbines, such as curtailment protocols that may add wear and tear by increasing the number of times the turbine starts and stops over the lifetime of the project. A mitigation plan is required to address device failures, which may cut into power production. These issues may be particularly costly and disruptive for any unplanned maintenance required on a device mounted on the turbine blades, as blade maintenance requires significant downtime and logistical support to address.

Warranty Challenges

Physical installation of a device on a wind turbine has the potential to void the warranty. There is concern that blade-mounted technologies could compromise lighting systems. If installation of a device requires any holes to be drilled in the blade, nacelle, or tower, these holes could increase risk of water ingress into the interior of the wind turbine. Modifications the SCADA system to integrate with an after-market technology may also lead to a voided warranty.

Communications and Security Challenges

Some technologies use large amounts of video, acoustic, or other data that must be accessible to the user. Data transmission can require a lot of bandwidth, posing logistical challenges particularly at rural wind energy facilities. Integratinga device into the SCADA system or other technology systems at an operating facility may also introduce vulnerability to cyber attacks. Moreover, it may be difficult for external technology providers to update cybersecurity requirements over the long term to ensure protection in a fluid, rapidly changing environment.

Safety Challenges

Novel equipment may introduce hazards to site personnel including radar, intense light, and the potential for equipment to fall from a wind turbine and harm somebody.

Need for Collaborative Research and Development

In the current framework of technology research and development, issues surrounding integration are typically not addressed until later in the design process. If wildlife technology designers collaborated with turbine manufacturers earlier in the design process, it could significantly reduce barriers to deployment, and encourage turbine manufacturers to incorporate wildlife considerations (e.g., curtailment, blade-mounted technologies) into their design process.

This issue is particularly important to consider given the way that the market and turbine fleet are evolving. In the coming years, wind turbines are expected to increase in height and blade length and have greater spacing and larger footprints. This increase in size may affect existing technologies used to monitor and minimize impacts. For example, tower- or nacelle-mounted ultrasonic acoustic deterrents may not be able to ensonify the rotor-swept area of larger turbines, thus blade-mounted devices may become necessary. Similarly, cameras, positioned on the ground and pointed up to monitor wildlife activity or collisions, may be unable to view the entire rotor-swept area.

In addition, wind energy development is increasingly expanding into lower-wind-speed areas and into the offshore environment, which will have implications for wildlife species that may be at risk. Curtailment strategies for bats may not be economically viable in low-wind-speed environments, so deterrents or other strategies may be needed in those areas. Offshore environments present further challenges including the inability to recover carcasses for evaluating effectiveness of technologies and harsher environmental conditions. Offshore wind energy facilities will be difficult and expensive to access, so the reliability of any equipment deployed is essential.

4.2 Legal, Regulatory, and Practical Considerations To Guide Technology Development – Ben Cowan

Several laws protect wildlife species, such as the Endangered Species Act (ESA), Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act (BGEPA). When considering how technologies will be adopted and implemented in the short and long term, it is important to be mindful of the statutory and regulatory constraints, obligations, and incentives of these statutes, as well as the full economic implications of the technology. From a legal and economic perspective, for a technology to be widely adopted it must either a) result in increased conservation at equivalent expense compared to the status quo, b) achieve equivalent conservation at a lesser expense compared to the status quo, or c) facilitate the permitting of a renewable energy project that otherwise would not be possible.

Permitting Process

There are three ways that a technology may assist a company in obtaining permits or meeting permit requirements:

1. **Meet issuance criteria**: ESA and BGEPA take permits require a company to minimize and mitigate take to the maximum extent practicable. This requirement is subjective and context specific. Risk minimization may be increased with the use of a proposed technology, and both the economics and the efficacy of the technology are considered in comparison to alternate conservation strategies.
2. **Achieve compliance with permitted take limits**: Technologies that reduce risk for bats without the use of curtailment may allow for development in lower-wind/higher-risk areas where development might otherwise be prevented. It is important to understand whether the minimization benefits of a technology can be accurately predicted, quantified, and measured; if

not, it will not facilitate the permitting process, and may result in costly adaptive management if performance does not meet predictions.

3. **Demonstrate compliance with permit limits**: Technologies may be used to assist in post-construction fatality monitoring to demonstrate compliance with permits. However, there is an ongoing trade-off between investing in monitoring or conservation measures. The industry would prefer to shift investment from monitoring to conservation. While conservation should be the priority, most permitted projects are subject to heavily burdensome and expensive monitoring requirements and there are no clear regulatory mechanisms for weighing this trade-off. The industry is looking for technologies that can reduce the cost of detecting wildlife fatalities, and advocating for a reduction in the required level of monitoring so that funds can be redirected to conservation.

Research on new monitoring and minimization technology requires 2 or more years of field testing just to move beyond proof of concept. Collecting data on listed species is particularly difficult because of their scarcity. It typically takes 2–5 years to develop a habitat conservation plan (HCP) and an incidental take permit, though construction of a facility may only take approximately 1 year. Coordination of these timelines can be very difficult, particularly because a site-specific estimate of efficacy of the new technology is usually needed, which requires data collected from the project area.

Advancing technologies toward widespread adoption may require innovative uses of or changes to the existing regulatory framework. Currently, the burden of establishing a technology's efficacy is on the developer. This system effectively discourages the adoption of new technologies because deployment without reliable data establishing its efficacy does not assist a company in obtaining permits or meeting permit requirements. But one cannot obtain data demonstrating consistent efficacy without deploying the technology in areas where the technology is needed. Thus, there is little incentive for deploying new tools on a project-level scale; to do so creates substantial risk to the project. The solution may be to adapt the regulatory framework that facilitates, if not incentivizes, research and data collection to validate the effectiveness of promising technologies. It is not enough to demonstrate a "preponderance of evidence" in one installation or one project—sufficient evidence to support broad-scale adoption comes only after multiple studies show consistent results across geographies, environmental conditions, and species.

Life Span of the Equipment

While wind energy facilities have an operating life span of approximately 30 years, the equipment that many technologies rely upon may only last about 10 years. Companies will have to build the cost of replacement units into the financial model to evaluate the investment. This disparity raises several economic and practical concerns: Will the equipment manufacturer still exist in 10+ years to provide service or replacement units? If a permit is built around the use of a technology but the technology provider is no longer capable of supporting it (e.g., the company discontinues the technology or the company no longer exists), the developer holding the permit may be in a challenging position. There is also uncertainty about the effectiveness of future generations of units. While presumably these units will be improved over time, that is not guaranteed as minor changes in design may have unanticipated impacts on effectiveness.

Commercial and Practical Considerations

Warranties

Original equipment manufacturers (OEMs) are strict about modifications to wind turbines and blades, and technology integration may affect or void a warranty. Some OEMs may permit the installation of only select brands of technology on their equipment. Procurement, installation, and integration can be lengthy processes that require a lot of troubleshooting both legally (contracts and warranties) and technically.

Maintenance/Downtime

Maintaining technology or equipment may result in downtime and power loss at the facility. Further, if the facility's permits require the use of a specific technology to operate, there could be significant losses incurred if the failure of a technology/unit leads to curtailment until the problem is resolved.

Economic Model

Many technologies that are hardware-based are offered only for purchase by the manufacturer because of low residual value. That approach places greater risk and cost on the developers for the reasons discussed above. A better model might be to offer the technology as a service, with equipment and support provided for a fee on an annual or other periodic basis. As a result, some of the risk of performance, durability, and uncertainty would be shifted away from the developer and onto the manufacturer, who is better equipped to manage it.

During a group discussion with workshop participants, some advocated for integration to be included in the design process early on (i.e., beginning in the "bench testing" phase), others suggested that due to the complex and expensive nature of integration, technology developers should ensure that their product can fulfill its function prior to addressing integration challenges. Participants also indicated a desire for a new regulatory mechanism by which new technologies can be deployed and tested, which may include incentives for research as mitigation or "credit" given to companies testing novel technologies.

4.3 Survey Results – Dr. Taber Allison and Dr. Cris Hein

The organizers summarized the results from a survey that had been sent out to before the workshop. The survey results are available in Appendix A.

Barriers to Technology by Stage

Survey responses identified fewer barriers to technology development in the earlier stages (e.g., bench testing), and that the barriers increase with each stage through full-scale field testing and deployment. Barriers to acceptance (ranked in order from largest to smallest by the attendees) include:

- Lack of clear process of regulatory review and approval of project-scale adoption.
- Equipment and manufacturer warranties/constraints.
- Lack of agreed-upon criteria of efficacy, statistical power to measure rare events.
- Difficulty of including appropriate control treatments in validation studies (i.e., obtaining exceptions to permit requirements).
- Rate at which results from a study become publicly available.
- Lack of clear regulatory process for review and approval of research.
- Insufficient market demand.

There are many more potential barriers not included in the previous list, such as unknown criteria for effectiveness, scalability, access to study sites, costs, and barriers to accessing both public and private funding. Further, there was no consensus regarding what the main barriers are, suggesting that perceptions differ among stakeholders.

Discussion among the attendees centered on sharing experiences working through barriers to technology development and deployment. Challenges included lack of buy-in from regulatory agencies, bankruptcy of a company whose technology solution was required in the permit of a wind energy facility, and an insufficient commercial market to support the amount of research and development needed for successful technological solutions.

5. From the Bench to the Field: Early Field Testing and Validation

Speakers:

- **Dr. Roberto Albertani** – Oregon State University
- **Brogan Morton** – Wildlife Imaging Systems (WIS)

5.1 Case Study #1: Strike Detection – Dr. Roberto Albertani

The Oregon State University research team has been developing a blade-mounted automatic blade impact detection sensor since 2014. The device has high sensitivity to detect impacts of small animals, such as birds and bats, and has low energy requirements. It is accompanied by a system of daylight and infrared cameras to record impacts. Dr. Albertani is also leading the development of a system that automatically detects eagles in flight and either deploys a ground-based deterrent or activates a form of turbine curtailment. The system uses a small single camera feeding a live video to a deep neural network algorithm to detect and classify eagles in images. Much of Dr. Albertani's research is funded by the U.S. Department of Energy's (DOE) Wind Energy Technologies Office (WETO), and his research teams include close collaborations between biologists, engineers, and industry partners. The WETO-funded projects have been both challenging and expensive, with a single project costing $1.9 million. Limited field testing has occurred on 2.5-megawatt test turbines at Mesalands Community College in New Mexico and at NREL's Flatirons Campus in Colorado but has been conducted at commercially operating facilities.

In the deployment of technologies, there will always be challenges, but the goal is to minimize turbine downtime. It is critical to test all communication protocols in realistic field settings. Field testing reveals challenges and can lead to improvements. The single-camera system to detect and classify flying eagles was developed using a single 360-degree field-of-view camera. However, testing has indicated that this field of view, although efficient at a relatively short distance, is too wide for reliable long-range eagle classification.

The use of "surrogates" in place of carcasses for blade-impact testing can also pose challenges; for example, if the surrogates have a significant lift, their trajectory could be unpredictable, and they can be carried great distances while falling to the ground. Despite challenges with surrogates, Dr. Albertani recommends their use, thus avoiding experiments using wildlife for impact detection tests. Training for detection of flying targets should be performed with live specimens away from wind turbines or when turbines are not in motion.

Four significant challenges faced by technology developers include:

1. **Administration of Research Awards**: The acquisition and administration of federal grants to support this research are difficult and time-consuming processes. The proposal selection cycles do not necessarily align with the academic cycle, making it difficult to incorporate graduate students into the research projects.
2. **Engineering**: Design and testing the communication between the various components for applications on generic turbines, filtering of normal operational "noise" for blade impact detection, and storage and delivery of impact data and images from a generic installation.
3. **Field Testing**: For research on bats, the field seasons are generally restricted to the fall migration season. Field research on bald and golden eagles may also have seasonal limitations, which vary across the species' ranges. If a project is not ready to launch in time, it will be necessary to wait

an entire year to conduct field studies. Weather conditions can be unfavorable and may make testing schedules longer. Additional challenging factors include uncertainty around animal behavior and sample size (e.g., detecting flights of wild eagles, bat counts) and scheduling of wind turbine time for testing.

4. **Commercial Development**: Improve support/interest from companies.

5.2 Case Study #2: Camera-Based Fatality Monitoring – Brogan Morton

WIS received a 2020 National Science Foundation Small Business Phase 1 grant to support technology development. The purpose of the program is to create a product that can be commercialized and sustain itself or be acquired. After Phase 2 of the grant, the project is expected to get support from venture capital or other sources.

WIS's technology is a thermal video camera system that monitors for wildlife collisions. To conduct a pilot test of the system, WIS is setting up cameras to monitor the rotor-swept zone and save videos to memory cards for later analysis. In the future, video processing may be integrated into the facility so it can be monitored in real or near-real time. The camera system uses thermal cameras, computer vision, and machine learning to detect bats in flight and bat strikes. The technology is designed to pinpoint the time and location of bat fatalities, which could be used to develop more precise smart curtailment strategies, thus reducing revenue loss from curtailment or streamling fatality monitoring.

Technology Failures and Challenges With Field Testing:

- **Seasonality:** Because bat fatalities peak during the fall migration season, there is a limited window available for field testing. Bat-related technology tests must be ready to begin by late June or July. If there are any major hurdles, the study may be delayed an entire year.
- **Rare Events**: In many environments, bat fatalities do not occur in high numbers, so you must monitor a lot of turbines, which is costly, and/or collect data over multiple seasons to get statistically robust results. This challenge is compounded if you need data on listed species whose fatalities at wind facilities are rare.
- **Data Management**: If you are collecting video or acoustic data, you may end up with a large data set. Data management strategies are critical, and you must consider data storage and data sampling strategies.
- **Integration**: Several stakeholders are required to appropriately integrate a technology, including the technology developer, wind developer, and the OEM. Turbines are precisely engineered, so any modifications to the structure or electronics that the technology developer propose may prove to be a huge impediment. It is possible to encounter unknown challenges during the integration process.
- **Value**: The technology must be desirable, feasible, and viable. You need to know the value of the problem you are trying to resolve. For example, if you are offering an alternative to curtailment, it is necessary to know the cost of curtailing a wind turbine, which is challenging given the nuance of wind regimes and the market. The solution that you provide needs to achieve the same or better conservation impact as the status quo solution at a lower cost, or it will not be desirable.
- **Lessons Learned**: When trying to integrate a technology, do not assume anything. Challenges will arise, so you should be prepared to troubleshoot and pivot. When you encounter a problem, it may only be a slice of a bigger problem that may require significant adjustments. If possible, do whatever testing you can with simulations and/or surrogates, and conduct validation with live animals at the end. It is cheaper to run experiments at smaller scales and use successful results from a small test to justify a larger-scale study. When developing your system, incorporate engineering feedback into the design. For example, the first prototype of WIS's technology used

near-infrared cameras, but through testing, WIS realized that thermal cameras were a much better fit.

- **Funding Challenges**: Timing of grant/funding cycles may not align well with the seasonality of the data collection. It is important that the tech developer retains their intellectual property rights when accepting public funding because it could be difficult to obtain private funding further along in the process if DOE or another agency holds your intellectual property rights.
- **Timeline**: Development of a system based on novel hardware can take years, whereas developing a system based on a new application of existing hardware combined with new software can be a much more rapid process.

6. Breakout Session: Early Stages of Development

The first breakout session focused on the barriers and opportunities of early stages of technology development. After the larger group reconvened, a representative from each group presented highlights from the small group discussions, summarized here:

- The process for navigating a technology from validation through commercialization needs to be clarified and made more achievable.
- Integration challenges (e.g., physical installation and cybersecurity) should be considered early so that technology developers do not build something that cannot be installed.
- Collaboration between technology developers and turbine manufacturers should be strengthened to reduce barriers to integration.
- The technology research and development community is small and there needs to be a more concerted effort by industry and federal agencies to reach out to other potential researchers from new companies and universities with relevant expertise.
- There are differences between private and public funding. Private funding may have fewer limitations and may be more efficient with less reporting and administrative burden, though ideas and data are more tightly guarded and may reduce opportunity for collaboration, compared to public funding. Public funding may have a more rigorous review process and is often considered to be more credible. Moreover, public funding typically has a cost-share component that increases the overall investment.
- Know your audience when writing proposals, and how to present your information to the people who will be reviewing your proposal.
- Reporting requirements associated with both public and private funding can be onerous and costly.
- Reducing the administrative burden of smaller grants that focus on early stages of technology development would be beneficial.
- Project financing for offshore wind energy is driven by tax credits. Can a similar model be used to drive innovation and research for technologies? Business structure is not conducive to supporting research.

7. From Field Testing and Validation to Project-Scale Experimental Deployment

Speakers:

- **Carlos Jorquera** – Boulder Imaging
- **John Ugland** – NRG Systems

7.1 Case Study #1: Camera-Based Detection and Curtailment System – Carlos Jorquera

IdentiFlight is a camera-based detection and curtailment system for eagles and other raptors. To date, it has been installed at 20 wind energy facilities in five countries, on three continents, and monitors 250 turbines to reduce raptor collisions. IdentiFlight has been integrated with General Electric, Siemens, Vestas, Goldwind, Suzlon, Nordex, and Enercon turbines. The IdentiFlight system was originally developed to track large targets, but efforts are underway to use IdentiFlight to detect bats.

Timeline of IdentiFlight Development/Deployment:

- 2014: Built beta units
- 2015: Initial installation/data collection at Duke's Top of the World facility (TOTW) in Wyoming
- 2016: First formal field study began at TOTW
- 2018: First commercial installation at TOTW
- 2019: Expanded to global market
- 2020: Developed a new "IdentiFlight Dashboard"
- 2021: Incorporated advancements to neural network
- 2022: Next generation of design will launch, including capabilities for offshore wind energy and smaller object detection (e.g., bats and birds).

Barriers and Challenges:

- Prior attempts at developing similar technologies failed
- Skepticism and resistance from environmental stakeholders
- Research to evaluate the system takes a long time
- Cybersecurity and SCADA integration issues take a lot of work and collaboration, and must be repeated for each turbine manufacturer
- Permitting/legal landscape is unclear.

Lessons Learned. Establishing strong partnerships and collaborations is a key to success. Duke's investment in the pilot system, involvement in validation research, and first full-scale deployment was essential to establishing the legitimacy of IdentiFlight and its subsequent adoption by other companies.

The research and development of IdentiFlight was supported entirely through private/industry funding, but funding to support validation studies research to evaluate the system was provided by REWI and WETO. While IdentiFlight's efficacy has been demonstrated, there is always a need for more research and evaluation as capabilities expand, and as IdentiFlight is used to conserve different species, in new regions, and in response to different regulations.

Comment: IdentiFlight has been used in the development of the Eagle Conservation Plan at Duke's TOTW facility; however, USFWS has been cautious about providing credit for the use of IdentiFlight without sufficient data over multiple years. Duke paid compensatory mitigation fees up front and will reconcile fees later after take reductions have been measured.

7.2 Case Study #2: Ultrasonic Deterrent – John Ugland

NRG Systems has developed a nacelle-mounted ultrasonic bat deterrent. NRG's deterrent has been commercially available since 2019, and is currently used on turbines generating nearly 1 gigawatt of power in eight countries across four continents. The deterrent has been installed on several turbine brands and NRG Systems has a strategic partnership with Vestas.

Timeline of NRG's Deterrent Background and Development:

- Early 2000s: The Bats and Wind Energy Cooperative was established to address bat fatalities at wind energy developments
- 2009–2010: Bat Conservation International conducted an experimental study of an early-generation deterrent, developed by Deaton Engineering, at an operational wind energy facility in Pennsylvania
- 2014: NRG Systems took over the rights to the Deaton Technology and began developing their own technology
- 2015–2019: WETO-funded Bat Conservation International to conduct a validation study at an operational wind energy facility in Ohio. Texas State University and Bat Conservation International conducted a study in south Texas.
- 2020–2021: WETO funded NREL and partners to conduct a behavioral study using a flight cage in Texas to assess species-specific response behavior.

Funding for Research and Development R&D

Product development and initial field testing (pond trials) were privately funded. Larger field studies were publicly funded by WETO with private funding from industry partners. Public and private funding of the 2009–2010 study of an early-generation deterrent demonstrated the effectiveness of the approach used by this technology, encouraging investment by NRG Systems and other parties. Subsequent studies were funded and gained industry support/partnership due to prior public funding.

Barriers, Challenges, and Lessons Learned

Seasonality. The seasonality of bat and wind energy research slows the iterations and testing because you must conduct your field work during fall migration and wait until the next year to do further testing.

Cost. Since success is measured in the reduction of bat fatalities, validation studies require a robust experimental design to determine a treatment effect. These studies are expensive and require numerous turbines and large search plots. Conducting field tests requires close collaboration and financially involved partners to cover the costs of post-construction fatality monitoring including the clearing and maintenance of search plots in addition to the searches. Full-scale evaluations of technologies that require extensive monitoring tend to cost hundreds of thousands to millions of dollars.

Administrative Burden: Publicly funded studies may proceed at a slow pace, with many administrative steps from award negotiation, extensive review processes, and go/no-go decisions.

Integration: As discussed in most sessions of this workshop, there are many challenges to installing and integrating technologies at an operational wind energy facility.

Permitting: Even after a technology has been tested and shown to be effective, the context-specific nature of permitting may preclude automatic acceptance of a technology to be incorporated into a permitting process. Several questions regarding permitting include: 1) What is the scope of inference of studies to date?, 2) Does the research apply to the region where the project of interest is located?, and 3) Does a technology need to be tested/evaluated for each individual site? There are still many unknowns for how a technology will move from validation studies to acceptance and being incorporated into permitting processes. Many owner/operators request a small-scale test or site-specific data collection at their facility prior to full-scale deployment.

Questions at the end of NRG's presentation focused on what, if any, were the needs for continued monitoring after the deployment of NRG's bat deterrent. Some concern was voiced regarding prior results indicating a potential increase in eastern red bat fatalities in some of the evaluations of this technology. There was also some concern voiced regarding whether there may be long-term habituation to ultrasonic deterrents.

8. Breakout Session: Mid-Late Stages of Development

The second breakout session focused on challenges and potential opportunities to ease the path to later-stage technology development. After the larger group reconvened, a representative from each group presented key points from the small group discussions, summarized here:

- Some participants are not aware that there are standards and guidelines for the technology developers or industry to determine what metrics should be met for a technology to be validated and accepted for use (Sinclair and DeGeorge 2016[1]). Additional questions include: How many studies should be completed, and over what geographical range? What performance standards must it meet? What elements must a study design and statistical analysis contain to be accepted by the community?
- Guidelines on the timeline required for planning the integration process could be very helpful for technology developers. Permits can take a year, integration of the technology varies but can take a long time, especially if it needs to be mounted on a turbine or integrated into the SCADA system. Coordinating with landowners can take a lot of time, and some do not want to remove crops to accommodate research.
- Study designs are often written to fit the funding available, rather than funding the proper study design. Doing so reduces the value of studies and makes it harder for technologies to gain acceptance.
- Close collaboration with landowners, turbine manufacturers, and facility owner/operators could ease site-specific constraints of research.
- Lack of regulatory buy-in and incentives are significant barriers. Technology providers and the wind energy industry have seen companies deploy tested technologies and not receive regulatory credit for them in the permitting process. Lack of regulatory credit discourages further deployment of technologies. There is also a lack of incentives to deploy technologies for bats in situations where it is not a regulatory requirement. It will be difficult to advance technologies and conserve nonlisted species if companies do not get some sort of credit for their deployment.
- Regulatory flexibility would greatly ease barriers to late-stage technology development and acceptance. Having the ability to reduce mitigation later in the life of a permit if the technology is effective is one option. Currently, most of the burden and uncertainty falls on the developer, but if some of the uncertainty could be shared by the regulators, it could have great conservation impacts. More regulatory clarity to encourage technology options "on the menu" is greatly needed.
- Academic research and publication is slow, but the industry needs to advance at a faster pace.

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[1] Sinclair, K., and E. DeGeorge. 2016. *Wind Energy Industry Eagle Detection and Deterrents: Research Gaps and Solutions Workshop Summary Report*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-65735. https://www.nrel.gov/docs/fy16osti/65735.pdf.

9. From Evaluation to Broad-Scale Acceptance and Deployment

The final session of the workshop focused on overarching questions related to technology acceptance and adoption. A general question for the session was, How do we know when to stop research and development of a technology and instead invest in something with better potential for success? On the other hand, When can the community say "yes" to a technology? What does acceptance mean, and what are the standards and lines of evidence that it takes to get there?

9.1 Exit Stage Left: With What Criteria, When and How Do "We" Exit if a Technology Is Not Proving Effective in Impact or Cost?

Panelists:

- **Greg Aldrich** – Duke Energy Sustainable Solutions (Duke)
- **Kaj Skov-Nielsen** – Independent Consultant
- **Raphael Tisch** – Allegheny Science & Technology (Contractor to DOE)

Each speaker was given a few minutes to share their experiences and perspectives, followed by a facilitated discussion.

Greg Aldrich, Duke Energy Sustainable Solutions

Several years ago, a company approached Duke with an idea that ultraviolet light could be used as a deterrent for eagles. Duke approached REWI to conduct a third-party validation of the idea. A small-scale pilot field trial was conducted and determined that eagles do not react to ultraviolet light. This project was written up and published. Duke had a similar experience exploring a potential auditory deterrent for birds in which they directed loud sounds and music into the sky at a wind energy facility. Birds did not react to the sounds and music, and the project was discontinued. A third study on a radar system, which required expensive updates to the infrastructure to implement, found a fatal flaw within a few weeks of operations and the project was terminated.

Duke's advice is to carefully evaluate potentially expensive projects and walk away from a project if you do not see immediate positive results. In the case of the radar system, it was obvious that the system did not have the capability to tell the difference between a raven and an eagle, so this was an easy decision. For some projects it may be worthwhile to test if the expenses required to inform that initial result (go/no go decisions) are reasonable. It may be easy to observe whether an animal exhibits a behavioral response to a potential deterrent (e.g., ultraviolet light, loud sounds) but it may be much more challenging with longer-term curtailment studies.

Kaj Skov-Nielsen, Independent Consultant

It is easier to bail on projects when they are in earlier stages of development, and you have less at stake in the success of the study. There will be different risk factors at play depending on the target species, habitat, fatality rate, and technology. Technology development often stops when funding ends, or if stakeholders do not see the benefit of funding further development.

Raphael Tisch, Allegheny Science & Technology (Contractor to DOE)

From a federal funding perspective, the decision to stop or exit a project is complex and multifaceted. The simplest way for a project to end is if the recipient fails to comply with the contract. From a technical standpoint, DOE is not in the business of choosing winners and losers. DOE has attempted to structure their research program to meet the priorities of their stakeholders. When a study encounters a major obstacle, DOE does whatever it can to help overcome the obstacle. DOE-funded projects are structured to have “Go/No-Go” decision checkpoints, which have criteria defined at the beginning of the study to determine whether the project should proceed to the next phase. These criteria, which often include preliminary data or deliverables, are evaluated by DOE personnel, and often by external peer-review teams or other stakeholders. If the Go/No-Go criteria are close to being met, DOE may issue a “conditional” Go decision that is contingent upon a proposed path forward to meet any outstanding criteria. If the criteria cannot be met, or if the objectives of the project have become misaligned from the original intent of the Funding Opportunity Announcement, they might have to halt the project. DOE has an obligation to taxpayers and to the people who applied for and did not receive an award, so it cannot substantively change the subject, topic, or goals of a study beyond the scope of the original application once it has been awarded.

Discussion

The participants discussed whether DOE’s Go/No-Go process was set up appropriately, and whether the criteria to make Go/No-Go decisions relies on the right parameters. DOE-funded studies of technologies are often large, complex projects with multimillion-dollar budgets and lofty goals; every element added to the project is another potential failure point. Some have suggested to break big projects down into smaller, incremental pieces, though these studies are also often criticized for imposing a heavy administrative burden on the recipients.

It was emphasized by one attendee that in conducting research at operating wind energy facilities, inevitably there will be logistical challenges regardless of how well-designed or well-funded the study is. For example, a turbine can get struck by lightning and cause equipment outages, or the field team could run into conflicts with landowners and access to study plots.

There was discussion surrounding the meaning of “effectiveness” and whether there should be a uniform definition of effectiveness, or whether there are situations where a technology is “good enough,” even if it does not meet a hypothetical future broad industry standard. One attendee cautioned that there will likely never be a “silver bullet” solution for bat conservation and wind energy, and that the industry should focus on the concept of having a toolbox with multiple potential solutions that can be applied in different contexts.

The current framework regarding managing uncertainty surrounding the performance of technologies is focused on the risk of moving forward with a technology if there is still uncertainty. However, the flip side of the argument is also compelling: what is the risk of *not* moving forward with deployment of technologies?

Early-stage testing is less expensive and onerous, but the results are only preliminary proof-of-concept tests, and usually lack statistical rigor and all the complexities that must be considered for a full-scale deployment. If additional time and money are spent on the earlier stages of development, and on integration and weatherization in particular, full-scale studies may be more successful. You cannot adequately test the biological effectiveness of a system if it experiences chronic technical issues and excessive downtime.

The power of money and incentives to adopt and invest in technological solutions is powerful. If/when companies receive credit or incentives from regulatory agencies for deploying technologies, it will catalyze further investment, research, and deployment. On the other hand, if companies invest in technologies and receive no benefits, it could discourage future use and investment.

9.2 Acceptance: How Do We Get Acceptance? Who Accepts, How, and When?

Panelists:

- **Scott Pruitt** – USFWS
- **Garry George** – National Audubon Society (Audubon)
- **Stu Webster** – American Clean Power Association

There is no clear understanding as to what "acceptance" means. To help better understand the concept of acceptance, some questions to explore include: Who are the stakeholders that need to "accept" the use of a technology? How long does acceptance last for? What are the risks?

Stu Webster, American Clean Power

The market for technologies in the wind-wildlife field is small, which may limit interest from investors, and in turn may be a barrier or delay developing solutions. However, these technologies can be used internationally, or potentially in other markets (e.g., transportation, etc.), and the market may be more robust than it initially appears to be. Until private sector investment is attracted, research and development efforts that enable the scaling up of effective solutions need disproportionate public support/investment.

The legacy of previously failed attempts can be a barrier to investment in and acceptance of technologies. A clear definition of what acceptance means (i.e., a conservation or impact reduction goal) and what metrics are optimal (biologically meaningful, cost-effective, accurate and precise enough to detect an effect and replicate results) are needed to measure efficacy. The USFWS and the conservation community could be more involved in defining conservation metrics for use in an acceptance process, advocate for the use of effective technologies, and advocate for dedicated public resources. It is also important to acknowledge that there will always be a level of uncertainty related to the use of effective technologies, and for stakeholders including the USFWS and technology developers to agree on performance standards and protocols for a technology that reduces the need for future testing and monitoring after a technology has been deployed.

Addressing climate change is such an urgent priority that we as a community of stakeholders should do everything possible to facilitate the development of more renewables. Because the use of technology can reduce the impacts of wind energy development on wildlife, thereby reducing barriers to deployment, conservation and agency stakeholders could consider taking a more proactive role in facilitating the acceptance of technologies.

There should be clearly defined thresholds and targets for performance of technologies. There is considerable debate regarding which stakeholders have the power to decide what performance targets warrant acceptance for technologies. Industry stakeholders tend to agree that the USFWS has the power to decide if/when a technology is accepted. Therefore, the USFWS needs the support of the conservation community. Collectively, we need to advance technologies in an environment of uncertainty and risk.

Scott Pruitt, USFWS

The USFWS's mission to conserve fish and wildlife resources for the benefit of the American people is implemented for nonfederal projects through the ESA via the use of HCPs by avoiding, minimizing, and compensating for loss of protected species. The USFWS's position is that HCPs have clear annual take limits, and that the developer should be the decision maker regarding whether a technology is sufficient to meet legal take limits. If a technology meets the take limits established in an HCP, then it can continue to be used. However, if take is exceeded, then adaptive management measures must be implemented to reduce take (e.g., curtailment).

While there is no official standard performance target for minimizing bat fatalities, a common benchmark is a 50% reduction, which can usually be met by curtailing wind turbines to a cut-in speed of 5.0 meters per second. This benchmark has been used in HCPs and permits and would be a good performance target for innovators working in bat risk minimization.

Garry George, National Audubon Society

Audubon's perspective is that there is a need for rapid deployment of renewable energy to meet climate change goals and keep warming below 3°C above preindustrial levels. Audubon found2 that we may lose 389 species of North American birds if warming reaches that level; therefore, the lower we can keep warming by degrees, the better for our birds.

New technologies play an increasing role in wildlife conservation at wind energy facilities and may be useful for both pre- and post-construction data collection. Audubon supports the progress and investments made by federal and state agencies and wind energy developers in technologies meant to minimize collisions at wind facilities. Audubon highlights them in our magazine and other outreach efforts to inform our constituencies that wind and solar energy can avoid, minimize, and compensate for impacts on birds. In recent years, Audubon has published "deep dives" into IdentiFlight used at TOTW by Duke Renewables and the California condor geofence developed by Terra-Gen around wind energy projects in the Tehachapi Mountains in Southern California to warn of the approach by these birds as they expand their range. So far, no condor has been killed or injured by turbines at a wind project.

With offshore wind energy rapidly expanding in North America, Audubon's main technology-related priority is developing a tool that can detect and record collisions with turbines in the offshore environment, since it is not possible to search for carcasses beneath the turbines, as is typical at land-based wind facilities.

Audubon recognizes that a clear validation pathway for technologies is needed. Clean energy and conservation must go hand in hand3.

Discussion

Industry, conservation, and agency stakeholder groups expressed concern about the impacts of wind energy on migratory tree bats, and the need to avoid any of these species becoming federally listed. If migratory tree bats become listed under the ESA, it will drastically change how these issues are managed. In effect, a listing of a widespread species would put a substantial number of existing facilities in direct violation of the ESA question the regulatory scheme for facility operation while HCPs and permits are developed and issued. Some wind energy developers are prioritizing conservation of nonlisted bat species because of the regulatory consequences that could impact wind energy development if those species are listed in the future.

Migratory tree bats are already listed at the state level in some areas. In some cases, states may waive standard monitoring if proven minimization strategies are implemented. If alternative, unproven minimization strategies are implemented, states may require several years of intensive monitoring to validate their effectiveness. This additional monitoring can disincentivize technology innovation and research.

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[2] Audubon. 2022. Survival by Degrees: 389 Bird Species on the Brink. https://www.audubon.org/climate/survivalbydegrees

[3] Gray, Elizabeth and Michael M. Garland. 2022. Conservationists and the Renewable Energy Industry Can and Must Work Together to Fight Climate Change. https://www.audubon.org/news/conservationists-and-renewable-energy-industry-can-and-must-work-together-fight

The risk associated with uncertainties of technology application falls on the developer, though there need to be enough people who support the use of a technology for it to be incorporated into a permit. Under the BGEPA, there must be no net loss for golden eagle take (i.e., all golden eagle take must be offset). IdentiFlight is a minimization measure intended to reduce take, but like other technologies, it cannot prevent take. Thus, facilities must offset the remaining eagle fatalities.

There was discussion regarding how to approach adoption of technologies given that the USFWS does not see its role as approving technologies, but rather requiring a limit on take of listed species. While different stakeholder groups may disagree, the application of technologies and the regulatory landscape surrounding threatened and endangered species is well-defined. However, there is no straightforward path to broadly implement minimization strategies for migratory tree bats or other nonlisted species when minimization and mitigation are not required under the ESA. One participant noted that while 50% is a common target for fatality reduction for bats, there is no clear statement or instruction from the USFWS on the matter, and communication is not consistent across the field offices. Because confirmed fatalities of listed bat species are so rare, individual comfort levels of field staff can cause a lot of variation in how permits are implemented.

So how do we incentivize companies to deploy conservation measures for migratory tree-roosting bats before they become listed under the ESA? One participant suggested that the risk ultimately falls on the wind energy industry, and that it should be forward-looking regarding the consequences and costs of inaction. In the long run, it will be very expensive for the wind energy industry if hoary bats were listed under the ESA, and that might be the best incentive.

The USFWS is exploring potential regulatory mechanisms that may be applicable to incentivizing risk reduction to nonlisted species.

One major barrier to widespread adoption is the high cost of many of these technologies. However, if deployment gains traction, the economy of scale will help reduce costs. Another common barrier is the need to validate technologies in different scenarios. One possible approach is to be more strategic in selecting research sites to account for variation among species or habitats.

It is likely that a given strategy will not work at every site. Differences in wind turbine dimensions, cut-in speeds, weather patterns, and habitat may cause variations across study results. Thus, there will be no one-size-fits-all strategy. A suite of strategies is required so that each wind energy facility can select the option that best fits its situation.

9.3 Recommendations

Throughout the workshop, participants identified several recommendations to streamline technology research and development. Some of these recommendations can be achieved in the short term, whereas others may require more time. Continued collaboration among wind energy developers/operators, OEMs, technology providers, government agencies, conservation organizations, and researchers is needed to fulfill these recommendations.

- Greater collaboration is needed to modify the regulatory framework including:
    - Defining a clear pathway for the acceptance of effective technologies and their application to fulfill legal obligations under the ESA, BGEPA, and other federal, state, or local conservation laws.
    - Conducting a focused workshop of a small number of experts across this issue (e.g., legal, technical, economic) to explore the possible maximum flexibility or tools within existing regulatory frameworks, primarily the ESA.

    - Incentivizing research and development of technologies (e.g., novel permitting opportunities developed by USFWS to pilot-test or enable a “research as mitigation” program).
- Technology providers should contact OEMs during early stages of research and development to understand the constraints and limitations of wind turbine infrastructure and systems.
- The wind-wildlife community needs better mechanisms to identify technology providers and connect them with OEMs.
- Funding opportunities need to be aligned with field seasons.
- Flexibility of funding opportunities needs to be improved to encourage broader and reduced cost of participation.
- Frequency of funding programs needs to be increased to encourage applicants to better focus on a given step in the development or acceptance process rather than trying to accomplish everything under one large, complex award with several potential failure points.
- The speed of disseminating results needs to be accelerated.
- Increased public and private funding is needed to conduct the number of studies required to meet the “preponderance of evidence” standard for determining predictable and reliable impact minimization performance.

10. Appendix – Survey Results

Table 1. Barriers to technology by stage. Question asked in survey: Technology development may include the following steps: early bench testing to limited in-field testing (field testing without a wind turbine) to testing on a small sample (one to three) of turbines to an experimental field study (a suitable sample size of turbines within a wind energy facility) to full-scale deployment (in an entire wind project and across projects). In your view, please rank the stage with the least barriers to that stage with the most. Please choose one response per column.1= Least barriers, 5=most barriers.

	1-Least Barriers	2	3	4	5-Most Barriers	Total	Weighted Average
Bench testing	93.75% 15	6.25% 1	0.00% 0	0.00% 0	0.00% 0	16	1.06
Limited in-field testing	0.00% 0	93.33% 14	6.67% 1	0.00% 0	0.00% 0	15	2.07
Small sample size study	0.00% 0	0.00% 0	80.00% 12	13.33% 2	6.67% 1	15	3.27
Experimental field study	0.00% 0	0.00% 0	6.67% 1	80.00% 12	13.33% 2	15	4.07
Full-scale deployment	6.25% 1	0.00% 0	6.25% 1	6.25%12 1	81.25% 13	16	4.56

Table 2. Potential barriers to acceptance. Question asked in survey: Please rate the following potential barriers to acceptance (defined as broad application or adopted as a best practice) of a technology (i.e., deterrent device) or strategy (i.e., operational curtailment) for minimizing wind energy impacts to wildlife. 1 = low to no barrier of consequence and 5= very high and fundamental barrier.

	1-Low to No Barrier of Consequence	2	3	4	5-Very high and Fundamental Barrier	Do Not Know	Total	Weighted Average
Access to study sites	0.00% 0	18.75% 3	31.25% 5	18.75% 3	12.50% 2	18.75% 3	16	3.31
Equipment and manufacturer warranties and constraints on modification to equipment/systems	0.00% 0	12.50% 2	18.75% 3	31.25% 5	18.75% 3	18.75% 3	16	3.39
Insufficient or difficult-to-determine benefits-costs (researchers cannot get private cost data to ascertain cost implications or industry cannot get cost estimates from researchers)	0.00% 0	31.25% 5	12.50% 2	12.50% 2	18.75% 3	25.00% 4	16	3.25
Lack of clear process or regulatory review and approval of limited infield, small sample size and experimental field research	12.50% 2	18.75% 3	6.25% 1	18.75% 3	37.50% 6	6.25% 1	16	3.53
Lack of clear process of regulatory review and approval of project-scale adoption	6.25% 1	12.50% 2	0.00% 0	12.50% 2	56.25% 9	12.50% 2	16	4.14
Coordination or conflict challenges between permitting agencies(e.g., state says no, feds say yes)	25.00% 4	12.50% 2	12.25% 2	25.00% 4	6.25% 1	18.75% 3	16	2.69
Lack of acceptance by permitting authorities	18.75% 3	12.50% 2	0.00% 0	31.25% 5	31.25% 5	6.25% 1	16	3.47
Including appropriate control treatments, e.g., obtaining exceptions to permit requirements	6.25% 1	0.00% 0	31.25% 5	25.00% 4	18.75% 3	18.75% 3	16	3.62
Insufficient public dollars to fund early-scale [Bench testing &Limited in-field testing] research	12.50% 2	6.25% 1	56.25% 9	6.25% 1	12.50% 2	6.25% 1	16	3.00

	1-Low to No Barrier of Consequence	2	3	4	5-Very high and Fundamental Barrier	Do Not Know	Total	Weighted Average
Insufficient private dollars to fund early-scale [Bench testing &Limited in-field testing] research	6.67% 1	20.00% 3	33.33% 5	13.33% 2	6.67% 1	20.00% 3	15	2.29
Insufficient public dollars to trial and assess [Small sample size study &Experimental field study] promising technologies or strategies	18.75% 3	12.50% 2	25.00% 4	18.75% 3	18.75% 3	6.25% 1	16	3.07
Insufficient private dollars to trial and assess [Small sample size study &Experimental field study] promising technologies or strategies	0.00% 1	26.67% 4	20.00% 3	26.67% 4	6.67% 1	20.00% 3	15	3.17
Rate at which results from a study become publicly available	6.25% 1	12.50% 2	18.75% 3	43.75% 7	18.75% 3	0.00% 0	16	3.56
Lack of agreed-on criteria of efficacy-Scalability	12.50% 2	12.50% 2	25.00% 4	25.00% 4	25.00% 4	0.00% 0	16	3.38
Lack of agreed-on criteria of efficacy-Sufficient replication	12.50% 2	18.75% 3	12.50% 2	31.25% 5	25.00% 4	0.00% 0	16	3.38
Lack of agreed-on criteria of efficacy-Longevity, e.g., how many years will a deterrent function effectively	6.25% 1	25.00% 4	6.25% 1	31.25% 5	18.75% 3	12.50% 2	16	3.36
Lack of agreed-on criteria of efficacy-Desired statistical power to measure rare events	12.50% 2	6.25% 1	18.75% 3	18.75% 3	37.50% 6	6.25% 1	16	3.67

Table 3. Opportunity to advance. Question asked in survey: Please rate the opportunity to advance the following technologies/strategies in terms of their ability to improve our monitoring and minimization approaches (1 = limited opportunity to advance and 5 =great opportunity to advance.).

	1-Limited Opportunity to Advance	2	3	4	5-Great Opportunity to Advance	Total	Weighted Average
Ultrasonic deterrents	0.00% 0	25.00% 4	6.25% 1	31.25% 5	37.50% 6	16	3.81
Other types of deterrents	0.00% 0	37.50% 6	37.50% 6	12.50% 2	12.50% 2	16	3.00
Bats: Smart (informed, sensor-based) curtailment	0.00% 0	0.00% 0	12.50% 2	31.25% 5	56.25% 9	16	4.44
Raptors: Camera-based detect and (deter or curtail) systems	0.00% 0	6.25% 1	18.75% 3	37.50% 6	37.50% 6	16	4.06
Collision detection technologies	0.00% 0	6.25% 1	12.50% 2	25.00% 4	56.25% 9	16	4.31
Remote-sensing monitoring systems, e.g., radar & Lidar	6.25% 1	31.25% 5	18.75% 3	25.00% 4	18.75% 3	16	3.19
GPS or radiotelemetry tracking, e.g., behavior, movement, use	0.00% 0	18.75% 3	31.25% 5	31.25% 5	18.75% 3	16	3.50