Guidance for Potential Hosts of Wind-Wildlife Technologies and Strategies

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AWWI is a partnership of leaders in the wind industry, wildlife management agencies, and science and environmental organizations who collaborate on a shared mission: to facilitate timely and responsible development of wind energy while protecting wildlife and wildlife habitat.

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Executive Summary

A wide range of promising risk reduction technologies and strategies are actively being developed to help wind facilities minimize wind-wildlife risk. There are many reasons an operator would consider evaluating or employing a technology. Doing so can be helpful in permit negotiations, forestalling the need for permits or providing a source of avoidance or minimization credit for a permittee. For those with issued permits, the active evaluation or employment of a technology is a credible source of meeting adaptive management requirements, and for those permits with shorter terms (e.g., 5-year eagle permits), the use of a technology could be a means of reducing take estimates, resulting in lower mitigation costs.

Introducing any new system or technology into an operating wind energy facility potentially impacts all aspects of the operation and requires due diligence on the part of the host company prior to a commitment. This Guidance outlines considerations specific to introducing wildlife risk reduction technologies. Some of these considerations pertain specifically to hosting a technology evaluation study; but much of the same due diligence supports the decision to invest in a technology for longer term employment.

The first section of the Guidance, biological considerations, addresses elements associated with hosting a field evaluation study that pertain to wildlife biology, including collection of wildlife use data, fatality monitoring, regulatory considerations, and other aspects of the study design, as well as indirect impacts of the technology on site and neighboring land users. Predicted or known baseline conditions for prospective host sites should be compared with the anticipated value of evaluating or employing a technology.

The second section deals with all aspects of operational considerations pertaining to the site, installation and integration support needs, and supporting roles for operations teams such as asset management. Wind energy facilities are designed and operated to maximize production, and introducing a new system, whether temporary or permanent, impacts many aspects of operations and asset management. The host company may already have protocols or procedures in use to coordinate and guide the integration of new systems (e.g., software, hardware, platform, SCADA, security, network); this Guidance offers considerations specific to wildlife risk reduction technologies but can be augmented with pre-existing integration protocols or procedures.

Hosting Technology Testing and Evaluation

Much of this Guidance is written with technology testing and evaluation projects in mind. Testing a risk reduction strategy may benefit the host site by providing a minimization measure to the permit, or meeting the intent of adaptive management requirements. The installation and integration approaches for an evaluation study can be vastly different than for longer-term deployments, but if the confidence is high enough that the evaluation will likely validate an intent for deployment, then short-term installation and integration approaches should be approached with long-term installation in mind.

Evaluation studies often are designed to compare a technology or strategy with control (i.e., untreated) turbines. The feasibility of implementing such treatment/control regimes may be limited by the facility's Supervisory Control and Data Acquisition (SCADA) or by the terms of existing permits. Some SCADA configurations may limit the number of operational parameters that can be simultaneously changed or only allow for operational changes at the facility (not turbine) level. If increased cut-in speed is a condition of a site permit, it may be necessary to secure a research permit or other authorization to allow control turbines to operate normally to fulfill the objectives of a study design. Some sites may have a specialty permit which requires certain minimization measures be in place for a certain period (e.g., curtailment during periods of high eagle use), thereby precluding the ability of the site to host a deterrent or smart curtailment evaluation. Conversely, the pursuit of, or compliance with, an existing permit may be achieved by hosting a technology evaluation.

Planning and executing a technology evaluation study should include tracking and compiling all costs including costs to maintain performance and service of the technology. A cost/benefit analysis should be part of the evaluation in addition to the study's biological objectives.

Acquiring a Technology for Long-Term Deployment

While some of the factors discussed in this Guidance are specific to hosting an evaluation study, most of the operational considerations – and some additional due diligence related to procurement and contracting – apply to permanent technology acquisition and deployment.

New technologies come with uncertainties, but also with opportunities for operators and vendors. Long-term operation and maintenance (O&M) costs and useful life of equipment may be uncertain with newer technologies; buyers should seek engineering evaluations, analyses, or other evidence for a vendor's claims. A reasonable construct when procuring a new or early stage technology is for the buyer to negotiate a discount in exchange for providing host site, sweat equity, and substantive technical and commercial feedback to the vendor – invaluable feedback to inform further technical and commercial improvements on their system.

Whether for purposes of temporary or permanent employment, qualitative or quantitative technology performance targets should be defined prior to making an investment decision. Such targets should be defined for informing decisions to terminate a project that is not (or no longer) adding value to the operator. Decisions to abandon a course of action tend to be easier on all parties when performance objectives or some other set of pre-defined criteria for failure/success are part and parcel to the project.

Using this Guidance

This Guidance is designed primarily to help internal technology evaluation project advocates think through the myriad implications of hosting a proposed wildlife risk reduction technology or strategy at a wind energy facility.

Technology developers and vendors may also find this Guidance useful. Knowing the breadth of factors a prospective technology host (or buyer) must consider will help developers, vendors, and researchers anticipate and prepare to address host company management's questions or concerns about the proposed technology.

Appendix A is a cross-reference matrix of elements to consider when evaluating a proposed project and general internal and external parties that may have a role or responsibility with each element.

Appendix B is a two-tiered checklist that covers the biological and operational considerations. For each element there is summary guidance provided for 1) vendor or researcher, 2) initial operator evaluation for project and sites.

Section I: Biological Considerations

Provided by Dave Young, Western EcoSystems Technology, Inc.

This section covers environmental or biological items that should be considered when evaluating the suitability of various technological solutions for a proposed host facility. Some of these considerations pertain to both temporary (evaluating) and long-term implementation; others are specific to situations where a technology is being field evaluated. The considerations specific to field-evaluating can also help guide the development of study designs that will support informed business decisions.

1. Biological Data Considerations

a) Historical Data

Evaluating a new technology often requires that inferences be made about pre-evaluation conditions. For example, if the technology evaluation is looking at wildlife use of a site before and after the evaluation is implemented, data collected from the site prior to the evaluation may be useful to fulfill the experimental requirements. Existing biological data and knowledge of a site or project should be reviewed to ensure that the historical data needed to evaluate the technology is available.

b) Additional Data Collection

Ideally the value gained from collecting additional data in connection with evaluating or deploying a technology would outweigh any concerns – but host companies should recognize that any data collection effort may identify other, previously unknown or unanticipated issues. For example, due to climate change, species distributions are changing over time. Additional data collection (e.g., temporal or spatial data about species presence) may evidence species' presence that was not detected or thought to be a concern prior to project construction. This consideration is particularly important for older facilities with dated environmental due diligence information. Additionally, the collection of some target species' use of a wind energy facility can create liability risk for the operator

2. Monitoring Requirements

a) Conflicting Requirements

Existing monitoring requirements may affect research study design and should be evaluated. Some sites may have monitoring requirements in place to meet permit or company policy obligations (e.g., adhering to U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines or Bat and Bird Conservation Strategy obligations). If evaluating a technology delays or displaces existing monitoring studies, those obligations may be extended for longer periods of time unless the operator negotiates mutually agreeable terms ahead of time. Coordinating with outside interests (regulators, investors, local conservation groups) can be time consuming and therefore should be treated as a long lead item when developing an evaluation study.

b) Efficiencies of Combining Research Efforts

Existing monitoring requirements that can be tailored to a study design (or vice versa) are a possible source of cost efficiencies when conducting evaluations. However, such opportunities need to be balanced by identifying challenges when determining the suitability of a site for proposed research. For example, does the site have the target species of interest? How important is high searchability or the use of larger cleared plots? What are the regulatory permissions needed to conduct the evaluation?

A broad evaluation of potential host sites may inform where certain studies should occur. For example, evaluating the efficacy of bat mortality reduction methods is more likely to show results at sites where bat mortality is generally high in the absence of such measures. This consideration could potentially override the intuitive consideration of evaluating at a site that has, for example, identified a need for a risk reduction strategy but is otherwise not well suited to host an evaluation where accomplishing study objectives are uncertain or cost prohibitive to pursue. Once technologies and strategies are proven they can be subsequently employed to respond to an operational need without the burden of evaluating for efficacy, and ideally lead to a reduction of ongoing monitoring requirements or commitments.

3. Regulatory Considerations

a) Permitting Constraints

Permits to operate or other overarching mechanisms that impose operational conditions, requirements, or commitments on a site may affect evaluation study designs and objectives. For example, if an increased cut-in speed is a condition of the site permit, it may be necessary to secure a research permit to allow reference or control turbines to operate “normally” to fulfill the needs of the study design. Some sites may have a specialty permit(s) (e.g., Incidental Take Permits/Habitat Conservation Plans) with conditions that effectively prevent a site from hosting technology evaluations. For example, a permit may require certain minimization measures be in place for certain periods (e.g., curtailment during periods of high eagle use). Or, a rigid interpretation of applicable wildlife laws may view deterrents as a source of harassment for protected species. Both examples, while not insurmountable, could nonetheless challenge the ability of a site to host some technologies. Conversely, the pursuit of, or compliance with, an existing permit may be achieved by hosting a technology study. As such, a comprehensive, strategic commercial and regulatory approach is needed when evaluating prospective host sites’ suitability.

Many (though not all) evaluation studies compare fatality rate estimates between controlled and treated turbines. Handling and collection of carcasses found during fatality monitoring requires authorization from the U.S. Fish and Wildlife Service (USFWS), primarily through the issuance of Special Purpose Utility permits (SPUT). Recent changes to SPUT issuance criteria require the permit be issued to operators rather than hired researchers, a change some industry view as a liability risk. This regulatory hurdle could impact a set of evaluation objectives.

Some regional and field offices of the USFWS recognize the conservation benefit of evaluating risk reduction technologies and will work with operators looking to host a technology evaluation. As part of the regulatory due diligence for hosting a technology evaluation, operators or researchers might informally consult with the USFWS and/or state wildlife agency about streamlining needed authorizations. Research permits are another potential source of authorization that may lack the perceived regulatory exposure of SPUTs. If permitting remains a hurdle, it may be easier to change the study objectives to eliminate the need to collect and handle carcasses.

b) Regulatory Requirements

Federal and state wildlife laws, rules, and regulations such as the U.S. Endangered Species Act (ESA), Bald and Golden Eagle Protection Act (BGEPA), Migratory Bird Treaty Act (MBTA), or state-listed species need to be considered when employing or evaluating technologies. Knowledge about a facility’s regulatory environment may help determine its suitability as an evaluation site. If evaluations are designed to minimize impacts to listed species, compliance with ESA or BGEPA should be sought or in process.

Similarly, if there are state requirements for implementing mitigation for some species at a site, the effect of the technology evaluation on that mitigation should be considered. Using or evaluating a risk reduction strategy may benefit the host site by providing a minimization measure to the permit, or by meeting the intent of adaptive management requirements.

4. Environmental Attributes

The prospective host site's environmental attributes, such as terrain, play a significant role in evaluating the suitability for technology evaluation or use. For example, if more or larger-than-normal cleared plots are a component of a study's design, the cost of maintaining these plots could be greater than budgeted. In such cases, a business decision needs to be made between funding larger maintained plots versus otherwise accounting for limited plot size (e.g., with a searchable area correction factor). The latter may adversely affect the statistical confidence of some study designs. Study objectives should reflect such constraints to avoid setting the project up for failing to achieve stated goals.

Some sites may not be suitable because of land cover or landscape conditions that preclude the evaluation. For example, an agricultural site may not be adequate because of economic concerns associated with lost crop production. The use of dogs to find carcasses can be an effective remedy in some hard-to-search landscapes, but not all (e.g., forested landscapes in which the canopy can prevent carcasses from reaching the ground). Technologies in which underground facilities need to be installed could be complicated by geotechnical constraints (e.g., near-surface bedrock) or trigger cultural resource assessment requirements. Review of a facility's development and/or construction plans or a desktop geotech evaluation can expose possible constraints.

Other environmental attributes to consider are wind speed, humidity, ice, extreme temperatures, site accessibility and remoteness, terrain complexity, and scavenger frequencies. For example, if average wind speeds are comparable to the cut-in speeds being evaluated for a smart curtailment strategy, unacceptable on/off cycle frequency of turbines can be a complicating factor. Humidity can be a complicating factor for some technologies relying on electronics exposed to the environment. The efficiency of some camera-based detection technologies could be complicated by landscape features in the background of their viewshed. Still another example is sites where high scavenger activity might complicate the statistical confidence of fatality results.

5. Indirect or Unanticipated Impacts

Some technologies employ visual or auditory methods such as audible alarms or visual deterrents to reduce risk to target species by deterring them from the zone of risk. Identifying potential auditory or visual receptors such as raptor nests or homes in proximity to the site is critical due diligence.

There also may be wildlife staging areas, critical range or resources, or other receptors in the vicinity of the site that are sensitive to such audible and visual deterrent technologies. Local or state authorities may have established limits to audible and visual impacts. Technologies that create a clear addition to the surrounding landscape could raise concerns from nearby residents. Regardless of merit, such concerns can create unexpected expense for operators, and so should be part of the due diligence effort.

6. Research Objectives

Evaluation of a technology can vary in complexity. When developing study objectives, constraints from onsite operations and landowners' use of the wind energy facility can impact the feasibility of some objectives or elements of a research effort. Unique criteria or elements of an evaluation should be considered with these potential constraints in mind. For example, detection dogs have been shown to improve searcher efficiency and data collection for impact calculations, making it possible to study impacts under temporal and spatial considerations not accessible to human searchers. However, the use of dogs may present challenges at some sites related to underlying use of the land (e.g., crop damage) or the hostile nature of the landscape.

Use of tagged species to analyze a technology's effectiveness would likely require identifying a capable and licensed biologist to perform new tagging, or to actively manage an existing set of tagged species. Devices that monitor for fatalities offer potential efficiencies in data collection; however, costs associated with collating, processing, and analyzing large datasets need to be considered as a potential budget offset for savings on field labor.

The criteria and elements of an effective study design should include objectives that meet the needs of the host site as well as biological objectives. Technologies or strategies identified for evaluation or use should be compatible with the resource availability or energy production stipulations of the host's power purchase agreement. Unique research criteria or elements of an evaluation should be considered in the context of onsite operations and landowners' use of the site.

Section II: Operational Considerations

Provided by Kaj Skov Nielson, Independent Consultant

When exploring the possibility of introducing a new technology to an operating wind energy facility, there are a broad range of operational considerations that require due diligence. These include logistical constraints associated with the site, installation and integration considerations, and asset management factors such as the impact a given technology may have on energy production or operational budget.

Depending on the technology and its functions, the installation and integration effort can range from relatively seamless to time consuming and complicated. For example, a technology designed to operate independently of wind facility equipment and controls can be relatively straightforward to implement, whereas introducing a technology (e.g., a "smart" curtailment system) designed to interact with the Supervisory Control and Data Acquisition (SCADA) will involve a more complex integration effort.

Wind energy facilities are designed and operated to maximize production, and introducing a new system, however temporary or permanent, is a disruption. That said, given the regular introduction of third-party systems – software, hardware, electrical, SCADA, security, or network-related – that affect some or all aspects of an asset or entire fleet, the host operator may already have protocols or procedures in use to coordinate and guide such integrations. If not, an additional benefit of undertaking a technology evaluation effort is that the lessons learned and efficiencies gained will have relevance and application elsewhere in operations.

The following elements are provided as guidance to minimize disruptions and inform planning ahead for the unfolding process.

1. Site Suitability

Given the uniqueness of each operator and the facilities across their fleets, as well as the range of technologies for reducing impacts to wildlife, there can be no single comprehensive set of evaluation criteria. However, given that third-party system installation and integration is not a novel concept for an operations group, potential hosts should seek out internal resources that may inform the operator-specific due diligence necessary to determine site suitability. Facets to consider include age of the facility, remoteness of location, cellular signal strength and reliability, expansiveness of the facility, surrounding landscape and meteorological conditions, turbine platform, onsite workforce and workflow, and structure of the generation control (e.g., local or remote, self-operated or third-party services). For technologies being field evaluated, the research effort may require additional space (e.g., for a freezer if carcasses are being collected and stored, or for data processing equipment) as well as arrangements for researchers to access the facility during off-hours.

The age of the host facility can indirectly affect the introduction of a new technology in several ways. For newer sites, installation of a technology on turbines under warranty can create an additional level of due diligence not necessary for post-warranty facilities. Many technology vendors have had limited engagement with original equipment manufacturers (OEMs), having developed working relationships with only one or two of the OEMs, if any. (See discussion of Representation and Warranties below.)

Conversely for some older sites, the communications, security, and data flow integration requirements of a prospective technology may exceed the capabilities or necessitate otherwise prohibitive upgrades of older turbine or generation controls.

Another consideration for older facilities is the level of detailed recordkeeping since construction. Older facilities may lack accessible as-built drawings that delineate availability of network, power, bandwidth, and other infrastructure and/or capacities. For example, older facilities that installed spare network lines are now at capacity through subsequent facility upgrades, further complicating installation and integration plans. In such cases, the costs of installing additional capacities, generation control software upgrades, and compliance with North American Reliability Corporation's (NERC) critical infrastructure protection (CIP) requirements could be missed without sufficient due diligence.

2. Installation and Integration Support

Wildlife risk-reduction technologies and strategies can be stand-alone installations within the wind facility or can involve the installation of equipment on wind turbines. Mounting equipment on any part of the turbine requires engagement with some combination of turbine, blade, and tower OEMs (see below). Stand-alone equipment entails coordination typical of new construction within the wind facility, including the permitting and execution of geotech/grading; installation of power, network, and communication facilities; and applicable land-use authorizations. Factors to consider in both cases are discussed below, including considerations related to the health and safety of facility and researcher personnel, technology components exposed to the elements (lightning, ice, snow, corrosion), and ongoing O&M support requirements.

a) Mounting Requirements

i. Towers

Modern wind turbine structures are highly cost optimized – to the point where some projects are designed using dedicated tower designs for each location in a project in order to save as much steel as possible given the local wind and turbulence conditions. As a result, mechanical safety margins for the towers are small, and any kind of third-party equipment mounting that involves drilling holes in or welds to the tower needs coordination with the OEM as such modifications can be stress risers with the potential to cause structural integrity issues over the lifetime of the tower if not done properly. Non-invasive mounting such as magnets will be simpler for the engineering team to approve and particularly cost effective with temporary installations so operators and vendors should scale proportionately.

ii. Nacelles

For nacelles, the considerations depend on the type of nacelle housing. Some nacelle housings are designed as covers surrounding the machinery and protecting it from the elements without much of a weight-bearing structural component. For this type of nacelle (which may use fiberglass as the main material), mounting third-party equipment with penetrating fasteners may be less critical than for weight-bearing nacelle structures. Some OEMs have technical specifications that can be drawn from, thereby reducing the coordination effort.

Other nacelle housings are made of steel and may support significant weight, such as cooling systems and nacelle controllers. For this type of design, suitable areas for drilling additional holes for mounting third-party equipment cannot be established by a lay person, and the evaluation has to be done by a qualified engineer who understands how the structure behaves during operations and where the structural safety margins allow for any additional mounting holes.

iii. Wind Sensors

Wind sensors typically are mounted at the back or top of a nacelle, or in some cases out in the spinner in front of the rotor, and are critical for the operation of the wind turbines. Installing anything that could have even the slightest impact on the measurement accuracy of wind direction or wind speed readings can impact turbine performance. Importantly, seemingly minor alterations to the turbine can have tangible impacts on turbine performance or structural integrity, and may affect the manufacturer's warranty.

iv. Blades

Mounting third-party equipment on the blades will require even more careful considerations than for the tower or the nacelle. Wind turbine blades are highly optimized to handle peak loads of extreme winds and fatigue loads from a long life of repeated rotations during turbulent wind conditions. Blades are also finely tuned airfoils for capturing as much energy from the wind as possible with the least amount of structural weight and drag. Adding anything to the blades that changes the airflow around the blade will impact the productivity of the wind turbine at the very least, and may also have load implications.

Modifications of any kind to the turbine blades require very careful consideration by the OEM. In addition to concerns about holes and physically mounting third-party equipment, other concerns include impact on certifications, warranty risk, impeding water drainage, damage to the surface coatings, water ingress, rotor aerodynamic or mass imbalance, conductive material added, electromagnetic interference, altering the electromagnetic profile of the turbine, increased radar profiling of the rotor, and concerns about the dedicated current path for lightning current.

b) Power Requirements

Most wind facility locations do not have access to a conventional consumer grid with 120 VAC in addition to the three-phase medium or high voltage main supply. This means that all lower level voltages are based on dedicated transformation of the high-level voltage to the specific voltage, be it 690 VAC, 600 VAC, 400 VAC, 230 VAC, 120 VAC, 24 VAC, etc. Any additional equipment that is introduced and needs supply from the turbine controller will therefore need to be evaluated to identify the appropriate power source at the given location, and whether the power source has capacity to support the added load.

Importantly, the power supply must be able to handle in-rush current when the equipment boots up, combined with in-rush current of other equipment fed by the same power source, without overloading the circuit. When employing systems that use an Uninterruptible Power Supply (UPS), vendors and potential hosts should factor in the scenario that UPS will demand added load when the turbine power returns to remedy a UPS at a low battery state. Not factoring in this scenario could lead to tripped circuit breakers that otherwise have enough capacity. All total, the power supply will have to deliver these additional power needs across the entire temperature range for the facility without exceeding the temperature limits of the transformer.

For evaluations or other temporary installations, existing outlets in the wind turbines can be used in lieu of hardwire installations, but could result in limited space on the circuit for technicians servicing the turbine. Additionally, tower and nacelle outlets are typically protected by some form of ground fault protection (e.g., GFI outlets). During lightning events, there may be an increased risk that such protection trips take installed equipment offline. So, while existing outlets may be an easy fix, they may require repeated visits to reset the protection relay if the installation is in an area with high lightning intensity. Depending on the length of the project, it may be more economical to explore other power supply sources that do not risk periodic tripping – particularly at times when no one is present to reset the relay (see Lightning Protection below).

Regardless of the installation type, vendors and operators should coordinate closely with onsite personnel to factor the new installation into troubleshooting power supply issues (e.g., tripped breakers due to excess load on a circuit).

c) Health and Safety

The installation or operation of a technology involving elements that can be loose, sharp, hot, cold, very loud, very bright, have moving parts, be electrically or statically charged, or contain hazardous materials raise obvious health and safety concerns for people working on the wind turbines. For systems that are active only periodically, the technicians working in the turbines may need explicit instruction for determining if there is any risk of such devices activating while they are in the vicinity. If there is a risk that cannot be mitigated in any way, then the appropriate warnings will need to be posted and the appropriate training will need to be provided to all staff potentially exposed to such a risk, in the languages required in the specific region.

If the installation or maintenance of such a technology requires the use of special chemicals, then Material Safety Data Sheets (MSDS) for the relevant compounds and correct handling of such materials will need to be documented, and appropriate training will need to be provided.

Even though it is not expected, the safety measures may need to take the form of a lock out / tag out procedure in the event there is no other way to ensure worker safety while at the wind turbine. The authority to specify what constitutes safe working conditions may fall under the Occupational Safety and Health Administration (OSHA), the Coast Guard, or some other jurisdiction depending on the specific location. The owner should be able to provide such details.

Choosing the right components for the location may indirectly impact safety. Cables that will be exposed to hot desert sun for months need to be selected for resistance to UV light, and should be oil-resistant if there is any risk of exposure to gear or hydraulic oils or brake fluid.

Turbine-mounted systems must be designed to withstand the swaying of the nacelle during high wind conditions, as well as mechanical vibration from the turbine, without failing in a way that introduces a hazard to site crews. Even equipment mounted inside the nacelle may be temporarily exposed to some precipitation during service or repair. International Protection (IP) code IEC 60529 ratings should align with other components mounted in or near that specific location.

Finally, technicians working with the technology need to be trained to work at heights and be familiar with first aid, evacuation, and other site induction procedures required of other contractors working on a wind project.

d) Lightning Protection

Lightning strikes on wind turbines are very common, and thus an integral part of the design is defining a path to ground for the lightning current. The magnitude of the lightning current varies significantly with each strike but also varies with the frequency of strikes over time. The International Electric Code for lightning and surge protection for wind turbines (IEC 61400-24) necessitates that third-party equipment be designed and installed in accordance with the standard. Other comparable standards that may be followed by manufacturers or operators include American National Standards Institute (ANSI), National Fire Protection Association (NFPA), and Underwriters' Laboratory (UL).

For illustrative purposes, a lightning strike that produces a current of 100kA down a blade, through the hub, the nacelle, down tower, and to ground creates a potential for induction of significant voltage on parallel cables or conductors throughout the current pathway. There is the potential to build up induced voltage between components resulting in arcing that can cause fires or other damage to the system. Electronic systems using low-frequency circuits should not be routed near circuits conducting high-frequency lightning currents.

Technology developers need to design their own equipment for protection, but equally important is addressing the potential for collateral damage to vulnerable wind turbine components, which can reduce the availability of the turbine or even cause serious damage to the controllers.

The location of third-party detection or deterrent equipment should be selected such that it is out of any direct strike zone if possible; if not possible, additional protection against direct strike will have to be considered during the installation. Additional steps may include reducing exposed cables outside the nacelle, installing surge suppression at the point of entry into the nacelle structure, or using appropriate signal isolation devices, among others.

When evaluating the suitability of a technology that may introduce risk of high frequency lightning currents, some regions offer subscription services listing lightning strikes. Such lightning data subscriptions may provide time stamps, location, magnitude and polarity etc. which can be used to assess and quantify the risk potential of lightning, informing engineering requirements or investment decisions.

e) Corrosion

In some onshore and most offshore environments, corrosion prevention is very important. Extensive efforts should be put into minimizing the risk of corrosion of the technology or ancillary equipment both in terms of the potential structural impact, and in terms of the potential staining of the surface treatment of the tower or nacelle from oxidization. Prevention and best practices combined with the use of fasteners made from materials appropriate for the conditions address the problem and almost eliminate the risk of corrosion on the tower and nacelle.

From the perspective of the technology manufacturer, it may also be important to consider the long-term impact of exposure to a corrosive salt environment offshore on the actual sensors and transducers.

f) Snow and Ice

In regions with below-freezing temperatures, any equipment mounted on the outside of the nacelle risks being covered in snow and ice. This may impact the ability of the technology to function as specified. Additionally, there is risk of the turbine blades shedding snow and ice buildup that hits the top of the nacelle. Even relatively small lumps of ice dropping from the blade tip down to the nacelle may exert significant force and potentially cause damage to external sensors and transducers if they are struck.

For procurement purposes, the cost and schedule of a technology could be impacted if the vendor has not considered snow and ice protections or has yet to refine their protections to be cost effective or timely to deliver (see Capital Cost below).

g) Onsite Access Requirements

Access requirements mostly come down to risk and cost. If the selected location is hard to reach, it will pose a bigger risk to install or maintain the technology for the lifetime of the project, and safely performing the work may require additional equipment and specially trained teams, both of which can add costs. For equipment with a very high Mean Time Between Failures (MTBF), there may be less concern about frequent visits during operation. Given that the long-term reliability of new equipment may be more uncertain, this will be a potential risk for the operator.

Technology relying on the use of cranes may need to consider the potential limitations of such solutions on very tall towers above 100 m (the tallest tower in the U.S. currently is about 130 m) as well as offshore applications where access is very limited and very costly.

Access may also be of a more operational nature. It does not help to deliver a solution that requires the removal of the gearbox in order to replace a small part, or where it is impossible to retrace a cable after installation. Similarly, if third-party equipment is placed in such a way that normal turbine service or operation cannot be performed without a high risk of damaging the technology or its associated wiring, then the operational cost will increase and MTBF will drop. For technology being evaluated, consideration should be given to providing research personnel access to the facility; depending on the study design, this could include access at times when the facility is not normally staffed, such as overnight.

h) Ongoing Requirements (post-evaluation)

The quality of the vendor's technical support and service is perhaps the most critical thing to understand when deciding on a technology. Supply chain assurances, offsite troubleshooting support, training for operations personnel, ease of preventative maintenance work, and onsite technical support are important elements to understand when developing a business case for technologies. While most vendors offer a service contract and warranty for their technologies, the practical considerations of remote access and a broadly dispersed customer base means much of the operations and maintenance (O&M) responsibilities for the technology system fall to onsite personnel to manage and execute. Considerations of accessibility, frequency of O&M activities, labor time to perform O&M responsibilities, and technical knowledge needed to perform O&M are important.

i) Landscape Management (e.g., search plots)

Field evaluation of technologies often involves fatality monitoring and the evaluation of treatment versus control turbines to determine whether a deterrent or smart curtailment strategy is effective in reducing fatalities. The value to informing an investment decision is minimizing uncertainty in the results as much as possible. The primary means of increasing confidence is to search as large an area as possible, and to keep this area as clean as possible to enhance the efficiency of the search team.

Different landscapes create different challenges for search plot and search intensity design. Test site selection should optimize for high confidence in fatality estimates and available funding. Moreover, evaluation sites should be as similar as possible to the site(s) intended for employing the technology, as the effectiveness of a technology cannot be assumed to be equal across widely differing sites. Potential hosts and vendors should compare landscapes of any previous evaluation studies. Both replication and evaluations in new landscapes may have meritorious rationales; operators and vendors can identify the added value proposition for each prospective site.

3. Asset Management Considerations

The core responsibility of asset management is tracking the revenue and cost flows for each wind energy facility. As such, asset managers are critical partners in deliberations about evaluating or employing a technology. The following are areas of expertise and knowledge asset managers can provide as key stakeholders, though some elements may be outside of their immediate area of responsibilities (e.g., procurement, contracts).

a) Technology Procurement

i. Evaluating Commercial Readiness

Many of the risk reduction technologies available for deployment remain in a stage of development short of commercial readiness. The procurement of a technology for evaluation comes with less certainty than what would normally be available for fully commercial systems, and buyers therefore should exercise a higher level of due diligence. Service contracts should be structured such that O&M services and expectations for vendor support during the period of performance are well defined.

ii. Capital Cost

The least complicated element of procurement is the capital cost of the system. Depending on the level of sophistication of the vendor's price structure, care should be taken not to overlook details that have cost implications. For example, a system designed to integrate to a copper line network could incur tens of thousands of dollars in additional capital costs if integrating to a wind facility with fiber optic networks. Additional equipment needed to protect critical elements of a technology system from hostile weather conditions such as ice and snow can add costs. Unanticipated system installation constraints can require novel approaches that deviate from the core design of the system, leading to added costs.

Buyers of the technology should identify such areas of potential added capital costs and negotiate with the vendor regarding a cost-effective remedy. Vendors responding to a unique need will likely have substantial costs as a result of deviating from their standard platform package.

iii. Durability and O&M Costs

A less tangible cost to ascertain is the anticipated O&M costs for a technology system. With newer technologies, long-term O&M costs may be uncertain. Buyers should structure any procurement agreement to include a detailed set of expectations in a service contract. Depending on the maturity of the technology, vendors will have varying degrees of insight with respect to how well the components of their system are likely to hold up in hostile environments.

More diligent vendors will develop and test their components' durability based on capital and labor costs to replace them; those less expensive and easy to replace will likely be less durable. To the extent possible, investment of a system should be predicated on an engineering evaluation of a vendor's manufacturing process and review of the technical analysis used to determine component durability and O&M costs. At a minimum, buyers should seek some engineering analysis or other evidence that a vendor has strategically thought this through before executing a contract. Conducting an in-person meeting and taking a tour of the manufacturing/assembly facility can be insightful.

iv. Useful Life

Projections of the useful life of a technology are part and parcel to an investment decision. Most technology vendors are in the early stages of manufacturing and operating systems in the field. Some degree of uncertainty about useful life is inevitable, and assumptions will need to be made. However, vendors that have practically applied their technologies should be able to provide prospective buyers with an estimated useful life for critical system components.

Technology evaluation studies should include a cost/benefit analysis during system use so that the performance and service of the system is evaluated in addition to biological objectives. A reasonable construct when procuring new or early stage technology is for the buyer to negotiate a discount in exchange for providing sweat equity and substantive feedback to the vendor to inform further improvements on their system. The value proposition for the vendor is the benefit of working in partnership with the customer, as opposed to providing a system that has inherent design and engineering flaws that create additional costs associated with standard service commitments.

v. Representations and Warranties

Given the overall immaturity of the market, there are substantially fewer options for wind facility operators who prefer a hands-off, full-service technology. Such buyers will need to evaluate the comprehensiveness of a vendor's claims and warranties, challenge vendors to elaborate where commitments are vague, and seek agreements that address how unexpected circumstances and troubleshooting will be handled. Examples such as the two that follow are not insurmountable but do require honest brokering between vendor and buyer to establish roles, responsibilities, and expectations up front before contracts are signed.

Example 1: Turbines

The difference between field conditions and those used to develop the technology may be a critical failure point for the system's in-use design, potentially leaving the responsibility of remedying the field condition on the buyer – likely a circumstance well beyond investment expectations. For instance, say that three replacement circuit boards are deemed enough to cover an unexpected failure in the field, and that is what is provided for in the purchase agreement. However, if that replacement benchmark is based solely on lab test results of the circuit board, it may not take into consideration less stable power supply from a turbine platform.

Such a circumstance leaves the buyer and seller at odds as to who pays for any additional circuit boards, or who is responsible for a more expensive transformer that sufficiently conditions the power supply to avoid excessive failures. If a limited number of replacements of a critical component are part of the warranty, vendors should provide the benchmarks upon which the limited number is based.

Example 2: SCADA

Some technology options are integrated to the SCADA system of the wind facility. Such integration may be one-directional, such as polling for SCADA data critical to inform the technology's operations. Other technologies are designed to send and/or receive performance or decision-making data. In either case, the integration effort requires close coordination across multiple operational disciplines to identify and evaluate areas of potential non-compatibility. Elements of the integration effort can inform agreeable commercial terms in a purchase contract.

The unique characteristics of an operator's facility or fleet can have a demonstrable effect on the ability to integrate a vendor's technology, and potentially limit the objectives of a technology evaluation. For example, if the objective of an evaluation is to compare different strategies in parallel with control (i.e., untreated) turbines, some SCADA configurations may limit the number of operational parameters that can be simultaneously changed. Experimental design options can be limited by the robustness of the SCADA. Similarly, some operations may be limited to operational changes only at the facility level, and not at the turbine level. Lastly, older SCADA platforms operating in the background and not actively relied upon by operations could be an additional source of limitation or needed upgrade. Considerations such as these are important to fully understand prior to engaging with technology vendors.

vi. Support Service Contracts

Specificity is the cornerstone to effective and comprehensive service contracts. Actual service requirements may exceed what vendors anticipate as the standard terms and conditions of a commercial-ready service agreement. Such unexpected O&M needs are likely to fall to onsite personnel to support. Unexpected demands on onsite personnel can discount interest in investment. Carefully negotiated service contracts reflect the uncertainties due to the developing state of technology rather than that of an off-the-shelf technology. This is not to suggest that investment in near-commercial ready technology does not have commercial or technical upside; potential hosts should be objective with due diligence but be creative with the business case, looking for the direct and indirect value propositions.

Both operators and vendors stand to gain mutual value beyond that of a traditional buyer-seller relationship. Absent real-life deployment of their innovations, vendors face significant hurdles to market entry. Operators evaluating a technology offer vendors numerous opportunities, including but not limited to: system refinement or design improvements in response to uniquely hostile environments; insights of their potential customer base (e.g., limits of customer-provided O&M services on the technology); and gaining insight to practical limits of networks, SCADA, human-machine interfaces, and security facilities and requirements.

As such, operators and vendors should seek more collaborative terms for service contracts than would be normally provided with off-the-shelf systems. Approaching procurement of a technology with a partnership mindset can often mediate issues arising from unrealized expectations for both parties. While undertaking an evaluation of a technology does create an additional layer of complexity, it offers incentivizing value of a shared interest and risk in the project.

Onsite Support

Technical manuals and training for the operational onsite personnel who will likely perform many O&M tasks should be part of any service contract. Accessibility to technical support is imperative and something to engage with a vendor about, particularly those headquartered in countries other than a U.S.-based host site.

Onsite support services need to recognize the inherent challenge and cost of their own technicians being on site. Remote accessibility and a robust troubleshooting platform are critical elements of a technology's design. Automated condition alerts are necessary given the 24/7, remote-controlled nature of wind energy facilities. Additionally, there are often regulatory implications for non-operational conditions that could go unnoticed if not for automated alerts or constant human monitoring. Vendors need to design systems that are easy to maintain, and that do not require overly frequent maintenance.

Remote Support

Additional support from a vendor is necessary for operators remote from the wind facility. This is particularly important for technology types that integrate into a SCADA platform to either issue automated or manual commands such as curtailing during high risk periods. The unique nature of remote operations makes it challenging for any technology vendor to effectively design for seamless integration. Therefore, service contracts should have clear lines of responsibility for technical support on software, network, and security matters. Some vendors may rely on third-party software or network systems. The relationship of these third parties providing technical service to customers, either through or separately from the vendor, should be defined in the service contract. Lastly, software upgrades initiated by either vendor or customer should be accounted for to avoid change order circumstances.

vii. Supply Chain

A stable supply of consumable and replacement parts is critical to the successful O&M of any system. Problems can arise when a vendor is dependent on a less-than-reliable supplier, or a supplier that has a unique component without which the vendor's technology is rendered non-operable or ineffective. While supplier information is typically closely guarded, the difference between a sale and no sale is often leverage enough to secure the due diligence necessary to verify the supply chain. Short of such insight, a contractual obligation on the vendor to assure a steady supply chain is reasonable backup. Additionally, a comprehensive list of consumables and replacement parts should be defined in the contract along with useful life estimates, unit cost, and order-to-delivery timeframes. A good negotiation tactic is to secure a modest supply of replacement parts as part of the initial order.

viii. Operational Costs

The operational costs of temporarily or permanently employing a technology come down to comparing cost implications against alternative means of addressing issues in need of solutions. In addition to equipment and service costs, other costs associated with employing the technology need to be identified. Some associated costs can be easily estimated, such as production impacts (in the case of a curtailment strategy), while others are longer term and less specific.

Production Impacts

Costs associated with lost production are relatively easy to model. Smart curtailment strategies can be employed with any desired cut-in speed and compared against normal operations using a modest amount of historical wind data to estimate the difference in production when modeling a curtailment strategy. The main assumption for smart curtailment evaluations is the frequency of bat presence on site during a given period. Post-construction fatality monitoring and any acoustic bat monitoring data can provide insights, though annual variability is not unusual. One caution to note is that assessments relying on pre-construction acoustic bat data may not be a good predictor of post-construction bat presence. For reasons not fully understood, bat activity risk trends differently between pre- and post-construction monitoring. Whatever the inputs of an evaluation used, a life-of-project projection offers the most robust assessment of production impacts.

Turbine Wear & Tear

Despite concerns about the wear and tear on turbines with higher-than-designed stop/start cycles, wildlife curtailments have yet to result in any material impacts to turbines, and to date there is no indication of any OEM identifying a substantive issue. One notable caution is with smart curtailment strategies employing cut-in speeds close to a facility's average seasonal wind speed. Such circumstances may create an overabundance of stop/start cycles that confound the operations of the facility, irrespective of wear and tear. Operators that have experienced such circumstances have changed the cut-in speed to stop/start cycle frequency. Where such complications are not at play, the current state of research is focused on 5.0 m/s cut-in speed. While consistency across evaluations is useful, this is not to suggest discounted value in experimenting with other cut-in speeds.

Projected Return on Investment (ROI)

Where more aggressive avoidance or minimization measures are actively employed (e.g., seasonal curtailment at 6.9 m/s), a reliable comparison of a smart curtailment strategy's capital, operational, and production costs can be made against baseline conditions. The estimated difference in cost becomes, in effect, the ROI proposition. Less straightforward is deriving an ROI for employing a risk minimization strategy where no risk minimization measure is actively in use. However, several factors can inform decision makers lacking such objectively comparable data.

At the industry scale, there is little downside to reducing wildlife impacts from wind energy, cost implications aside. For example, the data strongly suggests that wildlife impact reductions in excess of 50% can be realized with relatively modest investments. Furthermore, with increasing demand for effective strategies, the market will mature. As a result, the price point of their use will decline, uncertainty about long-term reliability will diminish, and increasing the availability of strategy options will simplify site suitability assessments.

ix. Data Ownership & Accessibility

Many technologies will collect or archive data that may have value for post-hoc analyses. Additionally, some data may have regulatory or legal implications for the host site. Vendors also value this data as a means of evaluating performance, enhancing future customer service, and for the intrinsic value of having large volumes of data in hand. As legal arguments can be made about data ownership, it is prudent to negotiate clear data ownership and accessibility terms with the vendor/researcher.

Asserting ownership as the host site is best leveraged prior to contract signing. The nature of some data types might prove useful for unrelated inquires (e.g., facility-scale radar data could be useful to understand how bird migration patterns are affected by weather fronts). Accessibility and utility of data for some operators may be enough. For datasets only accessible and useable from the vendor's proprietary platform, operators can leverage value such as contractual service agreements that include operator-interest queries run by the vendor. Regardless of such arrangements, ownership and right of data use should be retained by the host site, and vendors' rights to use said data should be strongly constrained by the owner to protect interests and confidentiality.

b) Generation & IT Control Considerations

i. Remote Access Requirements

The need for remote connection and the specific bandwidth requirements for such a connection can be either a technical or financial hurdle to overcome, and at times it may be both. If a project is in a location so remote that only satellite connections with very limited bandwidth are available, installing technologies that require real time control or processing significant amounts of data will need to be considered carefully, not only in terms of the data throughput, but also in terms of resilience towards communication latency and jitter.

If bandwidth is limited and there are time-critical control commands on the same communication paths, regardless of the type of communication infrastructure, the communication design needs to accommodate some level of network segmentation to ensure that critical command signals are prioritized such that the plant controls can be executed in a timely manner and that more informative or historical type data can be transferred with a lower priority.

Remote connections and data security are closely tied together; see the following section on North American Reliability Corporation's (NERC) critical infrastructure protection (CIP) requirements for additional details regarding data security.

ii. NERC CIP Requirements

The introduction of a computer-based technology will most likely have some level of impact on the cyber risk profile for the project. Engaging security, network, and IT departments to fully understand the finer details of the specific design and how it ties in the existing plant infrastructure can reduce this risk. There is no simple best solution, and increased integration may elevate the risk but also potentially produce bigger operational returns, so this part of the evaluation requires looking at both technical and business factors:

- The plant level inventory of critical devices may need to be revised to reflect the elements of the technology system that are impacting the risk profile.
- The goals and expectations around cyber security may need to be spelled out and documented so that there are no misunderstandings between the stakeholders as to who is responsible for what, and what the operator's IT security rules are for the specific project.
- Operators should set up training for visiting technicians working on the technology systems so that when they visit the site, they will be properly informed about any data security procedures in place on the project.

NERC now requires operators to hold their 3rd party counterparties compliant with the CIP standards. This being the case, operators need to consider the following questions:

- Does the device qualify as a Bulk Electric System (BES) cyber asset, i.e., is the device being used to sustain reliability of the grid, and if rendered unavailable for 15 min or more, would it affect reliability of the BES?
- If it is, is the device being protected properly with physical security controls and electronic access controls? I.e., is it locked up, fenced, etc., and is there a firewall or something preventing a hacker from accessing any data?

- Is the device considered to be a transient cyber asset, i.e., is not a BES cyber asset but it connects into another BES cyber asset and could possibly introduce executable code? An example of this would be a laptop owned by a technician that remotely connects into the turbine vendor's server. The turbine vendor server is a BES cyber asset since it can remotely control the wind facility. If maintenance is needed, the technician would remotely connect to the turbine software via the laptop. NERC has recently mandated rules around transient cyber assets in order to protect BES cyber assets. Protection includes installing the correct patches and antivirus software, whitelisting, etc.
- Does the device use removeable media (USB connection) in order to plug into a BES cyber asset (such as a turbine)? NERC is discouraging the use of all types of removeable media from being used. It's mostly up to the NERC registered entity to determine what policies they will allow regarding this type of media.

Vendors should be prepared to have contracts amended to incorporate CIP language and encourage compliance on both sides. In summary, while the wildlife risk reduction technology wouldn't be considered to be a BES cyber asset, depending upon how the system is set up, it could be considered to be a transient cyber asset since it likely connects into turbine software in order to issue curtailment commands. Such systems that could abruptly result in turbine shutdown can affect forecasting and scheduling of the power on the grid. Depending upon the region of the wind facility, there could be penalties for not delivering the committed capacity as promised. These are often minor and probably considered acceptable in order to protect wildlife/endangered species, but should be vetted as part of the due diligence effort.

iii. Long-term Data Archiving and Data Access

For technologies that generate large amounts of data, the owner-operator will need to decide if the data should reside permanently in the technology vendor's system, or if the data will need to be transferred to the owner's server or archival system for long term storage and security backup.

iv. Continuous Plant Optimization/Continuous Plant Operation Stability Monitoring

From a control perspective it is desirable to ensure that the plant and individual turbines are operated in a stable manner. Any additional control algorithm applied to the turbine or plant control can inadvertently reduce the stability of the operation. For example if a "wildlife stop" command is issued to the turbine repeatedly at very short intervals, the operation may not be considered stable given that it takes some time to bring the rotor to a slow idle, and under low wind conditions can take several minutes to restore production. Operators can analyze the duration and distribution of stops, duration of starts, or other metrics that can demonstrate operational stability and can have a deliberate strategy to monitor for loss of stability, reducing the risk of long-term operation with unstable control settings as the conditions around the wind power plant may change with the seasons.

Appendix A: Responsible Entities for Areas of Consideration

		Turbine manufacturer						Operator (or Contract Support Services)												Vendor / Researcher		Land Owner		Regulatory Agency*		
Project teams can be defined different ways by different organizations; departments included here may vary significantly company to company, grouping and naming is only indicative.		Structural Engineer	Electrical Engineer	Service Engineer	IT Department	Commercial/Warranty	Legal	O&M Services	Health & Safety	Procurement	Engineering	Network/IT/Security	Onsite O&M	Construction	Meteorology/SCADA	Asset Manager	Permitting & Environ.	Risk/Insurance	Legal/Regulatory	Commercial	Technical	Private	Public	Local	State	Federal
Section I: Biological Considerations																										
1.a	Historical Data															x	x		x							
1.b	Additional Data Collection											x	x		x	x	x		x	x	x	x	x	x	X	x
2.a	Conflicting Requirements												x		x		x		x				x	x	X	x
2.b	Efficiencies of Combining Research Efforts															x	x		x	x	x			x	X	x
3.a	Permitting Constraints															x	x		x		x		x	x	X	x
3.b	Regulatory Requirements																x		x	x			x	x	X	x
4	Environmental Attributes												x				x				x	x	x	x	X	
5	Indirect or Unanticipated Impacts												x			x	x		x		x	x	x	x	X	
6	Study Design										x	x	x	x	x	x	x		x	x	x			x	X	x
7	Research Objectives					x		x			x	x	x	x	x	x	x		x	x	x	x			X	x

		Turbine manufacturer						Operator (or Contract Support Services)												Vendor / Researcher		Land Owner		Regulatory Agency*		
Project teams can be defined different ways by different organizations; departments included here may vary significantly company to company, grouping and naming is only indicative.		Structural Engineer	Electrical Engineer	Service Engineer	IT Department	Commercial/Warranty	Legal	O&M Services	Health & Safety	Procurement	Engineering	Network/IT/Security	Onsite O&M	Construction	Meteorology/SCADA	Asset Manager	Permitting & Environ.	Risk/Insurance	Legal/Regulatory	Commercial	Technical	Private	Public	Local	State	Federal
Section II: Operational Considerations																										
1	Site Suitability			x		x					x	x	x	x	x	x	x	x	x		x					
2	Installation and Integration Support	x	x	x	x	x		x			x	x	x	x	x	x		x	x	x	x					
2.a	Mounting Requirements	x		x		x		x			x		x	x		x		x		x	x					
2.b	Power Requirements		x	x		x					x		x								x					
2.c	Health and Safety	x	x	x					x							x		x	x	x	x					
2.d	Lightning Protection	x	x	x		x			x		x		x					x		x	x					
2.e	Corrosion	x		x		x				x	x					x				x	x					
2.f	Snow and Ice	x		x	x	x			x		x		x			x					x					
2.g	Onsite Access Requirements			x					x				x			x			x	x	x					
2.h	Ongoing Requirements (post-evaluation)			x				x		x		x	x		x	x	x		x	x	x					
2.i	Landscape Management (e.g., search plots)									x			x			x		x		x	x	x	x	x	x	
3.a	Technology Procurement									x	x	x	x	x		x				x	x					
3.a.i	Evaluating Commercial Readiness									x						x	x		x		x					

		Turbine manufacturer						**Operator (or Contract Support Services)**												**Vendor / Researcher**		**Land Owner**		**Regulatory Agency***		
Project teams can be defined different ways by different organizations; departments included here may vary significantly company to company, grouping and naming is only indicative.		Structural Engineer	Electrical Engineer	Service Engineer	IT Department	Commercial/Warranty	Legal	O&M Services	Health & Safety	Procurement	Engineering	Network/IT/Security	Onsite O&M	Construction	Meteorology/SCADA	Asset Manager	Permitting & Environ.	Risk/Insurance	Legal/Regulatory	Commercial	Technical	Private	Public	Local	State	Federal
3.a.ii	Capital Cost									x	x	x				x				x						
3.a.iii	Durability and O&M Costs	x	x				x			x	x	x	x		x	x			x	x	x					
3.a.iv	Useful Life									x	x					x					x					
3.a.v	Representations & Warranties									x	x	x	x			x				x						
a.vi	Support Service Contracts							x		x	x	x	x	x	x	x	x	x	x	x	x					
3.a.vii	Supply Chain									x	x	x				x				x	x					
3.a.viii	Operational Costs			x				x			x	x	x		x	x	x		x							
3.a.ix	Data Ownership & Accessibility			x								x			x	x	x		x	x	x					
3.b	Generation & IT Control Considerations			x	x	x						x			x	x				x	x					
3.b.i	Remote Access Requirements			x	x	x						x			x	x					x					
3.b.ii	NERC CIP Requirements			x	x							x			x	x			x		x					x
3.b.iii	Long-term Data Archiving and Data Access			x	x							x			x	x	x		x		x					
3.b.iv	Continuous Plant Optimization/ Monitoring			x		x						x			x	x					x					

Appendix B: Due Diligence Cycle

		Step 1: Vendor/Researcher Checklist	Step 2: Initial Host Evaluation
		Vendors/researchers anticipating areas or topics of prospective host site concern prepare specifications or questions to the host site, compiled and transmitted to support host site's initial evaluation.	The start of due diligence, tracking each identified area or topic of concern, and transmitting to vendor as supplementary request for information to the standard questionnaire.
Section I: Biological Considerations			
1.a	Historical Data	Researchers should assemble a list of pre- or post-construction data useful to evaluate the suitability of a site. Activity or fatality rates needed to derive statistically significant results, if known, should be included as criteria needed or desired.	Compiling historical due diligence reports and data to determine suitability as a host site. In addition to suitability, some evaluations may benefit from reliable data on activity or fatality rates.
1.b	Additional Data Collection	Researchers should assemble a list of data collection criteria necessary for purposes of the proposed project. Vendors with evaluation study ideas should likewise work to define necessary criteria.	Evaluation criteria should be included in a cost estimate to complete the study. All necessary parameters (fatality monitoring, plot maintenance, and handling of carcasses) should be addressed as a subtotal cost to complete. Agreements with stakeholders (landowners, regulatory agency) should be considered long-lead items.
2.b	Combining Research Efforts	Researchers should develop study design criteria that compliment standard environmental due diligence. Accomplishing an evaluation study by leveraging a host site's sunk costs for due diligence adds considerable value to the proposal.	Prospective host sites with standardized due diligence work planned offer considerable leveraging of associated costs. Plot clearing, crop damage compensation, and post-construction monitoring costs are significant areas of potential savings when combined with the proposed research effort.
3.a&b	Permitting and Regulatory Constraints	Researchers and vendors should consult with prospective hosts to determine regulatory constraints and opportunities. Study designs tailored to incorporate or avoid triggering formal regulatory processes save time and cost.	Research projects should be evaluated as potential constraints and opportunities with respect to permitting or regulatory requirements. Identified constraints should be divided between firm and flexible requirements and informed by informal consultation with relevant agencies.
4	Environmental Attributes	Vendors should provide a detailed set of site suitability criteria or otherwise list technology limits of deployment. Researchers should assemble a set of criteria necessary to effectively carry out study objectives. Factors include but are not limited to complex terrain, tree canopy, plot sizes, weather conditions, and searchability of site.	Comparing vendor/researcher landscape criteria or limitations against prospective sites, noting sites as less or more compatible with the study objectives or technology capabilities. Onsite visits or detailed site characteristics shared with vendor/researcher to further determine suitability. Identify underlying land uses and vet the project with landowners. Account for land-related costs, if applicable.
5	Indirect/ Unanticipated Impacts	Technology vendors with audible/visual impacts should provide assessments of spatial extent of potential nuisance complaints or unintentional wildlife impacts, particularly audible technologies, though visual changes to the landscape can be a sensitivity for some host sites.	For technologies that present possible impacts to neighbors or non-targeted wildlife, secure from vendor/researcher what the nature of the technology's broadcast is as well as any novel testing procedures that could cause complications (e.g., use of drones). Suitable sites may have landowners/neighbors with whom to socialize the project if noticeable changes to the environment and activities on the site are likely.

		Step 1: Vendor/Researcher Checklist	Step 2: Initial Host Evaluation
6	Study Design	Researchers to provide details of a proposed study design including study objectives, targeted level of statistical certainty, and a cost to complete estimate with assumptions. As due diligence is undertaken, refine the study design and include as the technical element of the project proposal.	General details of a proposed study design to be compared with opportunities and constraints for each prospective host site. Collaboratively develop study design with the vendor/researcher to customize design for each prospective site. Include non-biological elements of the study design such as projected production losses, contract delivery impacts, and onsite personnel requirements (Section II).
6	Research Considerations	Vendors/researchers seeking the use of novel methods to evaluate a technology should describe the activity and tools used in detail. Use of novel equipment or methods (e.g., dog searchers) can have unusual consequences and costs, potentially prohibited from use at a facility, or create insurance coverage in excess of budget.	Identify direct and indirect impacts resulting from use of novel research methods or tools and vet these with project team (operations, legal, risk, asset management, etc.). Vet novel methods with related experts to ascertain the usefulness of the technique, relative to conventional approaches. Cost implications should take into account benefits such as increased searcher efficiency using dogs, balanced with the level of accuracy or precision needed.
Section II: Operational Considerations			
1	Site Suitability	Vendors/researchers provide detail installation, integration, and operational parameters needed for the intended function of the technology. Older wind sites may lack modern facilities such as communication, power, network, and SCADA functions, limiting their utility.	Newer sites may have warranty hurdles or require technical support from OEM. Older or acquired wind sites may lack details of the installed facilities that complicate suitability determination. Prospective host sites should consider the age of facilities and whether technical specifications from vendor are compatible with known infrastructure (e.g., network capacity, programmable turbine control, remote accessibility, existing service contracts). Assemble costs associated with upgrades, technical support services, and equipment.
2.a	Mechanical Mounting	Vendors to provide technical specifications and instructions for installing technology, and note any uncertainties with respect to proper mounting procedures. Novel technology vendors with limited exposure to wind turbine technology or operations are encouraged to engage resources to consider installation, integration, and operational elements of interest to customers.	Technical support staff should review technology specifications and instructions, providing feedback to vendors in order to refine installation plans. OEM engagement may be necessary depending on warranty status or complication of proposed installation. Of principal interest is to estimate cost to install and negotiate with vendor how this cost is covered.
2.b	Power Requirements	Vendors should include in technical specifications detailed information on power supply requirements, vulnerability to unstable power or power surges, and implications of intermittent power loss. Capabilities for remote system reset are ideal if not a necessity.	Evaluation of power requirements and any expressed concerns from the vendor about power conditioning vetted with electrical engineering and/or turbine support experts. Power supply at turbines may be limited to 110 or 220 VAC such that intermediate equipment is needed. A summary of the evaluation should be prepared.
2.c	Health and Safety	Vendors/researchers assume a level of risk by working on a wind energy facility. Include with a project proposal a clear understanding of related health & safety topics, evidence certifications of applicable	Health and safety requirements should be vetted once the installation, integration, and operational nature of the technology is conveyed by vendor. Consult with internal H&S, risk, and legal support staff and

		Step 1: Vendor/Researcher Checklist	Step 2: Initial Host Evaluation
		training, and outline plans to be revised to comply with host requirements.	vendor H&S plans to be updated/revised to incorporate site specific requirements.
2.d	Lightning Protection	Vendors with up-tower installations should design the technology by accounting for potential of lightning strikes or related power surges. Energized technologies susceptible to lightning need to evidence the design capabilities to isolate the turbine from lightning potential unique to the technology.	Electrical engineering services should evaluate vendor technical specifications, verifying the management of lightning potential as well as means of isolating the turbine from lightning potential unique to the technology. Some installations may impact warranty or turbine service contracts.
2.e&f	Corrosion, Snow, and Ice	Vendor should use materials with high durability to corrosive, wet, and extreme weather environments. Onshore and offshore host sites present extreme meteorological conditions where corrosion conditions can be exacerbated. Technical specifications should include the manner in which installation and technology materials are designed to withstand such environments.	Technical specifications to be reviewed by onsite and other technical support staff, identifying areas of potential vulnerability and detailing mounting hardware suitable to mounting surface material and host site environment. Contingencies for uncertainties or never before field evaluated technologies should be identified and agreed upon with the vendor.
2.g	On Site Access Requirements	Vendor/researcher should identify the site access needs of the technology's use and evaluation. Site suitability will be limited by ease of access, ability to use installation equipment (service lift) or techniques (rappelling) to install or maintain technology, or ease of maintenance.	Remote accessibility, impassible weather seasons, skeleton onsite staff, and installation or operational requirements for the technology to be factors for identifying prospective host sites. Vendor specifications should be reviewed by technical and onsite support staff and limits or impediments identified. Costs for workarounds and contingencies included in the due diligence effort.
2.h	Ongoing Requirements	Vendors should develop service agreement terms that detail warranties, technical service capabilities and procedures, supply chain assurances and limits, training, preventative maintenance procedures, spare parts, and onsite and technical support needs from the host site.	Procurement support to evaluate service contract terms and conditions, negotiate terms specific to the hosting of evaluation study or employment of a technology. Onsite support expectations defined and coordinated with vendor, onsite and technical support, and contracts/procurement teams.
2.i	Landscape Management	Researchers to define plot sizes and maintenance criteria. Plot sizes should optimize for cost and scaled to meet the evaluation study targets defined for accuracy and precision.	Initially defined plot sizes and maintenance criteria negotiated with landowners, if necessary. Costs should be derived for recurring mowing and crop damage payments if applicable. Identify landowners not willing to participate or otherwise non-applicable. Revise study design to accommodate land or cost constraints for each prospective host site.
Section II.a: Asset Management			
3.a.i	Commercial Readiness	Describe the state of the technology's development, summarizing internal and 3rd party evaluation research to date (include citations where applicable), highlight areas of ongoing R&D or technical uncertainties, and describe objectives of reaching agreement with the prospective host site	Determine the readiness of the technology and identify areas that are either deficient or not yet addressed by the vendor. Compile a punch list of such items, working with vendor and technical support to derive understanding of resulting gaps or risks, particularly those impacting

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			cost, technical support needs, operational constraints, legal/regulatory issues, and labor.
3.a.ii	Capital Cost	Commercial-ready technologies have a quotable price. For earlier stage technologies, provide cost projection and assumptions, cost information from redacted business/investment plans, or pricing objectives with uncertainties disclosed.	Capital costs and assumptions defined for each prospective host site, with term sheet summarizing a general agreement for each site under consideration. Location, turbine platform, SCADA, and other system differences among sites can impact capital cost of equipment (e.g., premium for ice protection).
3.a.iii	Durability and O&M Costs	Vendors provide prospective customers with a detailed service contract that anticipates preventative maintenance, consumable and spare parts, and any engineering and materials testing that support warranties and O&M costs. Early stage R&D technologies should disclose unknown or uncertain elements of a system's durability.	Engineering evaluations of a technology's durability should be conducted and compared against vendor representations & warranties. Depending on the technology's commercial readiness and vendor assurances, additional technical information, negotiated procurement terms, or cost share arrangements with the vendor may be warranted.
3.a.iv	Useful Life of Technology	Vendors provide technical evaluations, rationale, and assumptions for estimating useful life of the technology. Consumable and short-lived components should likewise be summarized. Uncertainties and unknowns should be disclosed along with any related workarounds or contingencies.	The early commercial stage of most technologies means useful life projections will likely be based exclusively on qualified or quantified assumptions. Individual components with known useful life can be an indicator of overall system life expectancy. System software should be based on well-supported platforms or coded for ease of upgrades or modifications. The environment of prospective host sites should be factored into useful life projections.
3.a.v	Representations & Warranties	Describe the nature of warranties offered and list representations relied upon for establishing host site expectations. In absence of formal warranties, vendors should provide feasible assurances to account for uncertainties.	Procurement or contracts work with vendor to negotiate unique representations and warranties to account for circumstances of temporary or permanent installation. Summarize points of risk exposure and define contingencies as applicable.
3.a.vi	Support Service Contracts	Vendors should detail services to be provided during the evaluation study or contract term, defining remote and onsite support services to be provided. Establishing expectations of host site service support (technical or onsite services) and development of standard operating procedures should be provided.	Operations and technical support services should evaluate contract terms and conditions, providing criteria, questions, or concerns to negotiate with the vendor and/or service provider. Personnel and other technical service constraints for perspective host sites factored into suitability assessments. Consider accessibility, projected frequency, and labor associated with technology O&M.
3.a.vii	Supply Chain	Identify system components and materials, noting those that lack manufacturing certainty or otherwise not used at commercial scale	Procurement or Contracts identifies areas of concern related to materials or component availability, negotiate with vendor for spare parts inventory and associated costs. Different sites may necessitate different components or configurations (e.g., severe weather extremes).
3.a.viii	Operational Costs	Vendor/researchers should detail expectations of host site support for technology evaluation, line item summary of contemplated tasks, nature and level of anticipated effort, workaround and contingencies	Compare vendor/researcher needs with prospective host site and identify technical support services needed to support the evaluation study. Coordinate with vendor/researcher to respond to operational

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		when onsite or technical support is unavailable, and costs associated with training host site personnel.	questions and concerns about the project for prospective host sites. Include findings in site suitability analyses and cost/benefit analysis.
3.a.viii	Production Impacts	Vendors/researchers detail elements of the study design that potentially impact host site production. For smart curtailment strategies, vendors/researchers detail parameters to be factored in and the rationale and assumptions for estimated production losses.	Generation/meteorology projections of production impacts of each prospective host site. For curtailment, ideally analyzing a spectrum of cut-in speed regimes, and technology installation, integration, and O&M. Look at availability of species fatality and/or activity data, ideally for each prospect but data from proximate sites can be an indicator.
3.a.viii	Turbine Wear and Tear	Vendors and researchers provide technical feedback to prospective host site questions but largely nothing to prepare on turbine wear and tear.	Engage with turbine OEM concerning questions of wear and tear. Operations to identify unique issues for each prospective host site. Account for any related wear and tear costs in site suitability analysis and secure confirmations of technical considerations when applicable.
3.a.viii	Return on Investment (ROI)	Vendors and researchers provide commercial and technical feedback to prospective host site questions but largely nothing to prepare on ROI.	Assemble qualitative and quantitative cost and benefit data for each prospective host site, identify opportunity costs as well as risk reduction outcomes, near- versus long-term cost projections for identified scenarios to compare with the proposed project.
3.a.ix	Data Ownership & Accessibility	Vendors/researchers should detail intended datasets to collect or acquire and describe how they are applied to the study design. Prepare a set of terms to negotiate for drafting of data use/sharing/ownership agreements. Vendors offering data processing, security, and analysis services add value.	Vet proposed terms for data use/sharing/ownership with legal, contractual, procurement, and operations support. Determine any interconnection service needed by prospective host sites, and identify if any external services are needed for data management.
3.b.i	Remote Access Requirements	Vendors/researchers summarize network and communication needs for the project, detailing bandwidth, connection speeds, and rate of network use. Queries of SCADA and other sources of host site data need to be described, recognizing real-time versus post-hoc data uses present different coordination and connectivity issues.	Working with network, SCADA, and IT support services to evaluate the dataset and connectivity needs of the project, evaluating these needs for each prospective host site. Identify security requirements for providing network capacities and sharing of host site derived data. Assemble upgrade and implementation costs (labor and dollars) for each prospective host site.
3.b.ii	NERC CIP	Vendors/researchers are encouraged to design technologies and processes to address NERC CIP requirements on energy generation facilities. Identified host sites' limits of data accessibility or network use may necessitate changes to the technology's planned use. As such, building in flexibility and ad-hoc innovation in design and use of a technology is encouraged.	Security or network evaluations of prospective host site data and network facilities should be conducted early in the site suitability assessment. Older facilities may have different constraints than newer facilities. Remote locations may necessitate some cellular network use, which may be in conflict with some NERC requirements. Real-time and post-hoc data availability present different issues; adjusting expectations of vendors supports the development of their technology to be commercially viable.

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3.b.iil	Long-term Data Archiving & Data Access	Long-term data storage/archive should be a robust component of a technology system, where volumes of data are generated. If post-hoc analytical or reference use of data is anticipated or desired by host sites, vendors/researchers are encouraged to develop systems to facilitate. Onsite versus cloud storage systems present different challenges such that different host sites may express different preferences. Flexibility, optionality, and customization of data storage is therefore encouraged.	Close coordination with network, IT, and security to fully evaluate the data storage needs of a technology. Remote and onsite storage presenting different challenges means prospective host sites may have different limits or capabilities. Removable media may trigger NERC CIP requirements. Accessibility and utility needs of stored data should be determined early on as additional network and security issues could arise. In extreme circumstances, additional network infrastructure may be needed.
3.b.iv	Continuous Plant Optimization	Vendors and researchers provide technical feedback to prospective host site questions but largely nothing to prepare on plant optimization.	Engage with generation and turbine OEM concerning plant optimization requirements. Operations to identify unique issues for each prospective host site. Account for any related optimization costs in site suitability analysis and secure confirmations of technical considerations when applicable. Study designs should consider optimization constraints.