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Maine Audubon

Renewable Energy and Wildlife in Maine

Avoiding, Minimizing, and Mitigating Impacts to Wildlife and Habitat from Solar, Wind, and Transmission Facilities

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Additional Resources

An interactive map which allows you to explore the results of Maine Audubon's analysis of the intersection of wildlife resources and wind resources in Maine can be found at *maineaudubon.org/energy*

Companion reports by the Appalachian Mountain Club use the same new wind data to evaluate the visual impacts of wind power projects on high-value scenic resources across Maine and to analyze the overlap between wind resources and areas of high climate change resilience. These reports will be available late 2019.

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Renewable Energy and Wildlife in Maine

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Introduction

Today, Maine's wildlife and habitat urgently need Maine people to take action. Climate change, driven by fossil fuel pollution, is the biggest and most pervasive threat to Maine's wildlife resources, and there is actually something we can do about it. As Governor Mills said to the United Nations General Assembly at the Climate Summit on September 23, 2019, "Our whole state is experiencing climate change—our weather, our iconic lobster industry, our insect populations; the warming, rising fish-rich seas that bathe our shores."

Nearly one-third of carbon dioxide emissions in the U.S. are a result of electricity generation.[1] Eliminating carbon dioxide emissions from electricity generation has a straightforward solution: Replace fossil fuels used to generate electricity with cleaner, renewable energy sources such as wind and solar. Replacing fossil fuels with clean energy production also reduces other pollutants including methane, mercury, particulates, and sulfur that lead to acid rain and health issues; an equally profound benefit to our environmental and public health.

There is untapped potential for wind and solar energy across Maine and a growing recognition, demonstrated through public opinion and recent policy initiatives, that in order to stem the tide of climate change we must quickly and exponentially increase our renewable energy production and reliance. Regionally, Maine is also positioned between substantial potential renewable energy sources in Quebec and the Maritime Canadian Provinces and greater New England's energy demands. This location increases the likelihood of new and expanded transmission capacity through the state. Maine has the potential to play a pivotal regional role in the renewable energy revolution currently underway.

But like all development, including all energy production, renewable energy projects impart their own ecological footprints on the earth and can have negative impacts on environmental resources, as well as cumulative negative impacts across ecologically significant landscapes. New wind, solar, and transmission line projects can result in the loss and conversion of high value wildlife habitat including wetlands, vernal pools, bird habitat (waterfowl, wading, and shore birds), and intact forests. Additionally, once established, the operation of some

[1] *https://www.eia.gov/tools/faqs/faq.php?id=77&t=11.* The other two-thirds of carbon dioxide emissions come from transportation and heating.

energy facilities poses a potential mortality threat to some resident and migratory wildlife. With the opportunity to protect wildlife against the deleterious effects of climate change and other pollution comes risks to habitats and ecosystems that need to be managed carefully, but for which current regulatory tools provide limited ability.

This report, developed from a review of the current literature, describes the potential impacts of a specific portion of new energy infrastructure—onshore and offshore wind, solar energy, and transmission projects—on wildlife and wildlife habitat. It also outlines policy considerations, based on a review of the current literature, conversations with experts in the field, and policy in neighboring states, that Maine Audubon recommends Maine regulators, developers, and policy makers adopt in order to avoid, minimize, and mitigate impacts from renewable energy to wildlife and habitat. We chose to focus exclusively on onshore and offshore wind, solar, and transmission lines because we anticipate this is where there will be the most new growth in energy infrastructure in Maine, based on a suite of new laws (described below), increasing public support for renewable energy technologies, and Maine's proximity to renewable energy sources in Canada and off our coast.

This report is accompanied by additional resources including: an annotated bibliography detailing the principle literature reviewed for this report, an outline of the renewable energy policies and best practices utilized in other states to reduce impacts to wildlife and habitats, and the results of a Geographic Information System (GIS) analysis of the overlap of wind and wildlife resources in Maine. This GIS analysis details the results of a spatial analysis of the potential intersection between valuable wildlife resources and areas of commercially viable wind resources, and it updates the report titled "Wind Power and Wildlife in Maine: A Statewide Geographic Analysis of High-Value Wildlife Resources and Wind Power Classes" published by Maine Audubon in 2013.

In writing this report, we operate on a central thesis: We can—and should—promote well-sited and well-managed renewable energy projects, avoid the most detrimental impacts to wildlife, and protect high-value wildlife habitat at the same time. Our goal is to improve the planning, siting, operations, and maintenance of future renewable energy projects so that their considerable climate benefits are not diminished or negated by unnecessary harm to wildlife and habitats. If done right, significant impacts to Maine's natural resources can be avoided or minimized, and where impacts are unavoidable, they should be compensated. We are confident, based on our research, that this balance can be struck to the benefit of all Maine people and wildlife.

Wildlife and Habitat: Increasingly Vulnerable to Climate Change

According to a study co-authored by Maine Audubon and published by Manomet in 2013,[2] roughly a third of Maine's native plant and animal species are increasingly vulnerable to the effects of climate change. More recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services issued a staggering report[3] concluding that approximately 1 million animal and plant species are threatened with extinction, more than ever before in human history. The report found that climate change is a leading driver in this unprecedented change in nature, with the impacts from climate change expected to increase over the coming decades.

From Maine's iconic species such as moose and brook trout, to our boreal forests and coastal beaches, climate change threatens Maine's very identity. Ocean acidification and warming threatens our lobster industry, and shifts in natural communities and forest pests threaten our forest products industry.

In order for Maine to stay Maine, it is clear that we must reduce carbon pollution, the leading catalyst of climate change. Transitioning to clean, renewable energy sources will play a big part in stemming the impacts of climate change to Maine's wildlife and habitat, while benefiting Maine's economy and quality of place.

Wind and Solar Energy: A Viable Solution

Across the United States, nearly a third of carbon dioxide emissions are a result of electricity generation, with the other two-thirds coming largely from transportation and heating.[4] Efforts are underway to shift transportation and heating energy sources to electricity, meaning that electricity usage across sectors may grow as conversion to cleaner forms of transportation and space heating create more demand for electricity. Eliminating carbon dioxide emissions from electricity generation can be accomplished by replacing fossil fuels with renewable energy sources such as wind and solar. Once installed, wind and solar energy do not produce air pollution and can be harnessed by individuals and at community and commercial scales across Maine.

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[2] "Climate Change and Biodiversity in Maine: A Summary of Vulnerability of Habitats and Priority Species" *https://www.manomet.org/wp-content/uploads/old-files/BwHSummary_021914.pdf*

[3] *https://www.ipbes.net/news/Media-Release-Global-Assessment.*

[4] *https://www.eia.gov/tools/faqs/faq.php?id=77&t=11*

A recent economic analysis suggests that in North America, the average cost in dollars per megawatt hour for energy from wind and solar may now be lower than from coal and even natural gas.[5] With the price of solar energy infrastructure dropping, as it has dramatically since 2011, and new technologies in wind infrastructure allowing for efficient wind energy capture at more locations,[6] costs for wind and solar energy projects are expected to continue to drop.

Maine is already on the leading edge of wind power production in New England, with substantial potential for more onshore and offshore wind energy generation due to the abundance of viable wind sources, made increasingly more abundant through advances in wind infrastructure technology.[7] And while many may not think of Maine as an ideal location for solar energy, Maine receives more solar energy than Germany, the current world leader in solar adoption and production. In fact, Maine's lower temperatures increase the efficiency of solar panels compared to "sunnier" places like California or Arizona.[8]

New Policies Will Trigger More Renewables in Maine

Maine is poised to see a significant uptick in wind and solar development, thanks to the recent adoption of several laws and policies. In the spring of 2019, Maine's 129th Legislature passed and Governor Janet Mills signed laws that will trigger substantial renewable energy investments including:

- ***"An Act To Promote Solar Energy Projects and Distributed Generation Resources in Maine"*** lifted the cap on the number of people that can participate in community solar projects, which the Legislature's Energy, Utilities, and Technology Committee defined as being up to 5 MW in size. The law also directs Maine's Public Utilities Commission (PUC) to procure 125 MW of outputs associated with commercial and institutional accounts and 250 MW of shared distributed generation[9] resources by July 1, 2024.

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[5] Lazard's Levelized Cost of Energy Analysis Version 12.0*: https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf*

[6] See "A Statewide Geographic Analysis of the Intersection of High-value Wildlife Resource and Wind Resources," page 44, for more information on how the increasing height of wind turbines means they can be sited at lower elevations than before and still produce abundant energy.

[7] Note, however, wind speed is only one of many factors that interact in a complex fashion to make a site suitable for wind development. Others may include wind shear, turbulence, soils, slopes, as well as ownership and economic factors.

8 *https://news.energysage.com/solar-panels-in-winter-weather-snow-affect-power-production/*

[9] Distributed generation refers to technologies that generate electricity at or near where it will be used.

- ***"An Act To Reform Maine's Renewable Portfolio Standard"*** set statewide goals for consumption of electricity from renewable resources: 80% of retail electricity sales by 2030 and 100% by 2050. The bill also amended Maine's Renewable Portfolio Standard to make substantial room for newly developed renewable projects.
- ***"An Act To Promote Clean Energy Jobs and To Establish the Maine Climate Council"*** requires that Maine reduce its annual greenhouse gas emissions to at least 45% below the 1990 gross annual greenhouse gas emissions level by 2030 and 80% below the same level by 2050. The bill also created a Climate Council to update Maine's Climate Action Plan, which will include strategies to achieve the greenhouse gas emission reduction goals.

A handful of recent policy initiatives also signal a desire to move forward on wind projects off the coast of Maine. In June 2019, the State of Maine accepted an invitation from the Bureau of Ocean Management to participate in a federally-led Gulf of Maine Intergovernmental Regional Task Force on offshore wind with New Hampshire and Massachusetts. Maine is establishing the Maine Offshore Wind Initiative to identify opportunities for offshore wind development in the Gulf of Maine. The 129th Legislature also directed Maine's Public Utilities Commission to approve a contract for Maine Aqua Ventus, the first-of-its-kind demonstration project of deepwater floating offshore wind turbines in the United States.

Renewable Energy and Wildlife: Potential Impacts

Moving renewable energy projects forward in Maine should not mean allowing any project in any place at any time. Like any large development project, renewable energy projects can have significant impacts on high-quality habitat and the environment, even if the overall outcome is reduced carbon emissions for the benefit of the environment on the whole. There is a risk that a strong push towards renewable energy development could lead to the loss and conversion of high-value wildlife habitat—even endangered species habitat. Fortunately, with appropriate renewable energy policies and strong environmental protection standards, including siting criteria, this risk can be substantially reduced.

Habitat Loss

Any development project that alters the natural landscape has the potential to harm wildlife and wildlife habitats. Commercial and sometimes community scale renewable energy facilities require large areas of land in order to produce appreciable amounts of pollution-free energy, which can result in a direct loss of habitat.

The scale and extent of the habitat loss depend upon project location, the existing condition of the land at the site and in the surrounding areas, and other elements specific to the project. For example, individual ground-mounted solar photovoltaic (PV) panels can be maintained in functioning, early successional habitat for some species of reptiles, birds, and pollinators that are tolerant of the structures and the maintenance required to operate such projects. In such a scenario, and with sensitive operations and maintenance, habitat loss is limited. In comparison, greenfield[10] development solar arrays[11] that are mounted in groups on concrete pads and maintained with little to no vegetation allowed at the site (often achieved with regular mowing and/or extensive herbicide use) incur a significant loss of habitat. Additionally, such projects can lead to the degradation of the surrounding, undeveloped landscape. For example, large impervious surfaces can alter the hydrology of a site and its surroundings by increasing local runoff and reducing infiltration. This also increases local site temperatures, which in turn can influence adjacent stream temperatures and water quality in the watershed. With appropriate siting and design considerations, many of these impacts to the local habitat can be avoided.

The physical location of the renewable energy generation project is not the only area that is impacted when a large energy project is developed. The infrastructure associated with the project is often of greater concern than the impacts to the immediate site, and with energy projects, this is particularly true. Access to and throughout the site must be established if it does not already exist. That means roads, culverts, and clearing of natural vegetation. The newly produced energy must also be connected to energy recipients via miles of transmission lines with wide corridors that are most often maintained through regular mechanical cutting and/or herbicide use. These infrastructure features—roadways and transmission lines—can have a significant effect on high-value habitats and the environment by incurring direct habitat loss, fragmenting ecological systems, increasing the spread of invasive species, altering the microclimate and hydrology of an area, increasing edge habitat and reducing interior habitat, and providing new corridors for predators or new competitors to the native species of an area.[12]

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[10] A greenfield refers to a site that has not previously been developed, such as forested or agricultural land.

[11] A solar array is a group of solar panels.

[12] McMahon, J (2018) The Environmental Consequences of Forest Fragmentation in the Western Maine Mountains. Occasional Paper #2, Maine Mountain Collaborative *(https://mainemountaincollaborative.org/wp-content/uploads/2019/01/2019-01-Environmental-Consequences-ForestFragmentation.pdf).*

Terrestrial Wind Power and Wildlife

Much already has been written about the impacts of terrestrial wind power on wildlife and their habitats, including Maine Audubon's 2013 report titled "Wind Power and Wildlife in Maine: A Statewide Geographic Analysis of High-value Wildlife Resources and Wind Power Classes." However, as more wind projects come online, we continue to learn about the impacts of onshore wind power generation to wildlife and habitats, and how best to avoid them. Besides the loss and fragmentation of habitat described above, onshore wind projects can result in high collision risks to bats and birds moving through the area. In particular, birds and bats during migration in the fall and, to a lesser degree, in the spring are at greatest risk, as well as birds and bats moving during bad weather when visibility is poor.

Because long-distance migration requires a great deal of energy, many birds utilize weather patterns and natural features of the landscape to aid in energy-efficient travel. By moving with prevailing winds, migratory birds and bats can reduce energy output by simply riding the wind. Wind patterns are often concentrated along the coast and other geographic features like hills, valleys, and mountain ridges. Those hillsides can also aid in efficient migration in another way; when hillsides are warmed by the sun, warm air travels upslope, carrying birds effortlessly to traveling altitude. This works particularly well for larger diurnal birds such as raptors. With prevailing winds moving in the right direction, birds can simply rise on the thermals, then coast along with the wind, expending very little energy. Therefore, because bats and birds use prevailing winds to their benefit when possible, conflict with wind turbines—designed to intercept those same winds—is almost inevitable if not considered during siting with appropriate studies and identification of migratory corridors.

While location is a large factor in collision risk, it is not the only factor. The potential for bird and bat collisions with wind turbines, guy wires, or other structures also increases at night and in bad weather, when visibility is poor and structures are more difficult to avoid. Also, turbine lights tend to attract some species under poor visibility conditions. Even though fewer birds may be migrating during unfavorable weather conditions, they are more vulnerable to collisions, thus increasing the likelihood of mortality. Additionally, some birds and bats can be attracted to wind turbines due to type of construction, lighting, colors, and patterns, which developers can address through careful facility design.

Collision mortality is not the only risk to wildlife from wind energy projects. For many species, avoidance is preferable to flying through a wind farm. What that means for animals moving through the landscape is that they must expend additional energy to fly around the turbine array. There is variation amongst species, but any bird that must travel around a large array is expending extra energy. For birds that are flying around arrays on daily foraging trips, or migrating birds on extreme energy rations avoiding one or multiple wind turbine arrays, there may be cumulative effects that lower fitness and survival.[13]

Maine currently supports 923 megawatts (MW) of installed wind power capacity in the state including 386 turbines across 18 projects, with another 22-turbine 73 MW project approved.[14] There is room for new projects and new technologies to produce even more wind capacity across the state. When Maine Audubon analyzed the potential impacts of onshore wind energy projects on wildlife in 2013, standard turbine hub heights (the height of the rotor above the ground, where it connects to the tower) were 80 meters. Current proposed projects have hub heights of 117m, and within the next decade we expect to see proposed projects with hub heights of 140m, the size that is beginning to be built in Europe. Higher hubs are more efficient because wind speeds increase and turbulence decreases as you increase the height above ground. Unfortunately, as you increase the height of the turbine, you may also increase the possibility of collisions with birds and bats during migration. However, the benefit to wildlife of increased hub heights is that viable wind speeds are available over a much larger area—not just limited to mountaintops—providing developers with more options to avoid sensitive areas and important bird and bat migration routes. See "A Statewide Geographic Analysis of the Intersection of High-value Wildlife Resource and Wind Resources," on page 44, which high-lights the availability of commercially viable wind resources across Maine at 100m and 140m hub heights where high-value wildlife areas are avoided.

Companion reports soon to be released by the Appalachian Mountain Club (AMC) will address the visual impacts of wind power projects on high-value scenic resources across Maine, as well as an analysis of the overlap between wind resources and areas of high climate change resilience.[15] High resilience areas are of particular importance to plants and wildlife as they adapt to new conditions and move across the landscape

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[13] Masden, E.A., D.T. Haydon, A.D. Fox, R.W. Furness, R. Bullman, M. Desholm. 2009. Barriers to movement: Impacts of wind farms on migrating birds, *Journal of Marine Science*. 746-753.

[14] US Department of Energy at *https://windexchange.energy.gov/maps-data/321*; American Wind Energy Association at *https://www.awea.org/resources/fact-sheets/state-facts-sheets.*

[15] See "The impact of existing and potential wind power development on high-value scenic resources in Maine" to be published in late 2019 by the Appalachian Mountain Club.

in response to changing climatic conditions. Anyone concerned about all aspects of siting terrestrial wind power projects should review the AMC publications in conjunction with this report, which is focused specifically around impacts to wildlife and habitat.

Offshore Wind Power and Wildlife

Offshore wind is very likely to play a role in Maine's energy future, though the impacts of offshore wind on wildlife have not been studied as much as onshore wind. Offshore wind is stronger and more consistent than onshore wind, is usually closer to consumers, and may be easier to develop because it does not require negotiations with multiple individual landowners as onshore wind projects often do.

Evaluations into the potential for offshore wind energy development and its impacts on wildlife and habitats are only just beginning in the U.S. Currently, there is only one offshore wind project in the U.S.: five turbines nearly 4 miles offshore from Block Island, Rhode Island. The project began operation in 2016 and produces approximately 30 MW of power annually; more is potentially in the works. In May 2018, Rhode Island and Massachusetts announced they will be developing another 400 MW in Rhode Island and 800 MW in Massachusetts from separate developers. New York has announced contracts for almost 1700 MW of offshore wind and New Jersey 1200 MW.

Most offshore wind development to date has occurred in Europe, with some in Asia. The industry has grown rapidly since 2000 as technologies have improved and prices have come down. Global offshore wind capacity reached nearly 17 GW in 2017, with 3 GW of that coming online in 2017 alone, almost exclusively in Europe.

We can learn from offshore wind projects in Rhode Island, Europe, and Asia, but they are in relatively shallow water while most of Maine's viable offshore wind is in deeper water, requiring new research on technologies to tap into this rich resource and to understand its impact on coastal and marine life.

Maine has some of the highest potential for offshore wind development in the U.S., based on current offshore wind energy maps.[16] The University of Maine is taking the lead on supporting and researching the development of offshore wind in Maine. It leads a consortium, DeepCwind Consortium, of academic and industry leaders working to establish Maine as a national leader in the development of deepwater offshore wind power. The challenge in this endeavor is that the majority of viable offshore wind energy is in water deeper than 60m,

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[16] See map of land-based and offshore annual average wind speed at 100 m, produced by the National Renewable Energy Laboratory: *https://www.nrel.gov/gis/images/100m_wind/awstwspd100onoff3-1.jpg*

at which point fixed base turbines are not viable and must be replaced with floating turbines. Without a fixed base on the ocean floor, floating turbines are held in position by cables attached to the seabed. The technology for these floating turbines is currently being tested in Maine waters, but we may still be years away from building commercially viable floating offshore wind facilities.

For wildlife, many of the same issues that occur with onshore wind projects, such as habitat loss and fragmentation, as well as bird and bat mortality from collisions and avoidance of turbines, also occurs with offshore wind projects. But in the ocean, a whole host of additional species and habitats can also be affected. While some portions of underwater turbine foundations can create marine habitat in certain areas, such as through the creation of artificial reefs, habitat loss also occurs on the ocean floor, putting fish species, marine mammals, sea turtles, pelagic birds, and other species at risk. For flying species such as birds and bats, the risk of collision is with the wind turbines, but for marine species the risk of collision is with the tower and support structures below the surface of the water, or in the case of floating turbines, with the attachment cables. Researchers have also discovered that the underwater cables that transport the electricity from the turbines to shore emit electromagnetic fields (EMF) that may be disruptive to fish and other species that use such energy fields for navigation, orientation, and feeding.[17] Underwater construction also often involves blasting and drilling to establish the tower bases, and when this kind of noise occurs underwater, it can cause hearing damage in fish and other organisms in the area, as the sound waves move differently through water than through air.

Until additional information is available from current and future research, we will not have a full understanding of the effects of floating turbines on wildlife and habitat.

Solar Power and Wildlife

The primary concerns regarding siting and operating solar power are: direct loss of habitat during the creation and maintenance of a solar facility, and fragmentation of habitat from associated infrastructure (such as transmission corridors), as well as infrastructure maintenance.

There are two major types of solar energy generation projects. Distributed solar energy includes small photovoltaic (PV) panels on residential homes or small businesses. Utility scale solar facilities have much larger generating capacity and often occur separately and farther away

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[17] For an overview of the research into the effects of EMF on marine organisms see *https://tethys.pnnl.gov/short-science-summary-electromagnetic-fields* and especially *https://tethys.pnnl.gov/sites/default/files/publications/Marven-Report-2015.pdf*

from existing infrastructure. The two types have very different impacts on the environment.

Distributed solar energy is generated where the consumers of the energy reside or work, within developed landscapes and within or in close proximity to the existing energy infrastructure. This can require considerably less habitat alteration, thereby reducing or avoiding impacts to wildlife. Broad-scale adoption of distributed solar energy may require adjustments to the existing energy distribution system, particularly as new renewable energy storage systems are developed to help incorporate solar power into the grid. The original utility grid was built to facilitate a steady one-way distribution of power: from the energy generation facility to the consumer, at a consistent rate. Distributed solar would add energy to the system at various points and times, which could disrupt the electricity current flows and potentially overload the system. Additional lines could address this issue, but more lines mean more impact to wildlife and habitat. Adding storage systems between the distributed energy generator and the grid itself, however, can reduce the possibility of system overload at peak generation times, and provide additional energy at times of lower energy production but higher energy use.

Utility scale solar, on the other hand, is usually built at large, undeveloped sites, farther from future energy consumers and usually requires development of new transmission systems to bring the energy into the existing energy grid. This type of large-scale solar development brings all the risks of habitat loss and fragmentation that any other large development with linear infrastructure brings.

Transmission, Rights-of-Way, and Wildlife

As noted above, transmission corridors and roadways can have significant negative effects on wildlife populations and habitats. Linear habitat alterations cut the natural landscape into smaller pieces, which can be a problem for species that need large unbroken blocks of habitat. For other species, fragmenting features may cut them off from important pieces of their habitat like breeding grounds or high quality feeding areas. Still other animals are unable to traverse the opening—such as salamanders crossing a dry open right-of-way (ROW) on a hot summer day—while other species will not cross the opening because it makes them vulnerable to predators. Roadways and many ROWs, once created, become a draw for traffic from cars, trucks, and off-road vehicles. This traffic increases disturbance of wildlife, increases the risk of introductions of invasive species, and increases the risk of mortality for any animals that attempt to cross the road or ROW. Some animals are even attracted to these features. Turtles, for example, are drawn to open sandy ROWs for nesting and are then put at higher risk of mortality from vehicles and predators.

New roads and ROWs crossing streams and wetlands can also fragment and degrade aquatic systems. Stream crossing structures, such as culverts, are often undersized or improperly placed and can create barriers to movement and degrade habitat for fish, aquatic invertebrates, amphibians, rare mussels, and other important aquatic species. Undersized culverts increase water velocity through the crossing structure, making passage difficult to impossible for aquatic organisms that are not strong swimmers, particularly during high flow periods. This higher velocity water can also scour out the stream bottom on the lower end of the structure, creating a "perched" culvert in which the bottom of the culvert is above the bottom of the stream bed. Fish and other aquatic organisms that can't jump into the culvert can effectively be blocked from moving up the stream.

Undersized culverts are also easily blocked by natural debris or by beavers, again creating a barrier to movement for aquatic organisms. Additionally, culverts set at the wrong elevation or slope often disrupt the natural flow of the stream, leading to water backing up above the culvert—and creating a warm pond, rather than a cool free-flowing stream—and reduced flows within the culvert. Such low flows can again be impossible to move through for aquatic organisms, and high temperature ponded water can create a thermal barrier for cold-water fish such as Eastern Brook Trout or Atlantic Salmon. Cold-water fish have thermal limits above which they cannot survive, and the presence of such warm water within an otherwise cool stream system can prevent them from moving throughout the system. Temperature increases and erosion can also occur as a result of vegetation clearing near waterways, when shade trees and plants that intercept sediment and runoff are removed.

Fragmentation of forested habitat can have long-lasting effects on wildlife and the quality of adjacent habitats, and with permanent fragmentation such as regularly maintained ROWs, it can displace entire populations of interior forest species. This is because the impact of the fragmenting feature disproportionally affects the neighboring, otherwise intact, habitats. By fragmenting the forest, you actually change the characteristics of the forest that remains: more light is able to enter, so light tolerant plants are able to get a foothold in the forest; temperatures, hydrology, and wind speeds change; and open-habitat predators or competitors to interior forest species suddenly have access to these species and their resources.

Forest fragmentation from transmission lines also often creates hard edges between forest habitats and early successional habitats, rather than a more natural transition from grassland to shrubland to forest. This abrupt edge leaves trees on the edge vulnerable to increased wind speeds and wind throw. It also makes previously shaded interior forest plants vulnerable to increased sunlight and competition from shade-tolerant species, and makes animals vulnerable to predators. It is estimated that even if a fragmenting feature occurs on only 1% of the landscape, it affects up to 18% of the surrounding area.[18]

Transmission line rights-of-way provide a travel corridor into new habitats for invasive species that can be brought in on construction vehicles during initial site construction, on maintenance vehicles during regular maintenance activities, or on ORVs and other vehicles utilizing the new corridors for travel. Invasive plants tend to prefer disturbed soil and a great deal of sunlight—two things in large quantity in new ROWs. But native species often use transmission corridors in novel ways as well. Predators often take advantage of the maintained travel corridors to access previously unavailable prey, leading to an imbalance in the system and potentially driving out the existing populations.

Transmission corridors can have long-term and permanent effects on sensitive habitats. Wetlands, for instance, are often cleared of woody vegetation within the transmission corridor and are maintained that way in perpetuity altering wetland functions from forest or isolated wetlands to scrub-shrub with periodic impacts from clearing and herbicides. Vernal pools (breeding sites for many forest amphibians) and surrounding habitat for species depending on the vernal pools, sensitive natural communities, and fragile plant communities can all be impacted or eliminated through the construction and maintenance of transmission corridors.

Finally, infrastructure within the transmission corridors can create hazards for wildlife. Utility poles, electrical wires, and guy wires used for pole stability can all present hazards to wildlife using the area—from electrocution of large birds of prey to collisions with miles of guy wires and poles by smaller birds and bats.

Policy Considerations: Avoiding, Minimizing, and Mitigating Impacts to Wildlife and Habitat

As stated above and in numerous recent outside reports, climate change is already having dramatic effects on wildlife, and we must act now to reduce carbon pollution before it is too late. Greenhouse gas reduction and renewable energy development is a priority of Maine's current administration, and with the newly enacted laws described above, Maine is moving in the right direction to reduce its carbon pollution footprint. But as we take these bold steps toward increasing the production of renewable energy, we must remember our

[18] Forman, R.T.T and Alexander, L.E. (1998). Roads and their Major Ecological Effects. *Annual Review of Ecology and Systematics*. 29: 207-231

responsibility towards Maine's wildlife and wildlife habitats. As with all large developments we should follow the low-impact hierarchy: avoid harm, minimize harm, and only in rare instances allow harm with compensatory mitigation. By avoiding high-value wildlife areas from the start, energy projects will have fewer ecological impacts, an increased chance of public acceptance, and a favorable regulatory review. With proper siting, incentives, and planning, we can increase Maine's renewable energy footprint, reduce our carbon footprint, and still conserve the state's wildlife.

Renewable Energy Siting

General Siting Considerations

- *Avoid sensitive habitats, including important wildlife movement corridors and habitats (used daily, seasonally, or over lifespan) and highly resilient landscapes.*[19] Based on existing available information and results of surveys described below, impacts to sensitive habitats, wildlife corridors, and resilient landscapes can be avoided or reduced with proper planning, siting, and orientation. New technologies, such as taller wind turbines, may make it easier to avoid sensitive habitats as more low quality habitat areas become viable locations for renewable energy projects.

  Sensitive habitats include all of the habitats identified as "Significant Wildlife Habitats" under Maine's Natural Resources Protection Act, as well as additional areas and natural communities deemed to be rare or particularly sensitive to encroachment. Significant Wildlife Habitats include Deer Wintering Areas, Significant Vernal Pools, Inland Waterfowl and Wading Bird Habitat, Tidal Waterfowl and Wading Bird Habitat, Shorebird Resting and Feeding Areas, and Seabird Nesting Islands. Maps for these areas can be found through the statewide Beginning with Habitat program.[20] Please note that the completeness of Significant Wildlife Habitat mapping varies and that *Beginning with Habitat* is a planning aid, not a definitive regulatory tool. Other sensitive habitats include threatened and endangered species habitat, rare plant populations, important cold-water fish habitat, wetlands, eelgrass beds, rare natural communities, and Focus Areas of Statewide Ecological Significance, among other things. Large blocks of relatively unfragmented or interior forest habitat should also be avoided, as well as habitats

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[19] For additional information on resilient landscapes as defined by The Nature Conservancy, see "Conservation Gateway," *http://www.conservationgateway.org.*

[20] For more information about the Maine Department of Agriculture, Conservation, and Forestry's Beginning with Habitat program, visit *https://www.beginningwithhabitat.org*

needed by Maine's Species of Greatest Conservation Need[21] that are not protected by the Maine Endangered Species Act. Information on the location and conservation of these and other sensitive habitats can often be obtained through state resource agencies such as the Maine Department of Inland Fisheries and Wildlife, Maine Department of Marine Resources, and Maine Natural Areas Program, as well as through federal agencies and local nonprofit organizations. Consultation with these agencies and organizations can also help identify habitats and species locations that may not be part of publicly available datasets.

Wildlife corridors include migration corridors for birds, bats, mammals, and other terrestrial wildlife, as well as riparian and aquatic corridors such as streams and rivers. Wildlife species need to move across the landscape daily, seasonally, and throughout their lives in order to access important habitat features, and any development project can disrupt those natural movements. Energy projects typically include linear infrastructure such as roads and transmission corridors that can break up these wildlife corridors and disrupt movement patterns, including access to associated stopover and staging habitats needed for successful migration.

Aquatic corridors can be disrupted by roadways and undersized culverts, as well as by activities that alter the landscape surrounding water features. Maintenance and access roads should include Stream Smart[22] road/stream crossings (crossings that allow the stream to "act like a stream" and not impede wildlife movement) where stream crossings are necessary. Efforts should be taken to avoid stream crossings where possible. Changes in the landscape surrounding waterways, such as overstory removal or erosion and sedimentation, can affect the amount, quality, and temperature of the water, which can disrupt movement patterns and survival of aquatic organisms. Information on important aquatic habitats is available through Beginning with Habitat as well as through the Maine Stream Habitat Viewer.[23]

Likely upland and wetland habitat connectors are depicted on Beginning with Habitat maps, but terrestrial migration corridors aren't as well understood or thoroughly mapped as stream connectors. Site-specific information will need to be collected to properly avoid impacts.

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[21] For additional information on Maine's Species of Greatest Conservation Need, including the full list of species, please see the state's Wildlife Action Plan by visiting *https://www.maine.gov/ifw/fish-wildlife/wildlife/wildlife-action-plan.html.*

[22] For additional information on the Stream Smart program, visit *www.streamsmartmaine.org*

[23] The Maine Stream Habitat Viewer can be found at *https://www.maine.gov/dmr/mcp/environment/streamviewer/.*

Resilient landscapes have been identified by The Nature Conservancy as places that are climate resilient and are most likely to naturally sustain native plants and animals and natural processes, maintaining high natural biodiversity in the face of climate change. Their identification is based on an analysis that includes geophysical setting, landscape diversity, and local connectedness. Maps and additional information on this topic can be found through The Nature Conservancy's data portal "Conservation Gateway".[24]

- *Prior to development, in order to avoid and minimize impacts, conduct surveys to identify and understand local wildlife habitats and potential impacts of the proposed development.* With guidance from state resource agencies and local wildlife organizations, these surveys should be conducted over the entire project site, including areas for associated infrastructure, during all seasons and over multiple years, if necessary. One-time surveys rarely capture all the necessary information about local wildlife populations, as animals tend to move between habitats over seasons and years. Annual fluctuations in weather and local populations can make single-year surveys less effective at quantifying the true extent of available habitats in use. These surveys will augment existing datasets and will provide important information where data are currently lacking. They should also help project proponents as well as state and local agencies understand local habitats, species, movement patterns, etc., in order to avoid or minimize impacts to local species. For instance, surveying a potential vernal pool for vernal pool obligate species such as salamanders can help project proponents avoid harm to these species, preferably by avoiding the pool and surrounding critical terrestrial forest habitat. Conducting bird and bat migration studies can help wind developers avoid migration routes and therefore reduce impacts to wildlife and minimize the need for significant reductions in power generation during operations. These types of studies are often required by state and federal permitting agencies.

- *Locate energy projects near existing transmission lines/population centers.* As noted above, the fragmentation and habitat loss associated with the construction and maintenance of energy project infrastructure, such as roadways and transmission line corridors, can often have larger effects on wildlife than the habitat loss associated with the project site itself. Siting new energy projects near existing infrastructure will reduce or eliminate the need for additional fragmentation of habitats. Ideally, new energy projects should be developed on low quality habitat within or near existing developed landscapes, such as landfills and brownfields, and close to existing transmission lines, ideally next to substations.

[24] See "Conservation Gateway", http://www.conservationgateway.org.

- *Evaluate potential cumulative impacts, considering existing development and potential future development for a site*. Often when development projects are evaluated during the review process, they are examined as if they are the only such project to be developed within an area or region. Cumulative impacts such as amount of impervious surface within a watershed, water use and recharge in a watershed, road traffic within an area (including projected volume and traffic speed changes over time), amount of vegetation clearing within large land blocks, etc., should be evaluated across the landscape, rather than one project at a time. Wildlife displacement and existing habitat limitations should be considered when evaluating potential impacts of new projects. Future projected impacts should also be considered when evaluating each project and when determining siting and environmental impacts. For instance, if a ridgeline already houses 10 wind turbines, and another 10 are being proposed, the new project should address the full cumulative impact 20 turbines will have, not simply 10 additional turbines. By developing landscape-level planning mechanisms for energy and other types of development, cumulative impacts can be reduced and managed.

Wind Siting Considerations

- *Follow the United State Fish & Wildlife Service Land-Based Wind Energy Guidelines, developed in 2012.* These guidelines utilize a decision framework with a tiered system of risk analysis, beginning with preliminary site evaluation through construction and post-construction studies with the goal of addressing wildlife conservation concerns at each level. It is an adaptive management approach that allows a developer to decide at each stage whether to continue the process, make changes, or no longer proceed, based on the findings at each tier. It allows a project proponent to determine the amount of investigation and risk they are willing to undertake in order for a project to move forward at each stage, and it provides regulators and wildlife agencies with the information they need to properly evaluate the potential impacts of a wind project on wildlife.

- *Configure turbine arrays to reduce collision potential for migrating birds*. Orient turbine arrays parallel rather than perpendicular to migratory pathways, and offset them from the pathways themselves, reducing the likelihood of birds needing to pass through the arrays during migration. Break up large arrays of turbines into smaller clusters, so they can be more easily avoided. This will reduce the likelihood of birds trying to pass through large or long arrays or expending large amounts of energy as they navigate around large arrays. Avoid placing wind turbines within narrow landscape features known to "funnel" birds during migration.

- *Prioritize and encourage the integration of small-scale wind generation on agricultural facilities, where appropriate*. Small-scale wind projects—i.e., those with a limited number of turbines—can be used to offset some or all of the energy consumed at an agricultural site, possibly combined with solar PV on rooftops. Because agricultural land is already cleared, small-scale wind facilities do not require land clearing and the displacement of forest wildlife species or additional loss and fragmentation of forest habitats. Other siting recommendations such as avoidance of bird and bat migration pathways are still appropriate at agricultural facilities. Policies and incentives can be created to encourage wind power on agricultural facilities but should not displace agricultural production.

- *For offshore wind power, develop a state-specific comprehensive ocean management plan that includes offshore wind siting requirements and marine wildlife protections.* Such plans have successfully been used elsewhere to create protected areas where energy projects and other development are prohibited, and development areas where projects are encouraged. Protected areas can include important wildlife habitats such as nursery areas, important fishing areas, and areas of cumulative stressors where additional impacts should be avoided or limited. Energy projects and other development are then steered away from protected areas and toward areas where energy resources are high, but impacts to wildlife would be low. Comprehensive ocean management plans can provide a greater level of certainty to offshore wind power developers, as well as comfort to stakeholders interested in protecting vulnerable marine wildlife and other resources.

  A number of states and countries have developed individual ocean plans with varied success, depending on the priorities of the plans and what data are and are not included. In New England, a fairly comprehensive Ocean Management Plan—the Northeast Ocean Plan—was certified by the Obama administration in December, 2016. This plan provides a framework for setting and attaining regional goals for the management of the area's ocean resources, and it includes an online data portal to aid in that planning process. Data available through the online portal include information on species and habitat locations, bathymetry and physical oceanography, and human use locations such as shipping lanes, fishing locations, and recreational areas. This federal plan creates an excellent foundation for Maine to develop a state-specific plan for increasing renewable energy resources such as offshore wind power, while protecting the ocean's wildlife from the effects of such ocean developments, based on local resource values that may be more important at the state level than at the federal level.

- *Prior to deployment of large scale floating turbine arrays, conduct site-specific surveys to better understand the potential impacts to the marine environment and associated species at a potential site.* Studies should include investigations into wildlife concentrations, movement and migration patterns, and the potential effects on both ocean-dependent species such as lobsters and Right Whales, and the physical habitats affected, including impacts associated with bringing the electricity to shore. As with onshore wind projects, data collection should be conducted in such a way that captures seasonal, annual, and lifetime variations for all species at risk. Additional studies into the potential effects of electromagnetic waves on marine wildlife would be appropriate as well. The Northeast Ocean Plan data portal described above is an important resource for the development and implementation of such studies, as well as input from state and federal agencies, local governments, and nonprofit organizations.

Solar Siting Considerations

- *Prioritize and encourage distributed solar energy generation on residential and commercial properties.* Distributed solar energy development keeps the energy generated close to the energy recipient, without new habitat destruction and fragmentation associated with new transmission lines and roads. Because the primary impacts of solar energy development on wildlife are centered around habitat loss and fragmentation, implementing solar development within the built landscape reduces or eliminates new habitat loss. Developed landscapes typically already include energy infrastructure such as roads and rights of way, and therefore new such features would be unnecessary. Encouraging distributed solar projects through policy and incentives can thereby help reduce the need for larger solar facilities in undeveloped habitats requiring new associated transmission lines.

  Prioritize and encourage municipal solar projects across the state. Particularly in rural parts of the state where any new outside energy development would require new transmission lines, locally produced energy eliminates the need for new transmission lines. Because municipalities often include multiple facilities with potential for solar development (town halls, fire stations, schools, landfills, equipment garages, sand sheds, etc.) they can often generate more power than an individual property owner would be able to. They are also able to share the costs and benefits of the development of renewable energy with the local citizens. Additionally, by leading on the renewable energy front, municipalities can encourage local citizens to switch to renewable energy as well, thereby reducing additional carbon pollution and reducing the need for new transmission lines and other harm to wildlife and habitats. Encouraging municipal solar projects through policy and incentives can help reduce the need for larger solar facilities in undeveloped habitats with associated transmission lines.

- *Encourage dual use of solar power on agricultural facilities if it does not unduly remove land from food production.* Dual use means adding renewable energy production at an agricultural facility while still maintaining the overall agricultural production. Dual use reduces the need to clear additional land to replace agricultural production that has been lost as a result of solar energy development on agricultural lands. Agricultural facilities are often commonsense locations for solar energy development.

  Agricultural facilities have already been cleared to grow crops or pasture animals. Solar PV on posts can even be mixed with agricultural crops in some instances such as with shade-tolerant crops.

  Similar to commercial and municipal sites, agricultural facilities often include large structures appropriate for housing solar panels and can offset much of the electric energy consumed on the site.

  Large solar facilities on farmland that displaces agricultural activities should include a decommissioning plan to return the land to agriculture at the end of the lifespan of the solar equipment, should be prioritized on lower quality agricultural lands (i.e., not on prime agricultural lands or lands of statewide significance), and should be sited, designed, and maintained to have the smallest impact to the agricultural land and no impact on adjacent natural landscapes.

  A site maintenance plan should include land management techniques that promote and maintain habitat for native pollinators, benefiting both native wildlife and the agricultural system.

- *Prioritize and encourage solar development to occur only on low-quality, disturbed sites.* These include such areas as landfills, brownfields, floatovoltaics on water treatment facilities, highway medians and road edges, etc. By encouraging large-scale solar development to occur on previously degraded areas, and discouraging large-scale solar development on higher-quality natural wildlife habitat, the destruction of wildlife habitat for renewable energy can be reduced. This goal can be achieved by providing financial and/or regulatory incentives for utilizing degraded sites and disincentives (i.e., penalties) for developing previously undeveloped land for renewable energy. Areas prioritized for solar development may also be pre-identified and made available to developers through a bidding process that guarantees expedited permitting, as long as they adhere to stringent siting criteria.

- *Create a uniform statewide permitting process for new solar projects.* Rather than having each municipality create its own set of permitting standards, explore Vermont's approach that uses a uniform streamlined permitting process across the entire state. This gives more predictability to developers, lessens the burden on each municipality to create and adopt its own standards, and ensures all projects meet certain minimum criteria that hopefully holds projects to a uniform high standard. For larger projects, a regional review process may be appropriate.

Transmission Line Siting Considerations

- *Co-locate new transmission lines into existing ROWs, roads, or other existing man-made linear features, wherever possible.* By placing new transmission lines within existing fragmenting features on the landscape, additional fragmentation is reduced or eliminated. Policies, incentives, and regulations can be used to support co-location. Consideration should be given to what additional construction is necessary to allow for co-location and what the impacts will be. For example, it may be necessary to expand the width of a maintained ROW to accommodate additional energy infrastructure. The effects of such expansion on wildlife and habitats should be considered when determining if co-location is ideal for a given project.

- *Work with regional governments and resource agencies to develop a comprehensive long-term regional energy and transmission siting plan.* Such a plan should include all states and provinces that are connected to the same regional grid. It should also include estimates of future growth and energy needs, energy sources (i.e., variable renewable energy such as wind and solar), energy storage to account for fluctuations in renewable energy availability, decommissioning plans to return the land to an undeveloped state at the end of the life of the renewable energy or transmission system, and micro-grid integration allowing for local control of the local energy grid. Flexibility for integrating future technologies that reduce the need for transmission lines through otherwise unbroken natural habitats should be a cornerstone of such a plan. The ability to integrate new energy sources should also be foundational.

- *As part of the plan above, develop a system for evaluating the need for continued use of long-distance transmission lines and create decommissioning plans for lines that could be retired.* Changes in technologies and energy sources should lead to re-evaluations of our reliance on traditional transmission lines and grids. The current system relies on one large transmission system that crosses state and provincial boundaries as essentially the only mode of moving energy to consumers. Changes in energy transmission needs should be reflected in regular updates to the regional energy and transmission siting plan described above. Reductions in the development and maintenance of transmission lines across the region would benefit wildlife and habitat enormously.

- *Encourage microgrids and other local energy production and transmission efforts to reduce the need for new transmission systems through otherwise unbroken habitats.* A microgrid is a local energy grid that can be controlled locally and separated from the regional grid when necessary, such as during storms when external transmission lines may go down. Microgrids rely on locally-generated energy when not connected to the main grid, and this energy can be in the form of renewable energy, batteries (often associated with renewable energy), or other energy generators. The emergence of microgrids on the landscape provides an alternative to increasing the number of transmission lines needed to move energy to markets, as additional demands on the grid can be met with local power generation rather than with power brought in through new transmission lines. Microgrids encourage local energy generation and efficiency, allow for the development of more local energy infrastructure including renewable energy development, and can provide energy reliability for a community during outages.

- *Support research and development and deployment of energy storage systems, integration of storage into transmission facilities, and co-location with renewable energy producers.* Wind and solar energy are variable energy sources—wind energy can only be produced when the wind is blowing and solar energy when the sun is shining. A means is needed to store "surplus" energy at times of high renewable energy production to use during times of high energy demand. Our current transmission system was built for central-station, steady energy production, such as the energy generated from burning fossil fuels at large coal, oil, and gas generators, and is not designed to handle more distributed generation or significant fluctuations in energy production. Integrating storage systems, such as batteries, into the transmission system itself, as well as into homes and businesses utilizing variable renewable energy sources, will allow for additional renewable energy to be brought on to the existing grid and reduce the need to expand or build new transmission lines. Research into battery systems is currently underway and is showing significant promise, but more work must be done in order for this technology to be widely accessible. Additional energy storage systems being studied include: advances to the old-school hydro pump (in which water is pumped uphill when energy is readily available and "cheap", and generating electricity as it flows back downhill during times of high energy demand); using hydrogen to store surplus energy until needed later; creating ice at night when energy consumption is low in order to maintain cooling systems during the day when energy needs for cooling are high; flywheels used to create rotational energy storage; and even island systems that utilize electric vehicles to store excess energy while they are not in use.

- *Explore ways ISO New England, Inc. can be a player in encouraging renewable energy to be "hooked in" to the grid.* ISO New England, Inc. (ISO-NE) is the independent, nonprofit Regional Transmission Organization (RTO). ISO-NE oversees the operation of New England's bulk electric power system and transmission lines. Unlike ISO-NE, RTOs in some other states (such as Texas) encourage new renewable projects by allowing renewable energy to more easily interconnect with the existing grid by building efficient open access transmission to support renewable developments. If ISO-NE leads such an effort, utilities will follow, reducing the need for superfluous transmission lines.

Siting Incentives

Incentives are an important tool to help reduce fossil fuel pollution and encourage renewable energy projects to be built in the most appropriate places in Maine. Most states and nations with successful renewable energy sectors have strong incentives in place to encourage the development and use of renewable energy sources in the most appropriate places. For example, in some communities, tax rebates or exemptions and other financial incentives for renewable energy projects are only available to projects that are properly sited (i.e., on previously developed sites rather than on high-quality habitats) and projects sited within high-quality wildlife habitat or other green space could even receive financial penalties. Additional incentives could be added for re-utilization of contaminated sites such as brownfields, landfills, or uninhabitable urban sites. Incentives can come in the form of streamlined permitting, low-cost financing, and loans for renewable energy conversion. In addition, new solar projects should not be subjected to additional municipal property taxes.

Economic incentives can be utilized at multiple scales and for multiple renewable energy sources. They can target municipalities, businesses, and individuals. Municipalities could receive state incentives for including renewable energy sources within town infrastructure and for encouraging residents and businesses to create renewable energy locally. Residents and businesses could then receive both state and local incentives for installing renewable energy infrastructure within the built environment, reducing the need for new transmission lines that destroy and fragment habitats. Incentives could be developed to encourage microgrids and thereby reduce the need for additional transmission lines, while also providing the town with backup energy in case of grid outages.

Construction, Operation, Maintenance, and Decommissioning

General Considerations

- *Maintain existing native vegetation to the greatest degree possible and avoid impervious surfaces to the greatest degree possible.* By maintaining overstory vegetation and as much native vegetation as possible on site, long- and short-term impacts to wildlife and their habitats can be reduced. Established existing vegetation provides natural erosion control, increases water infiltration, moderates temperatures, captures carbon, and helps reduce the spread of invasive species. It can also provide a seedbed for site restoration, potentially increasing the success of restoration efforts and aiding in site restoration in future decommissioning efforts. Impervious surfaces increase temperatures, increase runoff, and reduce infiltration, thereby increasing erosion potential. By maintaining existing native vegetation and avoiding new impervious surfaces to the greatest degree possible, we can reduce habitat fragmentation, runoff and pollution, and the introduction of invasive species onto the landscape.
- *Minimize impacts to aquatic systems.* Where maintenance and access roads must be created and maintained, Stream Smart road/stream crossings[25] and proper erosion control techniques should be utilized, and the number of crossings should be minimized to the greatest degree possible. Provide wide undisturbed, vegetated buffers around wetlands and other aquatic systems to allow for the natural functioning of such systems, including retaining shade for streams and providing travel corridors for multiple fish and wildlife species. At a minimum, follow the Maine Forest Service Best Management Practices for Streams, but preferably adopt stream protection standards for buffers and cutting developed by the Maine Department of Inland Fisheries and Wildlife and/or Trout Unlimited who recommend a minimum of 100-foot buffers on all intermittent and perennial streams.

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[25] For additional information on the Stream Smart program, visit *www.streamsmartmaine.org.*

- *Where necessary, set timing requirements for work windows based on potentially affected species.* Based on the information gathering described above, restrictions may be necessary to avoid impacts to local wildlife populations. For instance, clearing trees when the ground is frozen will reduce erosion into aquatic habitats. Avoiding the use of heavy machinery during spring and early summer can reduce disturbance to nesting birds, forest amphibians, and other wildlife. Reducing traffic at a site during migration times can reduce direct mortality to animals moving across the landscape. Site-specific information will guide the need, dates, and extent of any timing restrictions.

- *Examine structural plans, and use deterrents if necessary during construction and operation to scare or lure wildlife away from harm.* Certain infrastructure associated with renewable energy generation can create an attractant for some wildlife species, leading to greater conflict and wildlife mortality during construction and operation. For instance, early wind towers included lattice structures that were attractive to raptors and other large birds as perches. This created a double effect of increasing predation of local wildlife populations by raptors, and increased mortality of raptors moving around active wind turbines. Lattice frames were replaced with monopoles, which eliminated this risk. Bats and birds can be attracted to particular colors, patterns, lighting, and possibly sounds at wind towers (see below for additional information), so less attractive features should be used. White noise devices and radar are also being examined for their potential use as deterrents. Open ground created during construction can attract species like turtles searching for nest sites. These species could be in danger if traveling through the site during construction, so silt fencing or other barriers could be used to prevent wildlife from entering the site during construction activities, as long as these barriers are removed as soon as construction activities cease.

- *Reduce the impact of fencing and other structures that can impede wildlife movements.* Fencing is often necessary around energy facilities, renewable or not, for public safety reasons. But these fences can also impede the movement of wildlife which could otherwise continue to safely utilize the site. For sites with areas of distinct, limited safety concerns, fencing should be limited to only those small distinct areas, such as around individual solar panels, wind turbines, etc., rather than enclosing the entire facility. For more extensive areas that must have fencing, alterations to the fencing can be made to facilitate wildlife movements as needed. For instance, fences can be installed with a gap at the bottom to allow for small animal moving across a site (such as turtles, small mammals, etc.) but still prevent humans from entering. Where site activities during construction or operation could endanger wildlife, silt fences and other barriers can be used to prevent wildlife from entering the site.

- *Have a decommissioning plan that includes site restoration to a natural or agricultural landscape developed up front with established timelines and funding sources.* The decommissioning of a renewable energy project can be just as important as the construction plan, as far as long-term impacts to wildlife and the environment are concerned. Most wind and solar projects have an expected lifespan of 20 to 25 years, at which point they can be repowered (retrofit to meet current standards) or decommissioned (de-energized and removed from the site). Oftentimes when renewable energy projects are proposed, they are described as being "temporary" structures because of this short lifespan, and are therefore not considered to have the same "permanent" effects of other developments such as commercial or residential developments. This is only true if the renewable energy facility is decommissioned and completely removed from the site at the end of its life, and the site is restored to a more natural landscape. If the site was previously forested, the decommissioning plan should include specific steps that will be taken to reestablish a forest. If the site was previously productive agriculture, it should be returned to that state upon decommissioning. The ease, cost, and ultimate success of such decommissioning and restoration are improved when impacts incurred during construction and operation are limited. The current Maine Wind Energy Act requires applicants for wind projects to provide a decommissioning plan and proof of financial ability to carry out the plan prior to project approval. Similar requirements for new grid-scale solar and new transmission line projects could easily be created.

- *After development, continue specific surveys to improve our understanding of the true impact of energy development.* Existing post-construction surveys do not provide significant data due to small sample sizes at individual sites. However, data from multiple energy development sites could be aggregated by type for a more meaningful picture of the impacts of energy development on wildlife and habitat. Currently, results of surveys associated with individual project proposals are considered to be proprietary information and thus are unavailable to independent researchers for review. We recommend making post-construction survey results available to outside researchers or allowing researchers the opportunity to conduct studies themselves in order to pool data with other sites. Consistent protocols and statements of purpose could also enhance the utility of such studies. This could provide us with a better understanding of existing problems or developing trends that might not be recognizable from a single project site. For instance, for wind projects, conduct wildlife carcass surveys to understand bird and bat mortality; for transmission projects, conduct invasive species surveys with a control plan for identifying and eradicating invasives before they take hold; for solar projects, examine the changes in local habitat specifics such as temperature, hydrology, and habitat use. Such research could help us understand existing issues and improve decision-making around siting and operating projects going forward.

Wind Considerations

- *Design turbines to reduce attraction for birds and bats and to increase avoidance.* Increased bird and bat activity near active turbines can result in increased mortality. Numerous studies have found that some species of bats may actually be attracted to wind turbines, although the reasons why are varied and still unclear. Similarly, certain lighting patterns often used in wind projects have been found to be attractive to bats and birds, although some types of lighting can be critically important to reducing bird collisions during times of low visibility. These considerations should be included in wind turbine design and operation planning, as described below.

  Still incompletely understood, bats' attraction to wind turbines has been theorized to be associated with sound, lights, mistaking them for trees, or as a potential source of food, as the turbines may attract insects. In order to reduce this attraction, tools such as ultrasonic acoustic deterrents are being developed. These emit sound to keep bats out of the area where the turbine blades turn. Effectiveness varies by bat species, but these devices continue to be studied and may show potential in the future. Additionally, insects may be more attracted to light-colored wind turbines (i.e., white or light gray), which may in turn attract more bats and birds to forage on them. This increased activity in close proximity to the turbine blades could increase the likelihood of collision. Use of darker paint colors can reduce the attractiveness to insects, and therefore reduce the probability of collision.

  Efforts to increase the visibility of the turbines and turbine blades to birds should be undertaken to reduce collision rates, particularly during times of low visibility. Use of contrasting paint and patterns on the turbines has been shown to increase visibility, and the use of UV paint—visible to birds—may reduce collisions as well. Lighting of wind turbines during periods of low visibility (at night and during poor weather) can increase visibility for some bird species as well, with studies underway to determine if the use of UV lighting provides superior visibility for birds. This is particularly important in bad weather during migration, as birds and bats reduce their flight elevation in bad weather, making them more likely to be flying at the height of wind turbine blades. However, lighting color and pattern have the potential to increase collision rates as well, as it has been shown that bats are attracted to red lights, while birds are more attracted to steady lights rather than blinking lights. For general lighting, flashing white strobe lights with low flash frequency appear to provide the safest lighting option for both birds and bats.

- *Curtail wind turbines at low wind speeds in fall to reduce bat mortality during migration*. The majority of bat fatalities at wind facilities occur at relatively low wind speeds and primarily during late summer and early fall. Increasing the cut-in speed of the turbines (the wind speed at which blades begin to turn) at this time of year and at other high activity periods can dramatically reduce bat mortality rates with very little loss of energy production.[26] Cut-in speeds above 6.0 meters per second (m/s), can eliminate most bat mortality from wind turbine collisions. The Maine Department of Inland Fisheries and Wildlife recommends wind generation curtailment at low wind speeds nightly when bats are active (between April 15 and September 30 each year when air temperatures are above 32 degrees Fahrenheit). Within that time period turbines can operate at cut-in wind speeds of 6.0m/s, and possible increased curtailment wind speeds between July and September when higher bat mortality typically occurs.[27]

- *Have shutoff option and specific implementation plan ready to be used during bad weather, during heavy migration, and during times of low visibility.* Using radar, bird migration data, and weather pattern forecasts, wind turbines can be shut down very quickly to dramatically reduce bird and bat mortality. Cornell University has developed real-time mapping of bird movements using radar that could be used by wind facilities to avoid large mortality events. Such real-time curtailment options are currently in use, so that rotors automatically shut down when risk factors, such as known bird movements and expected weather events, reach a certain threshold, protecting migrating birds and bats.

- *Create an independent research group to collect and analyze post-construction data.* Right now, all studies of post-construction impacts to wildlife, especially birds and bats, are conducted by the develop-

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[26] *See https://tethys.pnnl.gov/sites/default/files/publications/Arnett-et-al-2013.pdf* for a summary of results of 10 curtailment studies in North America.

[27] Maine Department of Inland Fisheries and Wildlife. 2018. Maine Wind Power Preconstruction Recommendations and Turbine Curtailment Recommendations to Avoid/Minimize Bat Mortality.

er on a site-by-site basis, and the results are considered proprietary. Because sample sizes are often small at each individual project site, the results are not always meaningful. In order to better understand the impacts of wind on wildlife, an independent third party should be established to work with developers, state and federal agencies, and other stakeholders to create a list of research questions needing answers, coordinate and conduct studies, and analyze and share results across all projects. Rather than requiring each developer to fund their own project, developers could contribute monies into a pooled fund that would be used to develop and conduct such studies, and data would no longer be considered proprietary. Federal and state resource agencies should consider the advantages of conducting a coordinated, regionally comprehensive ecological survey for baseline conditions with regular monitoring to track changes associated with wind energy developments as well as climate change.

Solar Considerations

- *For ground panels, use post- or pole-mounted solar PV panels rather than those embedded in large impervious foundations.* Post- or pole-mounted panels with a small "footprint" allow more native vegetation to remain, compared to those embedded in large concrete slabs, for example. Such ground-mounted panels can allow early successional habitats to remain at the bases of the panels, providing habitat for certain birds, reptiles, small mammals, and insects. They also allow for easier and more successful decommissioning and restoration at the end of the life of the project.

- *Maintain vegetation around ground-mounted panels with wildlife in mind.* The use of herbicides and other pesticides should be reduced or avoided in order to provide habitat for native plants and animals such as native pollinators. Maintenance activities should be timed to protect native wildlife to the greatest degree possible. For example, if mowing is required, avoid mowing during nesting seasons and when most flowers are in bloom. By waiting until plants have gone to seed, pollinators and other species are able to utilize the site longer, and native plants are allowed to reseed.

Transmission Considerations

- *If new electric transmission lines are necessary, require that they allow for additional future connections from other renewable energy projects, where possible.* Because habitat is lost and fragmented with the construction of new transmission lines, new transmission lines should be required to accommodate additional renewable energy in the future so the overall number and extent of new transmission lines is reduced. For example, transmission lines could allow open-access to other renewable developers subject to reasonable compensation regulated by the Federal Energy Regulatory Commission (FERC).

- *Develop and encourage common usage schemes for transmission infrastructure through open-access, particularly for offshore wind.* Currently planned offshore wind projects have dedicated generator lines that run from the turbine fields to shore. Given that there are plans for more than 8000 MW of offshore wind from Massachusetts to New Jersey, it is imperative to avoid unnecessary lines from each project to shore. Combined use of an offshore grid could significantly minimize environmental impacts, including disturbance of the ocean floor and fishing grounds. Such schemes could be governed by FERC or be supported by the states.

- *Develop implementation guidelines for the creation and management of transmission lines to reduce their impacts on native wildlife and habitats.* In addition to siting transmission lines to avoid wildlife and habitat, other strategies should be used to reduce impacts from these lines. These may include an invasive species plan, limitations on herbicides, avoidance of hard vegetative transitions (i.e., from grassland in the ROW to forest rather than having a shrub layer to help the transition), taller poles to allow for full canopy growth in particularly sensitive areas, burying lines to reduce above-ground maintenance, limitations on land clearing, devices for increasing visibility of guy wires and other structures within the ROW, and maintenance techniques that reduce land and soil disturbance.

  Invasive species plans should include monitoring plans to quickly identify the presence of invasive species, an eradication plan to address invasive species removal, and a flexible long-term maintenance plan to keep invasives out of the ROWs in perpetuity. Invasive species plan implementation should not end with the completion of the transmission line.

  Vegetation in ROWs should be "feathered" such that there is a more natural transition from open herbaceous vegetation, to shrubby vegetation, to forested vegetation, rather than an abrupt change from a short herbaceous layer directly to tall forest. Such a transition zone will create more habitat opportunities for wildlife, provide protection from predation and desiccation, and provide some protection of the forested habitat from encroachment by open-habitat species.

  Where appropriate and feasible, higher poles/lines should be built to allow for full canopy growth below. This can be particularly important in and near sensitive habitats such as rare natural communities and near wetlands and streams. Reducing the amount of vegetation clearing and maintenance can help protect water temperature in streams and wetlands, reduce invasive species introductions, provide additional habitat for forest species, and provide a possible movement corridor for species unlikely to cross an open or shrubby ROW. In addition, the requirement for regular treatment of vegetation in ROWs should be explored, adjusted, and lengthened to allow more vegetation to grow between treatments, where appropriate.

Where appropriate and where doing so will reduce the short-term and long-term impacts to habitats, electrical lines should be buried. This may only be necessary near particularly sensitive habitat such as wetlands and streams or where it is important to retain habitat connectivity. Maintaining the overstory above streams is critical to keeping the water cool, and maintaining the overstory between forests on either side of the transmission line ensures wildlife can move between the two areas. Some habitats are sensitive to soil removal, and where trenching would be used for burying lines, that may be incompatible with the habitat. For instance, some sandplain grasslands and shrublands—globally rare habitats—are particularly sensitive to tillage, and trenching may disrupt the natural seedbed, etc., necessary for the maintenance of the habitat. Horizontal directional drilling (HDD) is a trenchless technique for installing underground cable and pipeline without disruption to the surface, and should be considered where trenching for underground installation is too disruptive (i.e., under streams, etc.). However, HDD is limited by the length it can extend and requires additional infrastructure that may offset the value of using it to reduce environmental harm.

Utilize techniques to reduce collision and electrocution risks for birds and other wildlife with structures within the ROW. Utilize appropriate separation distances for wiring to reduce the possibility of electrocution for large birds, and sleeves and other devices to create visual cues around guy wires to reduce collision risks.

Where maintenance and access roads must be created and maintained, utilize Stream Smart road/stream crossings and proper erosion control techniques, and minimize the number of crossings to the greatest degree possible.

Mitigation

Development projects should always strive to prevent or reduce harm to native wildlife and their habitats by first avoiding impacts, then minimizing any impacts that might occur, and finally mitigating any unavoidable impacts. The considerations and recommendations above are geared toward avoiding and minimizing impacts of renewable energy projects on Maine's wildlife and their habitats, but where impacts cannot be avoided, they must be mitigated to substantially benefit all species and habitats being harmed and impacted.

Maine's Natural Resource Protection Act (NRPA) includes mitigation requirements for impacts to wetlands and other significant habitats, which can form the basis for mitigation associated with impacts to wildlife and their habitats from renewable energy projects. However, NRPA does not account for all wildlife and habitat impacts. At the summation of any new renewable energy project, there must be a net benefit to wildlife and habitat, even accounting for the project's climate benefits. This can be achieved using the modified mitigation methodologies described below.

Assessing and Calculating Impacts

Mitigation should address all impacts to native wildlife species, including direct impacts such as harm to individuals during construction, as well as indirect impacts such as habitat loss and degradation or disruption of biological functions such as breeding, feeding, nesting, migrating, etc. Mitigation for renewable energy projects should go above and beyond current minimum state and federal regulatory mitigation requirements.

While assessing impacts, consideration should be given to:

- The specific species being impacted;
- The types of habitats being harmed;
- Whether there are alternatives for the lost habitat (i.e., if a nesting area is being lost, are there other nesting areas nearby that can compensate for the loss?);
- The quality of the habitat being impacted;
- Cumulative impacts; and
- Landscape-level impacts, including habitat fragmentation.

Habitat loss should be calculated based on acreage of loss, lost functionality, and cumulative and landscape-level impacts.

- **Lost functionality.** As an example, if 10 acres of a 50-acre parcel of land is to be developed, but the 10 acres to be developed are spread across the entire parcel, the entire parcel may be degraded such that it can no longer provide habitat for the species in question. In such a case, the entire 50 acres should be mitigated. Alternatively, if the 10 acres of development is clustered in a single portion of the larger parcel—preferably in the portion of the parcel with the lowest quality habitat and adjacent to existing development—the other 40 acres can remain intact and usable by native wildlife. In this case, only 10 acres plus a buffer around that 10 acres would potentially need to be mitigated.

- **Cumulative and landscape-level impacts.** For instance, if the piece of habitat being lost is a critical linkage between two larger, otherwise contiguous areas of habitat, the total impacted acreage could be significantly more than the actual acreage lost. In addition to fragmenting previously intact landscapes, fragmenting features such as transmission lines can result in edge effects[28] and hydrologic changes that reach 0.5 to 1km into an interior forest that is otherwise unbroken.[29] Impacts can include changes to temperature, hydrology, species composition, etc., and should be mitigated for their full impact, not simply the acres of habitat directly lost to clearing.

  For example, some forest interior bird species require a minimum of 250 acres of contiguous high-quality habitat for survival,[30] so projects that fragment these effectively eliminate the habitat for those species, even if the "footprint" of the fragmenting feature is significantly smaller. Mitigation for such projects should go beyond the calculation of acreage of direct impact and may require an assessment of impacts on the local, statewide, and regional level. Impacts can include changes to temperature, hydrology, species composition, etc., and should be mitigated for their full losses of habitat functions for areas surrounding a disturbance, not simply the acres of habitat directly lost to cutting.

Mitigation should be calculated based on the full breadth of impacted acreage, with consideration to all impacted species and habitats, and with an assessment of the impacted habitat's quality. Finally, mitigation should be calculated based on both the short- and long-term impacts of the project. For instance, if a new energy project is developed on mature forest land, both the immediate costs—loss of forested habitat—and long-term costs—loss of carbon pollution captured over decades—of losing mature trees should be considered, calculated, and mitigated.

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[28] Edge effects are the effects seen at an abrupt transition between two very different habitat types. They are often caused by habitat fragmentation and can lead to habitat and species loss.

[29] Forman, R.T.T. et al., 2003. *Road Ecology: Science and Solutions*, Island Press, 481 pages.

[30] Yahner, R.H. 1988. Changes in Wildlife Communities Near Edges. Conservation Biology 2(4): 333-339.

Compensatory Mitigation Options

Mitigation options that should be considered for wildlife and habitat impacts include:

- **Permanent land protection.** Land protection could be used to mitigate habitat lost to development or harm to local wildlife populations, if the protected land will be held and managed to provide habitat and improve the long-term survival of the species being harmed. This approach is regularly used for mitigating impacts to wetlands and Significant Wildlife Habitat under U.S. Army Corps of Engineers and Maine Department of Environmental Protection regulations, though it does not capture all impacted habitats. Similarly, land protection could be used to mitigate upland and terrestrial habitat loss as well.
- **Habitat restoration**. This is a good mitigation option if habitat being lost is of a type that can be restored and there are viable restoration opportunities available. This could be on or off site depending on the habitats in question. Examples include creation of turtle nesting habitat, long-term habitat maintenance for species dependent on early successional habitats, restoration of native habitats overtaken by non-native species, or reconnecting aquatic systems where undersized culverts or old dams have disconnected portions of stream systems. Restored habitats often require more effort to create and maintain as high-value habitat than the natural habitats being lost, so mitigation ratios should incorporate habitat quality of both the lost and restored habitat into any calculation.
- **Habitat management**. For early successional or other habitats that require management to be maintained as high quality habitat, long-term habitat management plans could serve as some portion of a mitigation package. Depending on the habitat in question, management could include tree removal, mowing, grazing, burning, invasive species control, etc.
- **Funding for biological research.** Local populations of species being harmed by the project can benefit from research, if these research efforts are aimed at furthering our understanding of population dynamics, disease, or other conservation issues critical for enhancing the protection of species being harmed.
- **In Lieu Fee programs or mitigation banking.** By pooling resources across multiple projects, greater conservation outcomes can often be achieved for the species and habitats being impacted. The Maine Natural Resources Conservation Program for wetland impacts is one example of a successful In Lieu Fee program, but there are other options that could be created to capture other impacts.

The Compensation Plan for the Maine Power Reliability Project (MPRP), permitted by the Maine Department of Environmental Protection in 2009, provides a good example of mitigation that addressed the actual temporary and permanent loss of habitat associated with the project by going beyond U.S. Army Corps of Engineers and NRPA mitigation requirements, including additional acreage and In Lieu Fee payment. The project also addressed ecological impacts through restoration, enhancement, and preservation. While the project limited mitigation to wetlands loss, it should be viewed as beginning a trend for mitigating loss and impacts beyond Maine's current regulatory scheme.

Conclusion: Principal Policy Recommendations

Climate change driven by carbon pollution is the biggest and most pervasive threat to Maine's wildlife and habitat. In order to abate this threat, Maine must meet its recently adopted goal to reduce our annual greenhouse gas emissions by at least 45% below the 1990 annual emissions level by 2030 and 80% below the same level by 2050. This can be achieved, in part, by meeting the state's commitment to procuring 80% of retail electricity sales from renewable energy sources by 2030 and 100% by 2050.

To achieve this, we must act swiftly, but we must also act strategically in order to not unduly impact the very same species we seek to protect.

Through a review of current literature, discussions with experts in the field, and exploration of policies in other states, we have uncovered a number of best practices and policies that Maine can and should consider adopting to do just that. Maine can enjoy the benefit of learning from others. Our state has the opportunity to create a new body of evidence on how renewable energy and wildlife can coexist. That said, some things are already clear when it comes to balancing renewable energy development and wildlife:

Solar, located in the built or disturbed environment, is highly encouraged.

Compared to wind power generation, solar has the fewest negative impacts on wildlife. Co-locating solar where it is consumed, in the built environment, or in disturbed areas no longer providing high quality wildlife habitat, nearly negates the threat of habitat loss, as well as the need for new transmission facilities.

New technologies in terrestrial wind energy production will allow us to locate new projects to maximally avoid impacts to wildlife and habitat. The GIS analysis that accompanies this report demonstrates that taller wind towers mean that commercially-viable wind can be "reached" in more places, providing more opportunity to avoid impacts to wildlife and habitat. Developers must look broadly and think creatively when siting new projects.

We must direct resources toward developing offshore wind technology, including understanding how it can coexist with wildlife. Maine has an estimated 156GW of offshore wind potential (65 times greater than the amount of energy Maine people use each year) located in proximity to Maine's coastal population centers.[31] This capacity, coupled with a limited need for transmission infrastructure, means that the potential for meeting our renewable energy goals while minimizing impacts to wildlife is high. But there are many unknowns. Most of Maine's potential is in deep water, a new venture in the United States. Maine must direct resources toward understanding how to capture this potential, while understanding and minimizing impacts to wildlife.

Maine and other states in the region must change their regulatory approaches and engage in long-term planning to reduce the prevalence of transmission lines. There are many opportunities for improving the efficient use of our current infrastructure to reduce the need for more, if any, extensive new transmission lines. Where new lines are justified, they should be co-located with existing lines whenever possible. To avoid lines that crisscross the state, stakeholders must come together to plan how to generate and transmit electricity in a way that maximizes efficiency and minimizes impacts to wildlife and habitat.

Compensatory mitigation must reflect harm to all impacted species and habitats. Projects must strive to avoid and then minimize harm to wildlife. However, some impacts are unavoidable and must be compensated for. Traditionally, mitigation has been limited to listed species and acreage directly impacted. Renewable energy developers should strive to create projects that are a net-benefit for wildlife. That means addressing landscape-scale impacts caused by fragmenting features like transmission lines and accounting for impacts to all habitat types.

And while Maine must act boldly to achieve our renewable energy goals, we must always remember that reducing our energy consumption and increasing energy efficiency is the first and often cheapest line of defense that will pay big dividends for our climate. By walking instead of driving, weatherizing our homes, turning off lights when not in use, and replacing old appliances and heating and cooling systems

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[31] *https://composites.umaine.edu/offshorewind/*

with high efficiency models, we can have a significant impact on the amount of carbon pollution produced. For example, the national, widespread use of LED lighting could save the equivalent annual electric output of 44 large power plants. In addition, restoring urban areas and encouraging new homes and businesses to be built in designated growth areas will reduce the need for long car trips and leave more fields and forests in place to capture carbon—efforts that can make a big difference in reducing carbon pollution.

The climate crisis is here. Oceans are warming from the surface to the deepest seas and marine organisms are shifting to higher latitudes; large storm events occur more frequently now; and ocean acidification is taking its toll on shelled organisms like lobsters and crabs. The time for discussing what actions to take is over—we know what to do, we must simply begin. But with the urgency to act comes a responsibility to act well. We must not destroy the very systems we purport to protect in our rush to move forward. By including policy makers, energy executives, natural resources agencies, and the general public in straightforward discussions of both the urgency to act and the full range of available options, we can make smart energy planning the norm and protecting natural ecosystems the minimum standard.

As Governor Mills said at the U.N. Climate Summit, "We all have what it takes to combat climate change, to protect the irreplaceable earth we share and care for . . . Maine won't wait."

A Statewide Geographic Analysis

of the Intersection of High-value
Wildlife Resources and Wind Resources

Introduction

Maine's wind energy landscape is changing: where there was one operating terrestrial wind project when the Wind Energy Act passed in 2008[32] there are 18 today, and new technologies have produced taller wind turbines that are able to access steadier, stronger winds found at higher altitudes. Taller turbines create more opportunities to access commercially viable wind resources across more of Maine's landscape, making wind an important potential source of energy to help fulfill the state's commitments to a clean energy future.[33] However, taller turbines with larger rotors could pose a greater threat to wildlife and may have greater scenic impacts compared to turbines currently operating in Maine. With these changes comes the need for additional information and planning tools to ensure that Maine continues its transition to a clean energy future, while protecting the important ecological, recreational, and scenic values of undeveloped landscapes.

In 2013, Maine Audubon published a report detailing the results of a spatial analysis of the potential intersection between commercially viable wind resources and high-value wildlife resources in Maine ("Wind Power and Wildlife in Maine: A State-wide Geographic Analysis of High-value Wildlife Resources and Wind Power Classes"). The report determined that enough commercially viable wind resources that did not overlap with high-value wildlife resources were available to meet the state's wind power energy goal of 3,000 MW capacity, including both onshore and offshore wind.[34] In other words, wind energy could be developed in Maine with minimal impact to the state's wildlife. The report served as an important tool for developers and decision-makers as they navigated wind energy development.

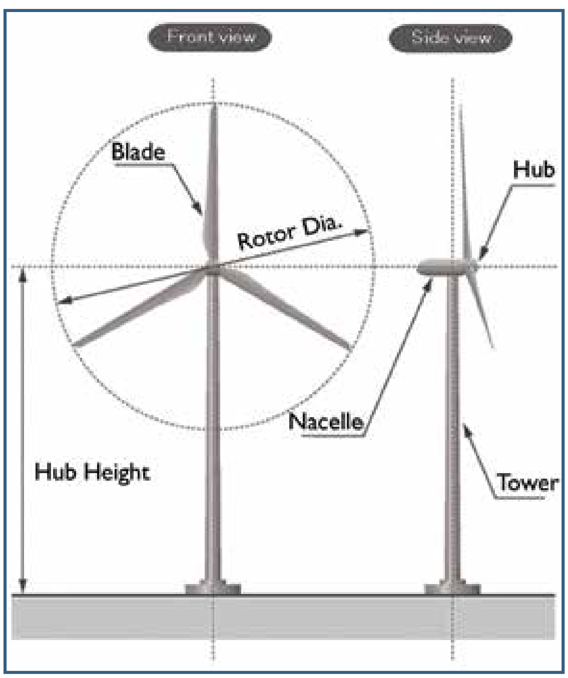

Diagram 1

This report details the results of a new Geographic Information System (GIS) analysis using updated natural resource and wind data, for the purposes of understanding where commercially viable wind resources and natural resources overlap today. New natural resource data include previously

[32] 35-A M.R.S.A, Chapter 34: THE MAINE WIND ENERGY ACT

[33] For highlights of recent policies supporting Maine's investment in renewable energy, see page 10 under the heading "New Policies Will Trigger More Renewables in Maine."

[34] 35-A M.R.S.A, Chapter 34: THE MAINE WIND ENERGY ACT §3404

unknown locations of rare species and natural communities, as well as new conservation lands. New wind resource data include wind resources at 100 meters and 140 meters above the ground, rather than the 80 meters analyzed in 2013. These heights represent current and expected proposed wind turbine hub heights (*see Diagram 1, from Venti Japan, Inc.*). These hub heights are currently used in other countries and are beginning to be proposed in the United States.[35] As in 2013, in this analysis we examined where these wind resources overlap with a variety of wildlife resources in order to determine where onshore wind energy resources can be developed in Maine while avoiding high-value wildlife resources.

For this analysis, Maine Audubon partnered with the Appalachian Mountain Club, who ran a similar GIS analysis to identify where wind projects may have visual impacts to recreationally-significant peaks and lakes in Maine, and the potential intersection of viable wind resource areas and areas identified as having high climate resiliency.[36]

This report is not meant to replace Maine Audubon's 2013 report, but instead is meant to supplement it. We encourage you to review "Wind Power and Wildlife in Maine: A State-wide Geographic Analysis of High-Value Wildlife Resources and Wind Power Classes," which can be accessed at Maine Audubon's website:maineaudubon.org/projects/wind. The 2013 report includes more background information and an assessment of the potential to meet the state's goal of 3,000 MW capacity of wind energy by 2030 with minimal impact to Maine's wildlife resources. Knowing that the goal is obtainable, this report focuses specifically on changes resulting from the new wind and wildlife data and is a part of a larger project evaluating how Maine's renewable energy future—focusing specifically on solar, onshore and offshore wind, and transmission—can have the smallest negative impact on wildlife. Like the 2013 report, the purpose of this analysis is to improve planning, siting, and permitting for future terrestrial wind power projects across the state by demonstrating that there is significant potential to increase renewable wind energy while avoiding high-value wildlife at the same time.

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[35] For example, the Weaver Wind project permitted for the towns of Eastbrook and Osborn, Maine, in 2019 includes turbine heights of 117m.

[36] Sites that are resilient are ones that are most likely to retain high quality habitat and continue to support a diverse array of plants and animals as our climate changes. For more information on the topic, please see The Nature Conservancy's Resilience Fact Sheet at *https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/Documents/ED_Resiliency%20Fact%20Sheet_full%20region_07112014%20(1).pdf*

Methods

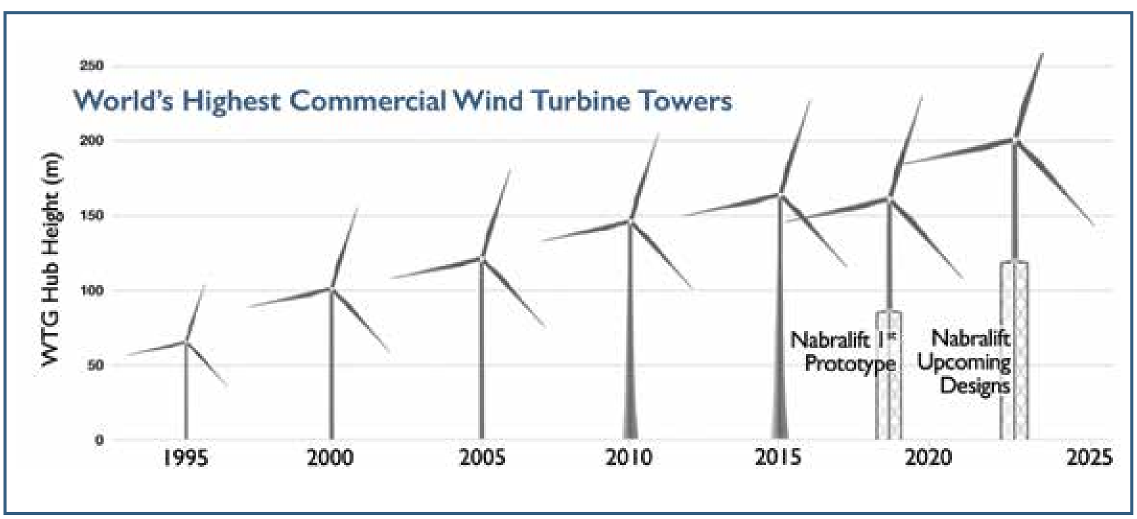
This analysis uses GIS layers of mapped wind energy resources at two different hub heights, 100m and 140m, and multiple wildlife resource values to identify their areas of overlap and to analyze the potential for wind energy development in Maine that avoids high-value wildlife resource areas.

Wildlife resource values are classified into two different groups: Tier 1 resources, which are site-specific and relatively discrete, including specific wildlife habitats and natural communities, and Tier 2 resources, which are landscape-level habitat areas that cover larger expanses, are in part based on spatial models, and that identify locations that are important at the landscape scale for multiple wildlife species.

This analysis is modeled on the analysis conducted for the 2013 report, with several critical differences:

- In 2013, wind resources were categorized according to Wind Power Class, which is a way of quantifying the strength of the wind at a particular height using wind speed and wind power density (how much energy, in watts, is available) on a scale of 1 to 7. The U.S. Department of Energy defined Wind Power Class in 1986, but the industry is moving away from the use of Wind Power Classes. In this analysis, we define wind resources simply based on wind speed in meters per second (m/s). That said, the viable wind speeds in this analysis roughly correspond to the wind speeds associated with the viable wind power classes used in the 2013 analysis.
- In our 2013 analysis, the wind resources examined were those considered potentially viable at 80m hub heights. Because stronger and more consistent winds are found at greater altitudes, raising the height of the wind turbines will allow for the capture of more wind power at any given site. Recent advancements in wind turbine technology have led to the development of wind turbines able to capture available wind energy at 100m, 140m,

Diagram 2



and higher. Taller turbines also have longer blades that can cover a larger area and therefore capture a larger amount of wind energy. This factor also allows more energy to be captured at relatively lower wind speed. This analysis uses wind resources at 100m and 140m hub heights to appropriately capture the geographic expansion of wind resources made available by these technological advances. For a graphic of the change in wind turbine heights over time, see Diagram 2 from Nabra Wind.

- Since 2013, there have been changes in the boundaries of the Expedited and Non-expedited Areas, according to revisions made under *An Act To Improve Regulatory Consistency within the Jurisdiction of the Maine Land Use Planning Commission*, enacted in 2015.[37] As a result of this law, over 731,000 acres of land previously delineated as Expedited Areas under the Wind Energy Act were removed and are now classified as Non-expedited Areas.

As in the 2013 report, we also placed special emphasis on analyzing the wind resources and high priority wildlife resources available within the coastal zone, delineated as the land extending two miles inland from estuaries and the coastline of Maine. Like ridgelines, the land along the coast experiences high wind speeds and this area is home to a high proportion of valuable wildlife resources. We therefore include additional analyses on the viable wind resources and high priority wildlife resources within this coastal zone at 100m and 140m hub heights.

GIS Layers Used in Analysis

Natural Resource Layers

We divided the natural resources for which we have GIS layers into two tiers. Tier 1 resources are based primarily on field surveys of known, mapped, and relatively discrete natural resources. These are generally places on the landscape where turbines and their associated roads and structures should be avoided. Tier 2 resources, in contrast, cover larger areas, and are primarily models of important habitat that stretch across the landscape. Avoiding Tier 2 resources to maximize quality wildlife habitat is preferred, but best management practices that minimize impacts may be practicable for siting in or at the edges of Tier 2 resource blocks. The specific Tier 1 and 2 layers are listed below. We removed open water from the wind layer as it cannot be developed for terrestrial wind. In order to draw a direct comparison, we also removed open water from the natural resource layer. This is not to suggest that terrestrial wind projects do not impact open water habitats, but rather, that direct impacts to open water habitats will be assessed using impacts to riparian and wetland buffers where construction activities for wind projects might occur.

[37] "An Act To Improve Regulatory Consistency within the Jurisdiction of the Maine Land Use Planning Commission," P.L. 2015, ch. 265.

Tier I Natural Resources: Discrete habitat areas based on site-specific data

- **Riparian and Wetland Buffers (Wetland Buffers):** We created buffers around riparian and wetland areas similar to those in place for municipal Shoreland Zoning. They include an upland buffer of 250 feet from the edge of lakes, ponds, rivers, coastline and wetlands greater than 10 acres, as well as 75 feet around ponds less than 10 acres and perennial streams. *(Source: Maine Department of Inland Fisheries and Wildlife (MDIFW), 2018)*

- **Deer Wintering Areas (DWA):** Polygons for these Significant Wildlife Habitats are included for organized towns as well as the Fish and Wildlife Protection Subdistrict (P-FW zones) within the Land Use Planning Commission's jurisdiction (LUPC). *(Source: MDIFW, 2018)*

- **Inland Waterfowl and Wading Bird Habitat (IWWH):** Polygons for these Significant Wildlife Habitats include moderate and high-value wetlands and a 250-foot upland habitat area around the wetland. *(Source: MDIFW, 2018)*

- **Endangered, Threatened, and Special Concern Species (ETSC):** This layer includes known locations for 101 rare and special concern species (*See List of Endangered, Threatened, and Special Concern species in the DIFW GIS layer, page 74*). Lands around observed locations or polygons are species-specific, based on habitat use. *(Source: MDIFW, 2018)*

- **Shorebird Habitat (Shorebird):** Polygons for these Significant Wildlife Habitats include a 250-foot area around all designated roosting areas and a 100-foot area around all designated feeding areas. *(Source: MDIFW, 2018)*

- **Tidal Waterfowl and Wading Bird Habitat (TWWH):** Polygons for these Significant Wildlife Habitats include the identified tidal wetland habitat. *(Source: MDIFW, 2018)*

- **Exemplary Natural Communities (MNAP):** Polygons provided by the Maine Natural Areas Program for rare plants and rare or exemplary natural communities include both specific points (or for some species, habitat) where populations of rare, threatened, and endangered plants have been documented, as well as rare natural communities and those that are common but in exemplary condition. *(Source: Maine Natural Areas Program, 2018)*

- **Wading Bird Colony Buffers (GBH):** This layer includes Great Blue Heron rookery locations plus land within one-quarter mile of the rookery. Herons travel well beyond this distance to feed, but any areas beyond a quarter-mile would need to be directional and based on observed behavior, so are not included in our analysis. *(Source: MDIFW, 2018)*

Tier 2 Natural Resources: Landscape-level habitat areas

- **Beginning with Habitat Focus Areas**: These are natural areas of statewide ecological significance that contain unusually rich concentrations of high-value and at-risk species and habitats. These areas support rare plants, animals, and natural communities; high quality common natural communities; Significant Wildlife Habitats; and their intersections with large blocks of undeveloped habitat. Beginning with Habitat (BwH) Focus Area boundaries are drawn based on the species and natural communities that occur within them and the supporting landscape conditions that contribute to the long-term viability of the species, habitats, and community types. *(Source: Beginning with Habitat, MDIFW, 2018)*

- **Modeled Bicknell's Thrush Habitat**: Bicknell's Thrush is the rarest migratory songbird in the east and is endemic to subalpine spruce-fir forest in the northeastern United States and maritime Canada. The layer includes potential Bicknell's Thrush habitat as identified in a model developed by the Vermont Institute of Natural Sciences in 2005. *(Source: Vermont Center for Ecostudies, 2016)*

Base Wind Layers

The base wind layers we used were developed from datasets accessed from Windnavigator, AWS Truepower, LLC, in August 2017. The data were in the form of floating point raster datasets projected in the World Geographic System (WGS) for winds at 100m and 140m above ground. To facilitate the spatial analyses, we reclassified these data to integer rasters with 0.5 m/s intervals above 4.49 m/s. We converted the rasters to feature classes, which were re-projected to UTM19N to work with the resource data.

We know that wind speed is only one of many factors that interact in a complex fashion to make a site suitable for wind development. While we cannot account for many of those factors, we eliminated areas with wind speeds too low to be considered commercially viable, as well as very small and isolated areas as their likelihood of development is quite low. Commercially viable wind speeds were determined by examining the average annual wind speeds found in the final configurations at all operating and potential turbines in Maine that are included in the November 2017 FAA data available from USFWS. Based on this information, we removed all areas with wind speed under 6.5 m/s at both heights of 100m and 140m. We kept the next lowest wind speed areas (6.50-6.99 m/s) only if they abutted areas with 7.0 m/sec wind or more.

In other words, areas of wind speeds 6.50-6.99 m/s had to abut areas of greater wind speeds to remain in the Base Wind Layers. We also clipped all polygons that were less than 4 ha in size, regardless of wind speed or proximity to other polygons, as well as any isolated 4 ha (single pixel) polygons that were more than 400m away from any other polygons. Additionally, we removed from the wind layer any wind resource overlapping open water (lakes, ponds, and ocean) as these areas are not developable for terrestrial wind projects.

We created two base wind layers using the methods described above for wind resources at 100m hub heights and 140m hub heights. These layers will be identified as the "100m Wind Base" and the "140m Wind Base" respectively throughout this report.

Expedited and Non-Expedited Permitting Areas

These areas were designated in the 2008 Wind Power Siting Law, *An Act To Implement Recommendations of the Governor's Task Force on Wind Power Development*, and have been modified by the Land Use Planning Commission (LUPC, 2018). Under this law, Expedited Permitting Areas are those areas defined by the legislature as being more appropriate for grid-scale wind energy developments. While standards for natural resource protection are the same in Expedited and Non-expedited Permitting Areas, standards for scenic impacts are higher in Non-expedited areas and they require an additional step of rezoning before the Maine Land Use Planning Commission. See Figure 1, Expedited and Non-expedited Wind Permitting Areas, for current delineations.

Expedited and Non-expedited Wind Permitting Areas

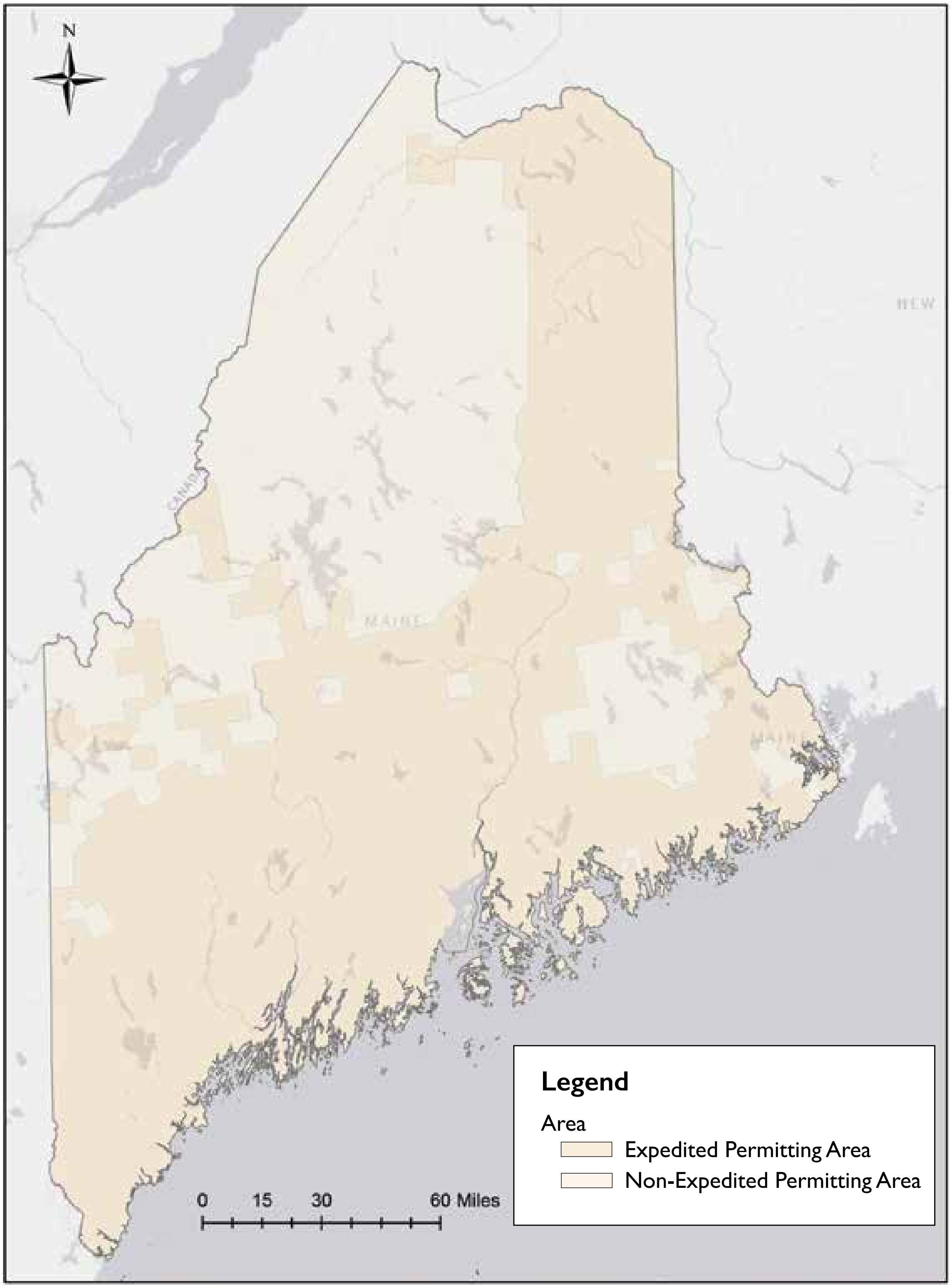


Figure 1: Expedited and Non-expedited Wind Permitting Areas pursuant to the Maine Wind Energy Act

Coastal Areas

For this analysis, we delineated the land base within 2 miles of the coast and estuaries. This is because terrestrial areas in close proximity to coastlines often contain important wind resources and important wildlife resources where the overlap between energy development projects and wildlife habitats may be higher.

Conservation Lands

The Conserved Lands layer contains conservation lands ownership boundaries at 1:24,000 scale for Maine land in federal, state, municipal, and nonprofit ownership and includes conservation lands held in fee and those with conservation easements. The ownership lines do not represent legal boundaries nor are the ownership lines a survey. *(Source: State Planning Office, 1993)*

Limitations

It is important, before a discussion of the results of this analysis, to highlight several limitations that should restrict the interpretation of our results.

1) **The wind data used for these analyses, although mapped on a fine scale, are only a model of actual wind power potential.** We recognize that the base layer of potential wind power is a model of expected wind, based on a suite of geographic variables and modeled on a fairly coarse grid across the state. We recognize that some areas with high wind speeds on the map will not be acceptable sites for wind development due to other factors such as sheer, turbulence, soils, slopes, etc. We also recognize that some of the areas identified as having low wind resources may in reality have much higher wind speeds, and that developers must collect several years of site-specific meteorological data in order to fully evaluate and assess the potential suitability of a site for development. Any maps created as a result of this project should not be interpreted as pinpointing specific, project-level locations on the ground. The wind speed data used in this analysis provide a starting point for the creation of possible scenarios for where viable wind resources might be more or less likely, but we realize that it vastly oversimplifies the process used to identify suitable sites for wind development.

2) **The siting of wind development projects is a complex process.** There are many factors that affect the profitability, and therefore the economic viability, of a wind development project. It is beyond the scope of this analysis to evaluate the economic viability of different locations within the state, especially in relation to transmission lines, either existing or proposed.

3) **Not all wildlife resources have been adequately mapped, many wildlife resources lack statewide geographical information, and not every available mapped wildlife resource was included in this analysis, though many deserve consideration during the wind permitting process.** Because of these data limitations, the results of this analysis should not be used to absolutely identify areas for wind development with an expectation that there will be no impacts to wildlife. Rather, the lack of complete wildlife resource data illustrates the continued need to evaluate wind project proposals on a site-specific basis. Areas that show up in this analysis with little or no potential impacts to natural resources may in fact, once evaluated more closely with site-specific data, be unsuitable for wind development from the perspective of adverse impacts to wildlife resources.

4) **There are many values on the landscape beyond wildlife resources that may affect the level of impact of any particular wind development project.** Maine Audubon's mission is conserving wildlife and wildlife habitat, and that is our focus when evaluating the impact of potential wind developments. This analysis is limited to wildlife-related resources and potential overlap with wind resources. The Appalachian Mountain Club used the same wind speed data to analyze potential visual and scenic impacts, as well as potential overlap with the landscape resiliency data developed by The Nature Conservancy[38]; these should be taken into consideration when evaluating a potential site as well. Additional values such as noise, impacts to recreation opportunities, tourism, etc., are not included as part of this analysis.

5) **Impacts from wind development projects extend far beyond just the turbines and pads.** Access roads, clearing for maintenance, and transmission lines are all necessary components of an industrial scale wind project and can have significant and cumulative impacts on rare and endangered species, high-value habitats, wetlands and other water resources, soils, steep slopes, habitat fragmentation, and connectivity. We are unable to fully account for these impacts in our analysis of the overlap of known wind and wildlife resources.

[38] See "The impact of existing and potential wind power development on high-value scenic resources in Maine" to be published late 2019 by the Appalachian Mountain Club.

Wind Resources

As expected, increased turbine height significantly expanded the area available for potential wind projects, with commercially viable wind resources found on 3.3 million acres in Maine (16% of the state's total land cover) using the 100m Wind Base, and nearly four times that amount—12.2 million acres—using the 140m Wind Base. With taller wind turbines, more than half of the total land cover of Maine—59%—has the potential for commercially viable wind resources. The wind speed distribution of available wind resources is fairly similar at both heights, with most of the available wind power concentrated at the lowest viable wind speeds (87% at each height, at wind speeds between 6.5 and 7.5 m/s). However, because of the dramatic expansion of commercially viable Wind Base available with taller turbines, there are 1.6 million acres with wind speeds above 7.5 m/s at a hub height of 140m *(See Figure 2, Wind Resources Available)*.

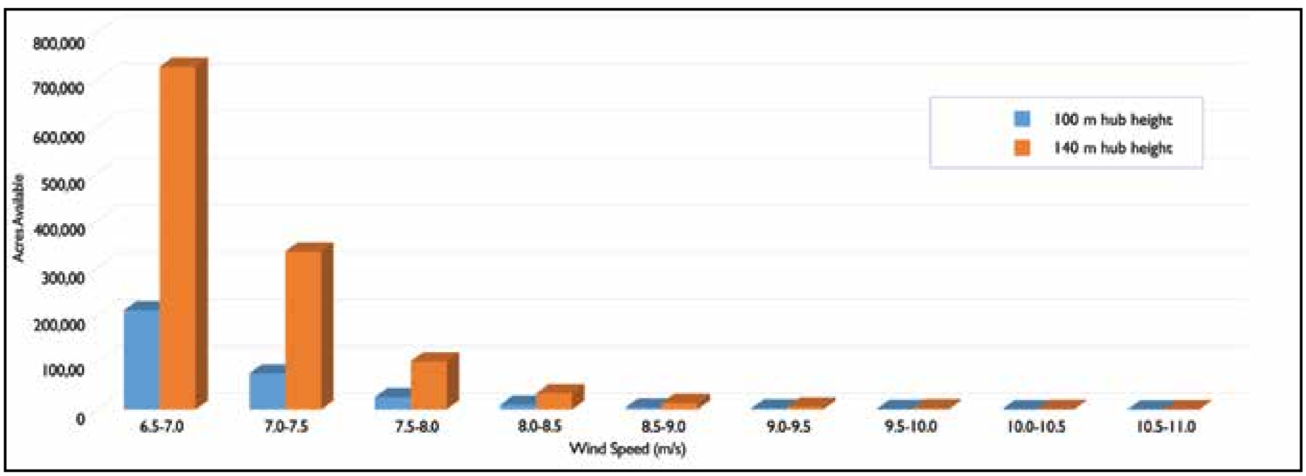


Figure 2. Wind Resources Available at wind speeds above 6.5m/s, at 100m hub height and 140m hub height.

The areas with potentially viable wind speeds at each of these heights are also split fairly evenly between the Expedited Areas and the Non-expedited Areas. See Figures 3a-3c for comparisons of proportional acres of land within the Expedited and Non-expedited Areas, and the proportional acres of land with commercially viable wind resources within these permitting areas at 100m and 140m hub heights. Figures 4 and 5 are maps showing where commercially viable wind resources at 100m and 140m hub heights can be found in Maine.

Proportion of Land within each Permitting Area

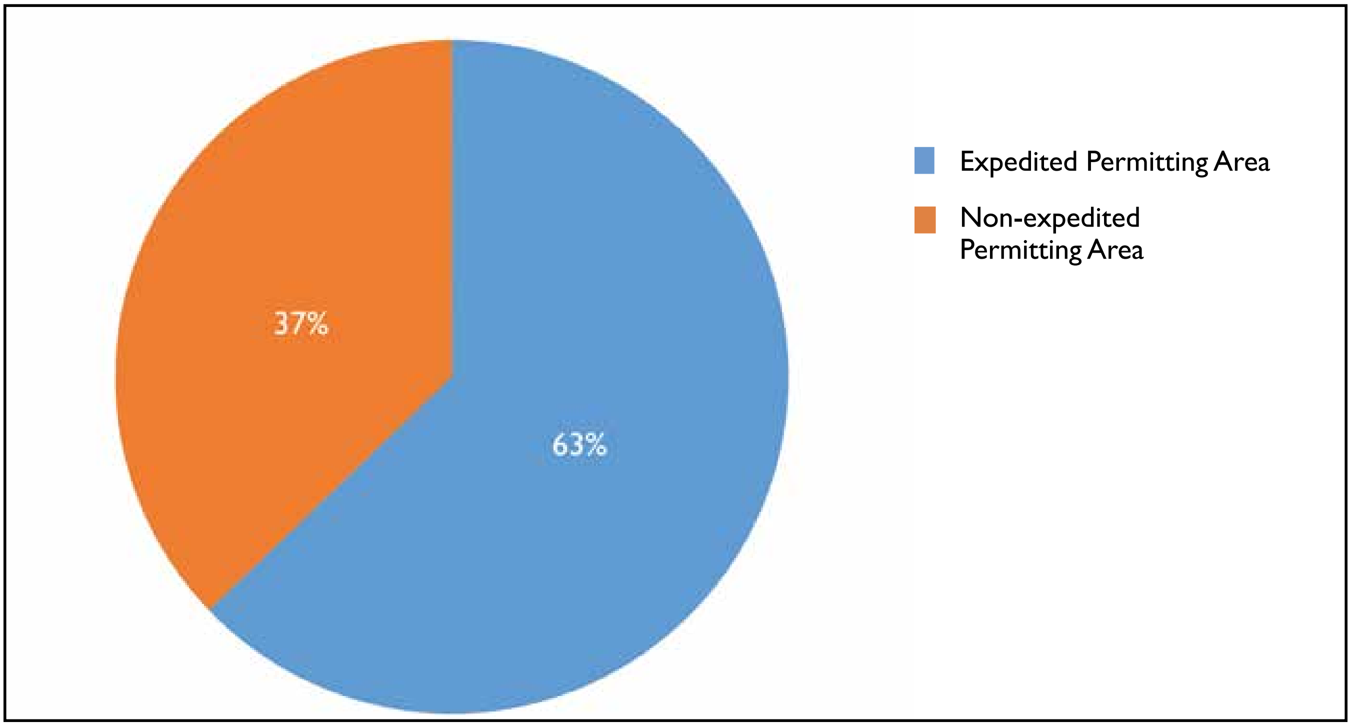


Figure 3a. Proportion of land within the Expedited and Non-expedited Permitting Areas within the state of Maine.

Proportional Viable Wind Resources at 100m Hub Heights

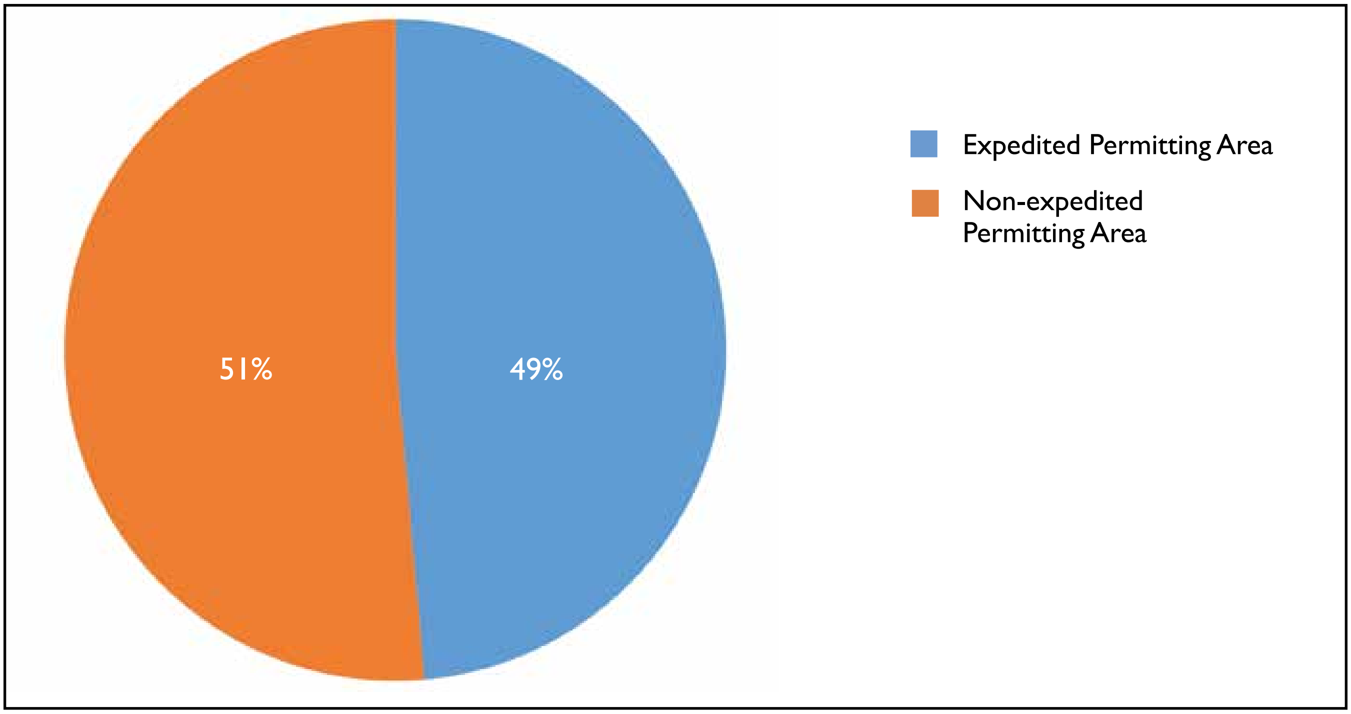


Figure 3b. Proportion of land with commercially viable wind resources, at a hub height of 100m, found within the Expedited and Non-expedited Permitting Areas within the state of Maine.

Proportional Viable Wind Resources at 140m Hub Heights

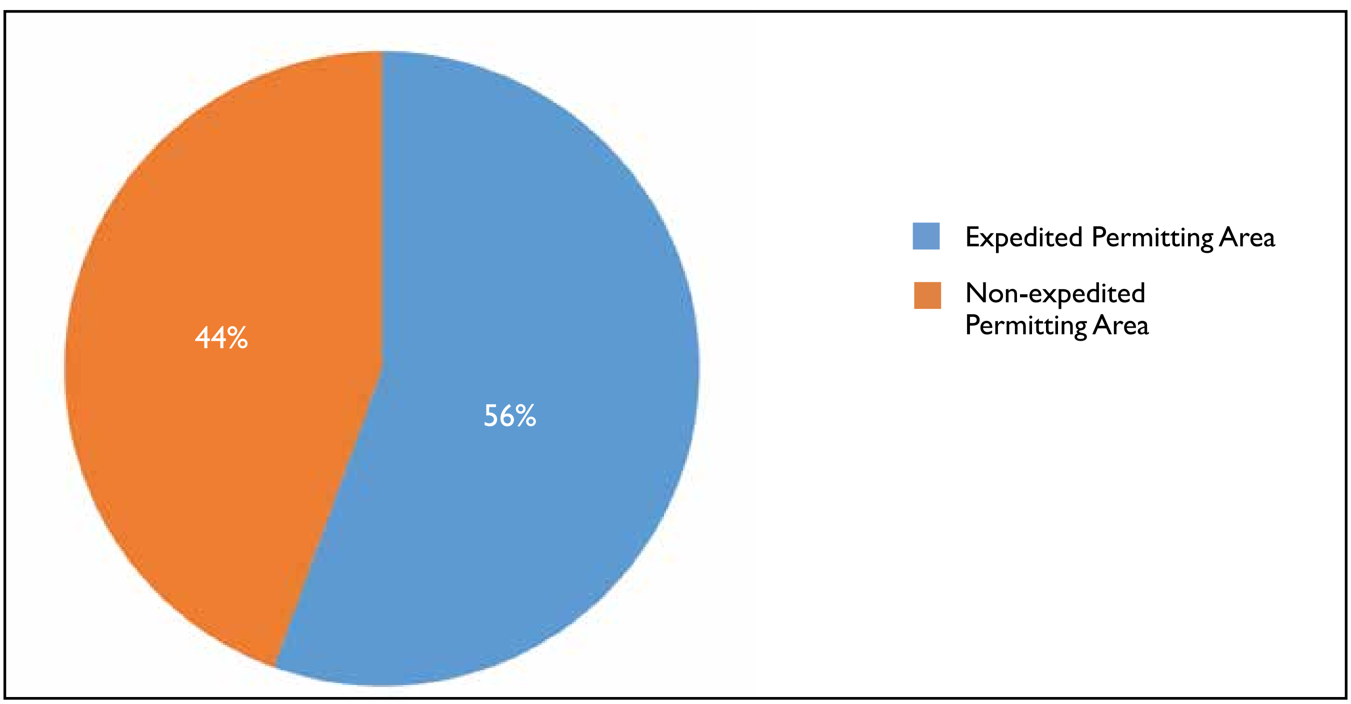


Figure 3c. Proportion of land with commercially viable wind resources, at a hub height of 140m, found within the Expedited and Non-expedited Permitting Areas within the state of Maine.

Commercially Viable Wind Resources at 100m Hub Height

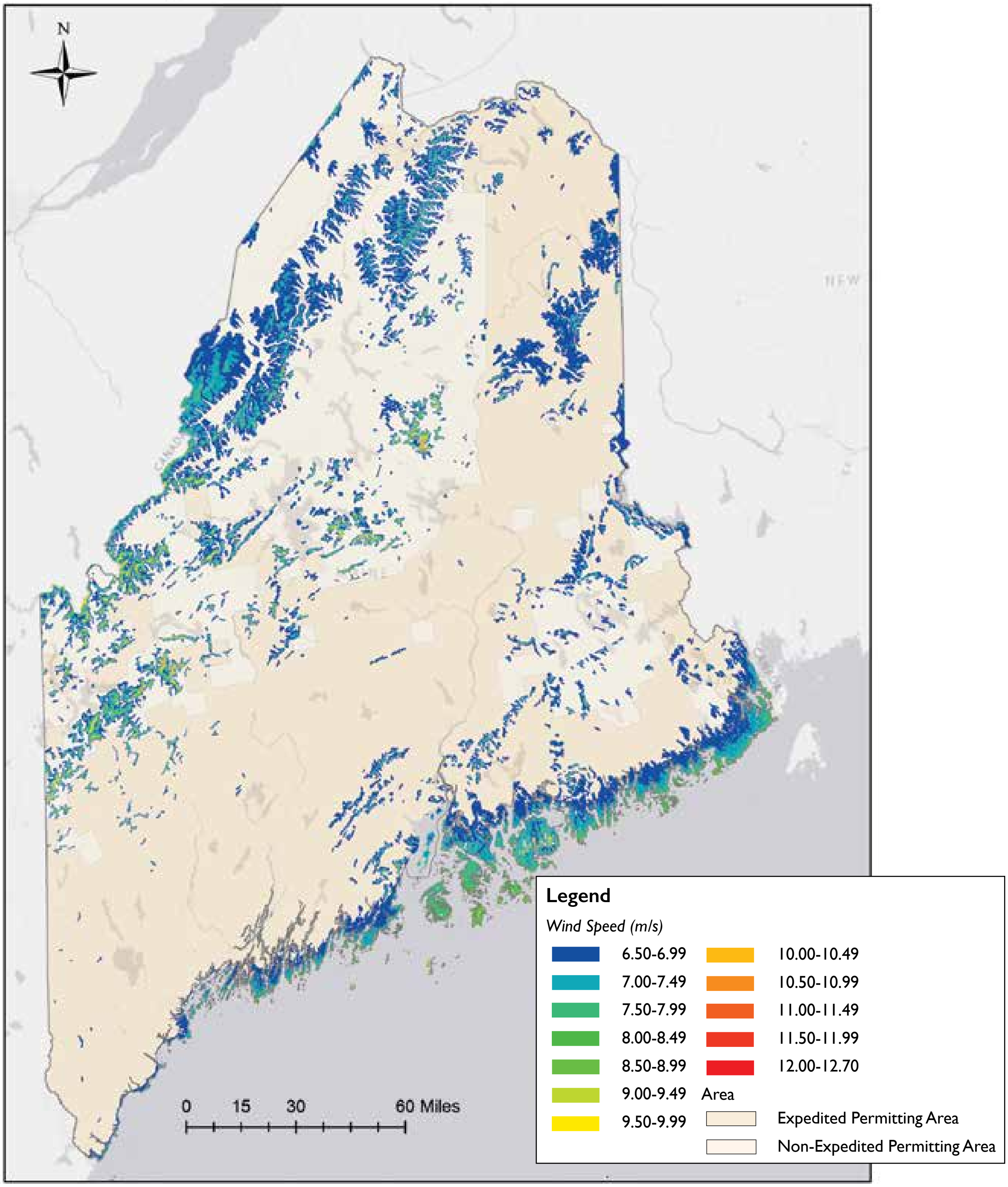


Figure 4. Map of where commercially viable wind resources at 100m hub height can be found in Maine.

Commercially Viable Wind Resources at 140m Hub Height

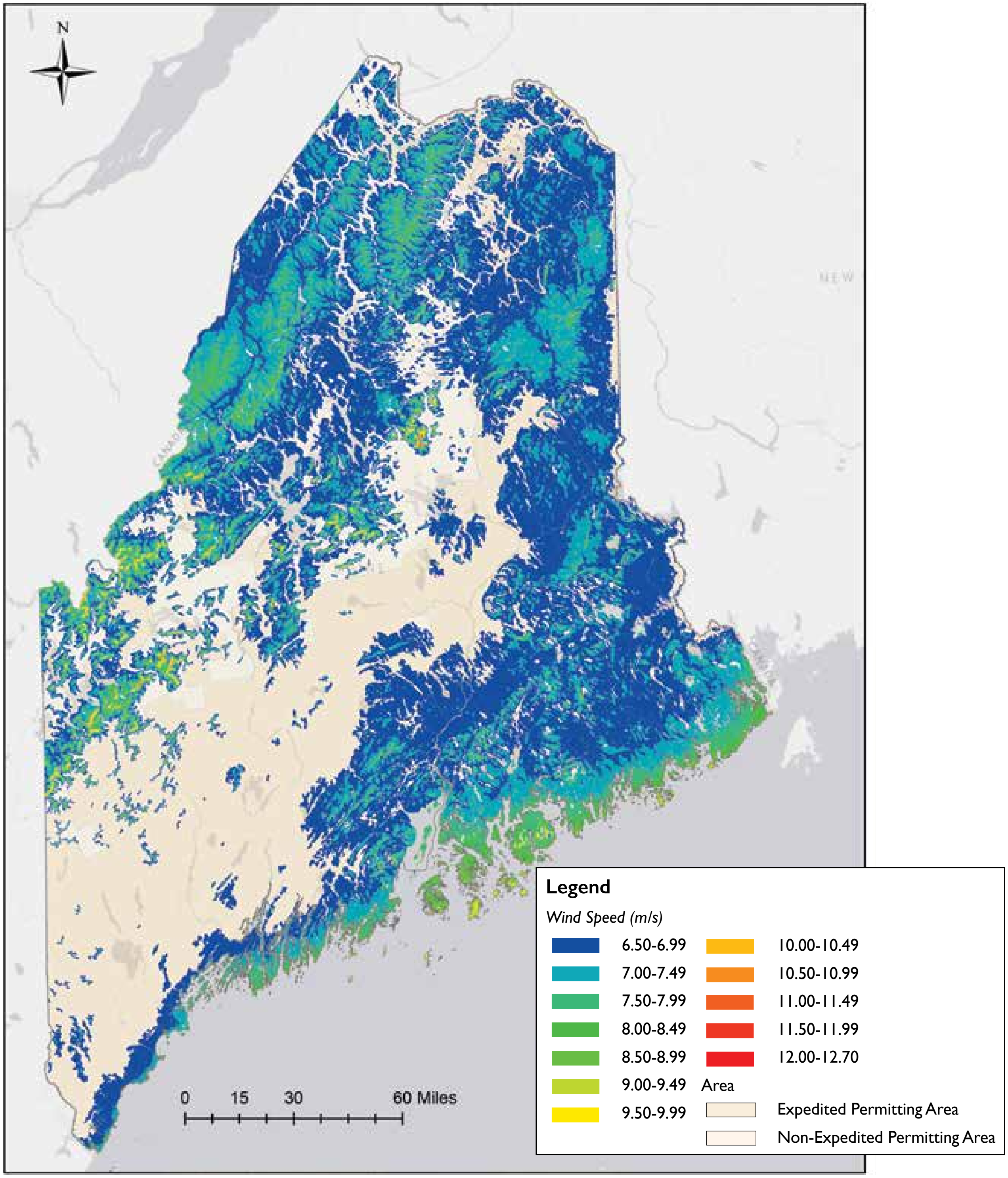


Figure 5. Map of where commercially viable wind resources at 140m hub height can be found in Maine.

Wildlife Resources

The potentially viable wind resources available at the different hub heights overlap the wildlife resources differently, e.g., shorter turbines are likely to be sited at higher elevations where vulnerable alpine natural communities and Bicknell's Thrush habitat can be found, whereas taller turbines can be located at lower elevations where there may be more wetlands and wetland buffers. More specifically, a larger proportion of the 100m Wind Base overlaps with rare species habitats (ETSC Resources) and Exemplary Natural Communities (MNAP Resources) compared to the 140m Wind Base. Similarly, a larger proportion of the 140m Wind Base overlaps with Wetland Buffers, Inland Waterfowl and Wading Bird Habitat, and Deer Wintering Areas compared to the 100m Wind Base. Please note many of these wildlife resources overlap with each other, so totals add up to more than 100%. See Figure 6.

As noted in Figure 6, many of these wildlife resources overlap each other, with some areas housing multiple Tier 1 Wildlife Resources as well as Tier 2 Wildlife Resources. Areas with multiple Tier 1 and/or Tier 1 and Tier 2 Wildlife Resources should be prioritized above others to avoid when developing wind energy projects or other development, as impacts to such unique places can have long-term and far-reaching effects on wildlife and habitat. See Figures 7 and 8a-8d showing multiple Tier 1 and Tier 2 Wildlife Resources overlap and where they overlap with the 100m Wind Base.

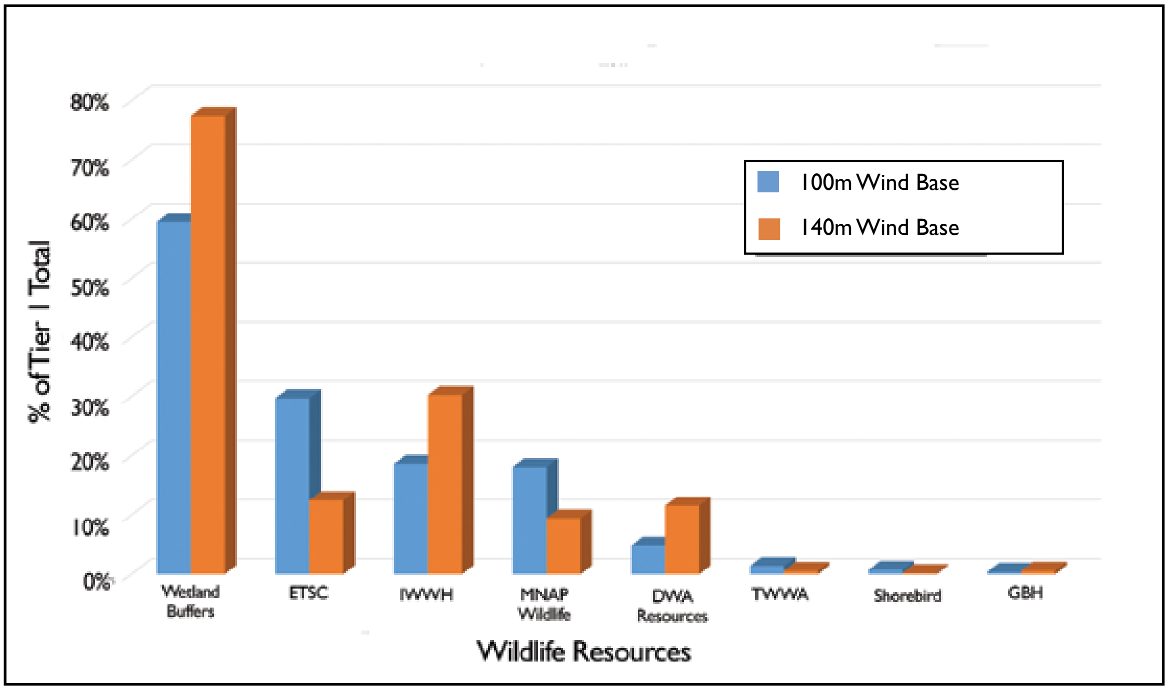


Figure 6. Distribution of Tier 1 Wildlife Resources overlapping with areas of commercially viable wind at 100m and 140m hub height.

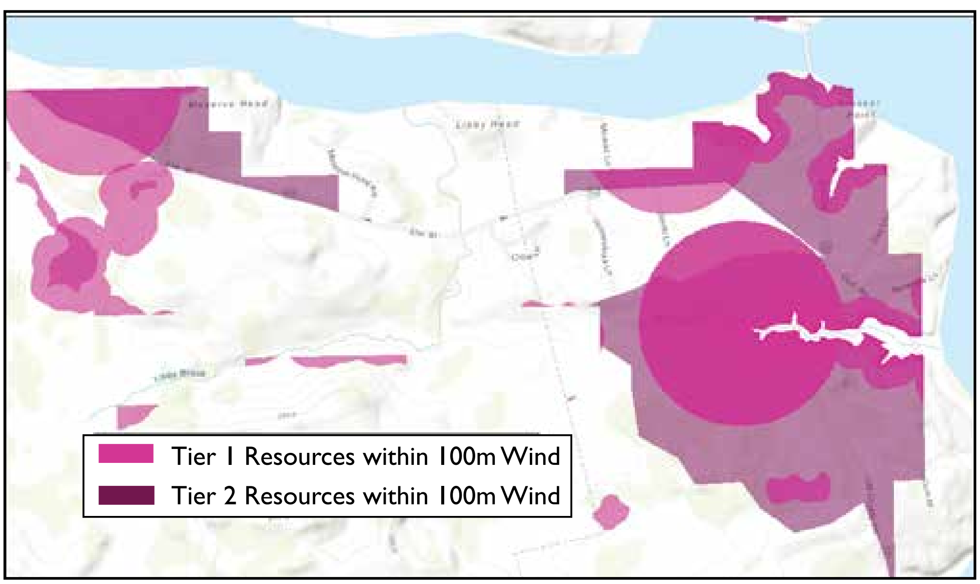


Figure 7. Multiple Tier 1 and Tier 2 Wildlife Resources overlap within the 100m Wind Base. Note here and in detailed example below how wildlife resources are "clipped" to the boundary of the Wind Base layer.

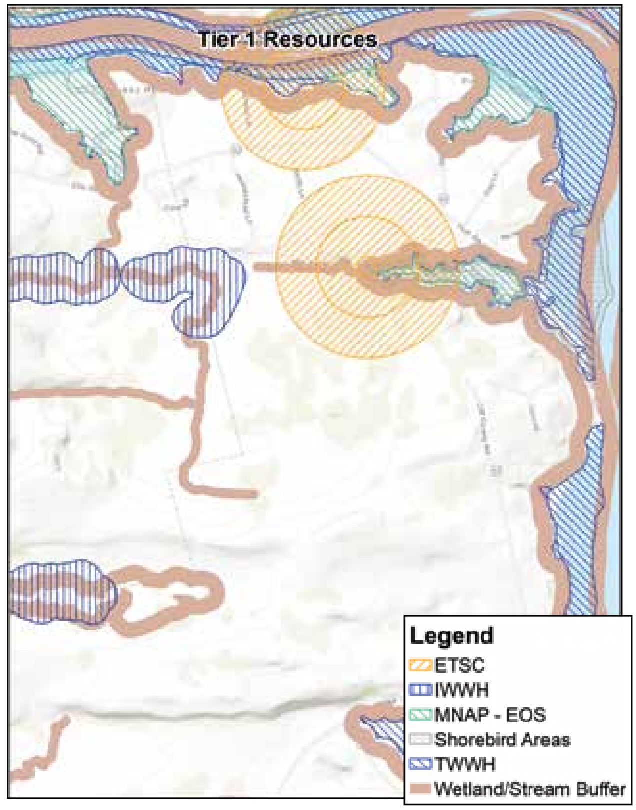
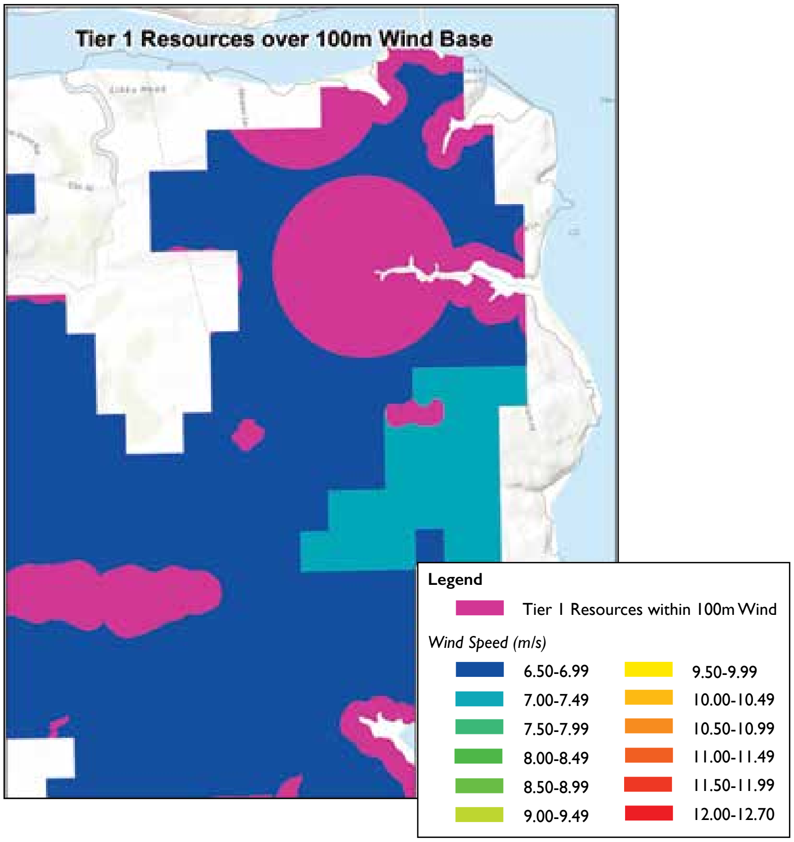
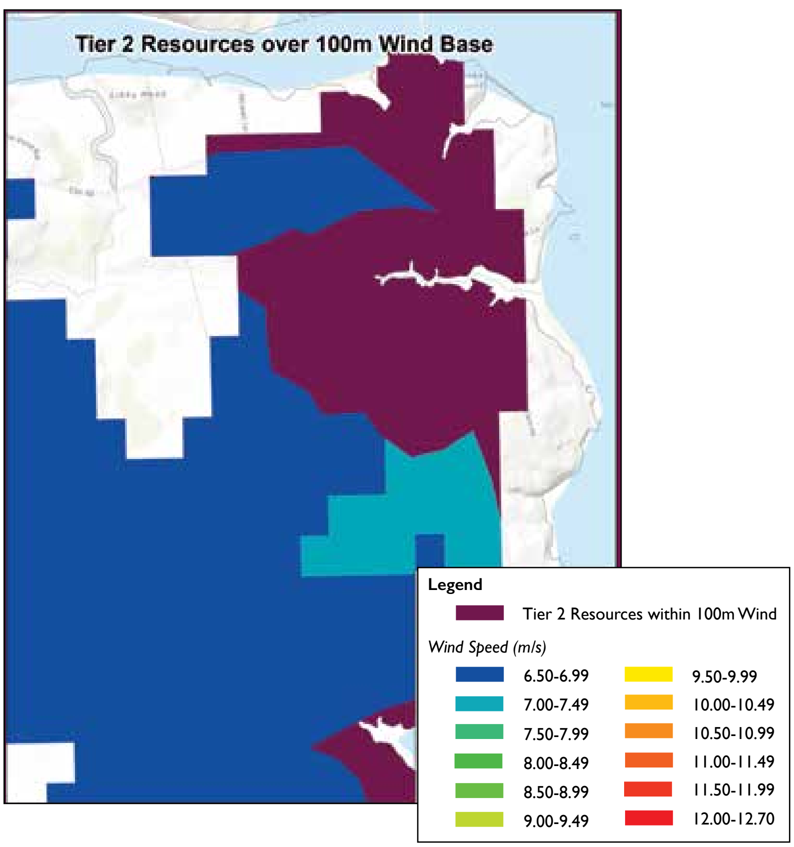


Figure 8: a) Multiple Tier 1 Wildlife Resources overlap; b) Tier 2 Wildlife Resources in the same area.





Because increased hub heights expand the available acreage of commercially viable wind resources, it may be possible for new wind projects to avoid mapped wildlife resources altogether. Even using the 100m Wind Base, if all mapped Tier 1 resources were avoided, 2.8 million acres would still be available for commercial wind power generation. If Tier 1 resources *and* Tier 2 resources were avoided, 2.4 million acres of 100m Wind Base are still available; that is more than double the 1.1 million *total* acres of Wind Base available at 80m, as detailed in the 2013 report *(See Figure 9, Map of 100m Wind Base, minus Tier 1 and Tier 2 Wildlife Resources).*

Looking at the 140m Wind Base, if mapped Tier 1 resources are avoided, 9.4 million acres are still available, and avoiding both Tier 1 and Tier 2 resources leaves 8.7 million acres, or 71% of the total commercially viable wind resource at 140m *(See Figure 10, Map of 140m Wind Base, minus Tier 1 and Tier 2 Wildlife Resources).* Of that, 3.7 million acres have wind speeds at or above 7.0 m/s.

Please note, a desktop evaluation of these resources should not take the place of detailed site-specific investigations of any proposed site to identify any unmapped habitats, species, or resources such as Significant Vernal Pools and talus slopes/rocky outcrop areas present at the site. Likewise, it should be recognized that GIS mapping may not be accurate and site specific investigations may supercede GIS mapping.

Figure 8: c) where Tier 1 Wildlife Resources overlap with an area of commercially viable wind resources at 100m hub height; and d) where Tier 2 Wildlife Resources overlap with areas of commercially viable wind resources at 100m hub height.

Commercially Viable Wind Resources at 100m that Avoid Tier 1 and Tier 2 Natural Resources

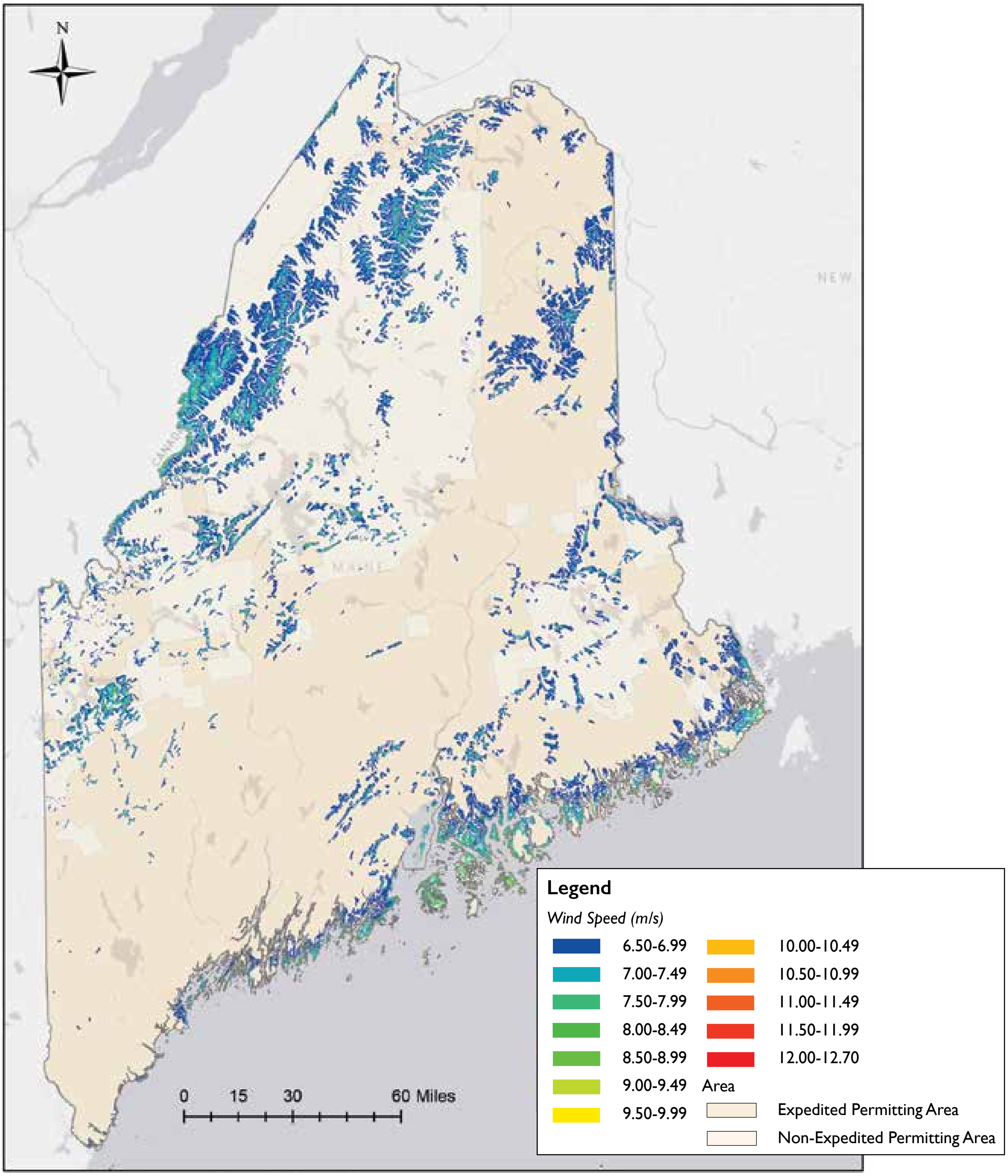


Figure 9. Map showing commercially viable wind resources at 100m hub height if Tier 1 and Tier 2 Wildlife Resources are avoided. 2.4 million acres of area with commercially viable wind resources are available.

Commercially Viable Wind Resources at 140m that Avoid Tier 1 and Tier 2 Natural Resources

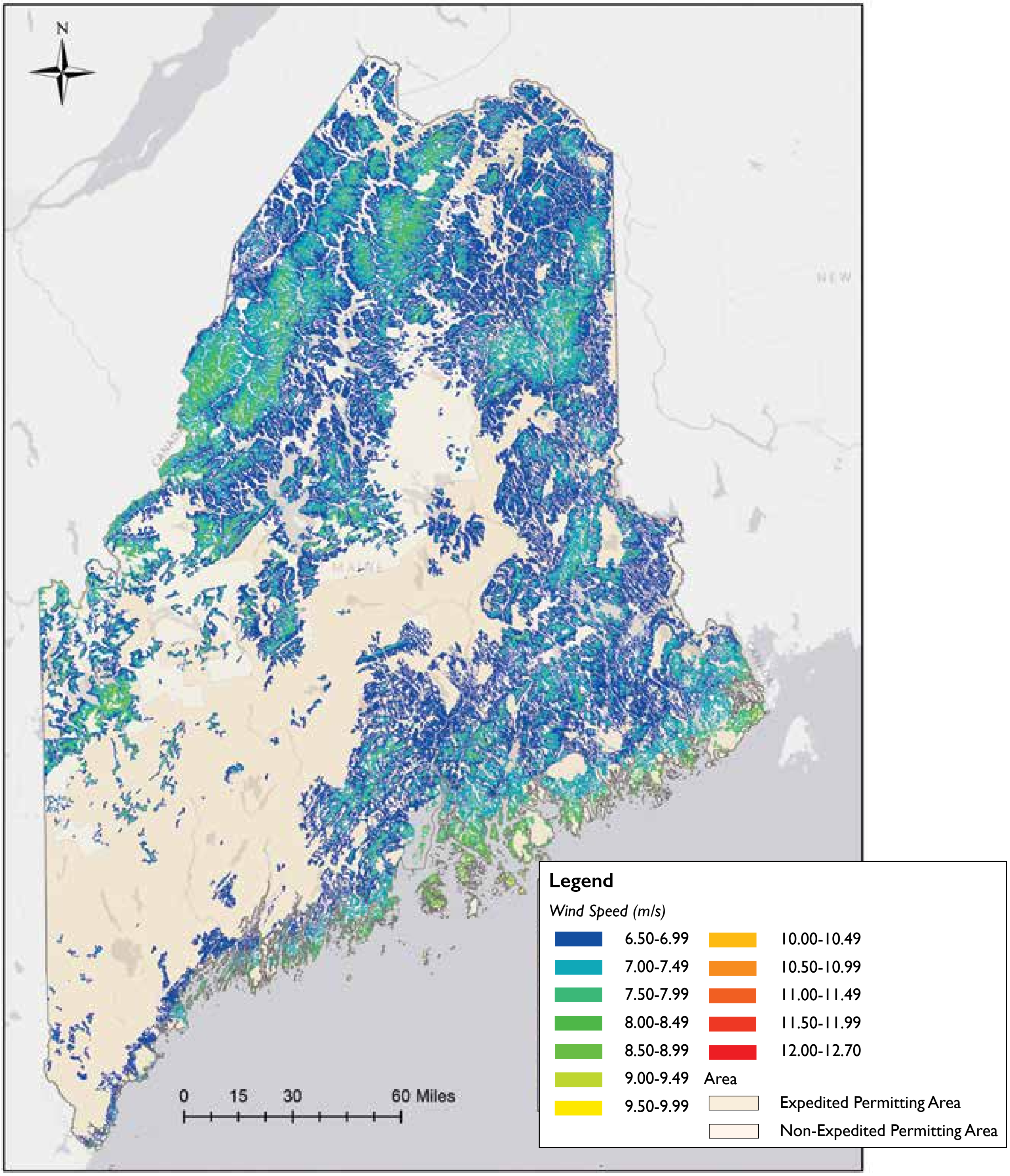


Figure 10. Map showing commercially viable wind resources at 140m hub height if Tier 1 and Tier 2 Wildlife Resources are avoided. 8.7 million acres of area with commercially viable wind resources are available.

Coastal Habitats and Wind Resources

As noted in the 2013 report, wind resources at 80m hub heights are often concentrated along ridgelines and in coastal areas; this is also true for wind resources at 100m hub heights. As in 2013, we looked specifically at the wind resources available on the land base within 2 miles of the coast and estuaries of Maine. For the 100m Wind Base, 20.4% was found within the Coastal Area *(see Figure 4, 100m Wind Base map)*, even though the Coastal Area only accounts for 7.2% of the land base of Maine. In addition, the wind speeds in the Coastal Area included a larger proportion of higher wind speeds *(see Figure 11).*

The 140m Wind Base, however, told a slightly different story. While wind speeds were higher along the coast, the 140m Wind Base was not as concentrated in the Coastal Area as it was for the 100m and 80m Wind Bases *(see Figure 5, 140m Wind Base map)*. The proportion of Coastal Area compared to the entire 140m Wind Base, at 9.7%, was much more aligned with the proportion of Coastal Area compared to the land base of Maine, at 7.2%. In addition, proportionally more of the 140m Wind Base in higher wind speed categories is found along the coast, compared to the distribution of wind speeds across the state *(see Figure 12)*.

Distribution of Wind Resources at 100m Wind Base

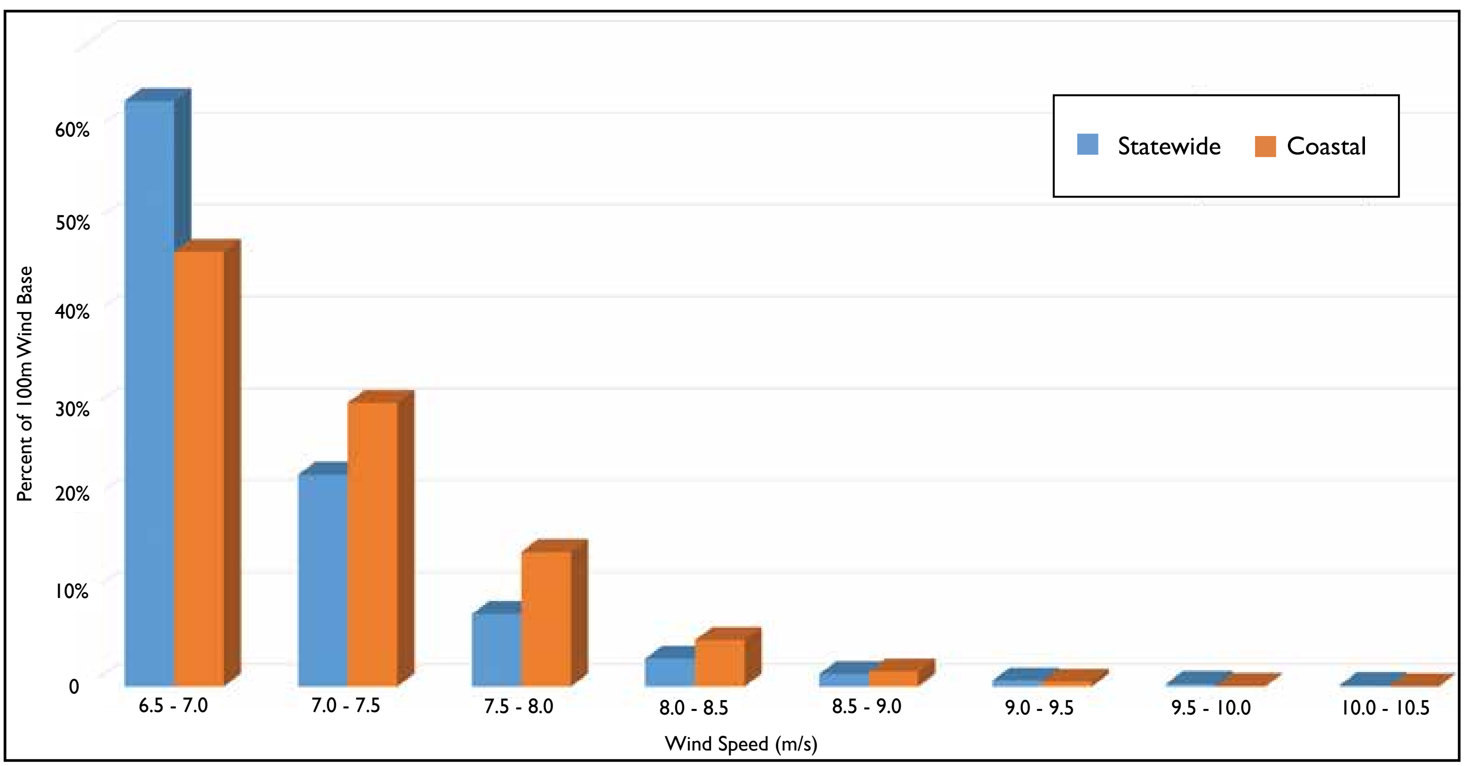


Figure 11. Comparison of the distribution of commercially viable wind resources at 100m hub height within the coastal area vs. statewide. Higher wind speeds are found within the coastal area compared to the rest of the state, proportionally.

Distribution of Wind Resources at 140m Wind Base

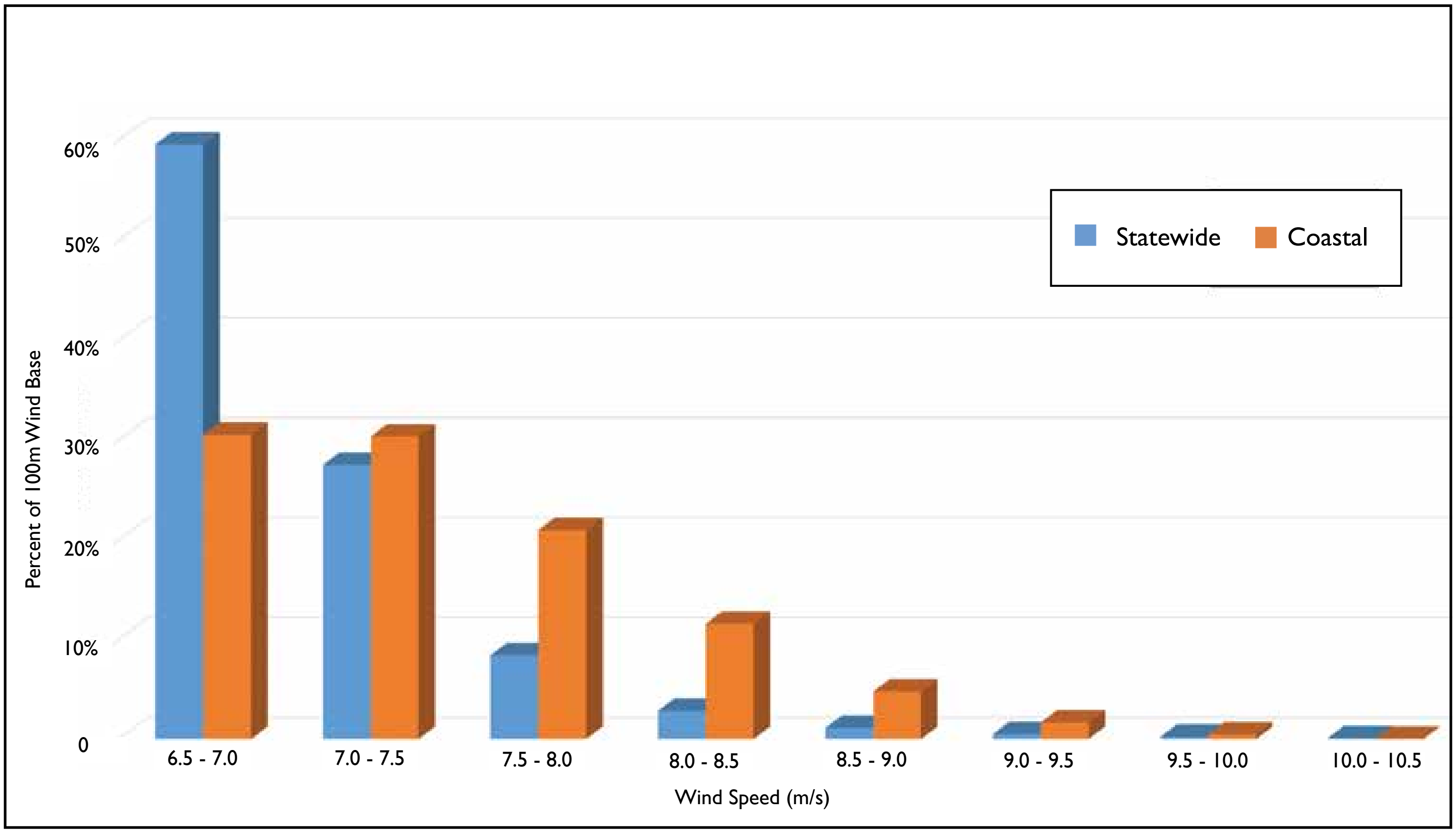


Figure 12. Comparison of the distribution of commercially viable wind resources at 140m hub height within the coastal area vs. statewide. Higher wind speeds are found within the coastal area compared to the rest of the state, proportionally.

Conservation Land

Conservation Land is land protected in fee and/or through conservation easements to provide land-based recreational, ecological, economic, and scenic values for this and future generations *(see Figure 13).* They are another valuable natural resource on Maine's landscape that could be impacted by wind energy development. Making up approximately one-quarter of both the 100m Wind Base and the 140m Wind Base, conservation land significantly but not overwhelmingly overlaps the commercially viable Wind Base *(see Figures 14 and 15)*. These lands and waters typically contain important ecological values, restrict development in order to maintain agricultural and forest resources, and provide habitat for rare, sensitive, and high-value fish and wildlife. In addition, they often provide public access and opportunities for hunting, fishing, and nature-based recreation and tourism. In unusual circumstances, some of these lands may allow wind energy development, but in general conservation land should be avoided, and every effort should be made to seek alternative sites for wind turbines and alternative routes for transmission lines.

Conservation Land

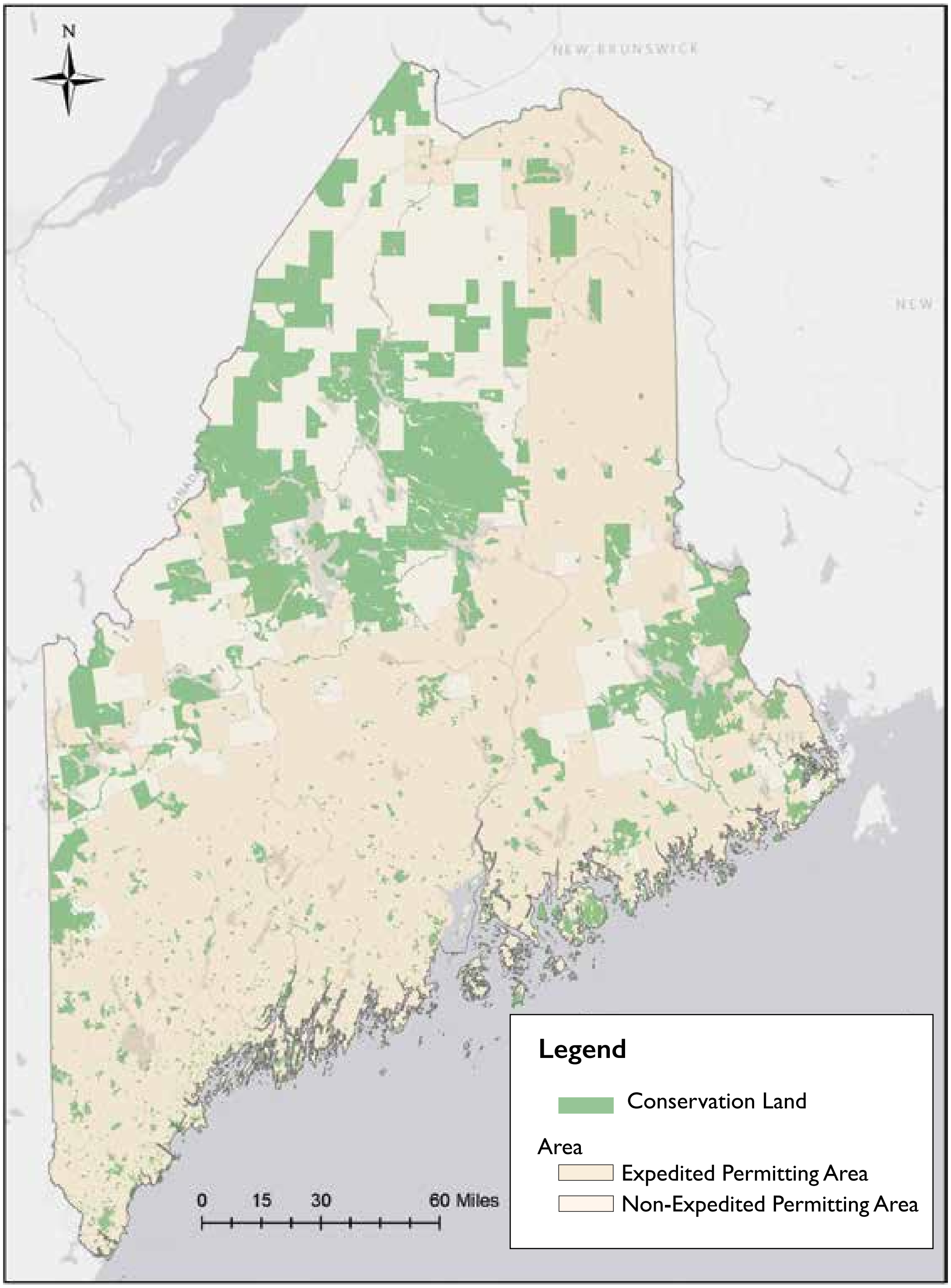


Figure 13. Conservation land across the state of Maine.

Conservation Land and Wind Resources at 100m

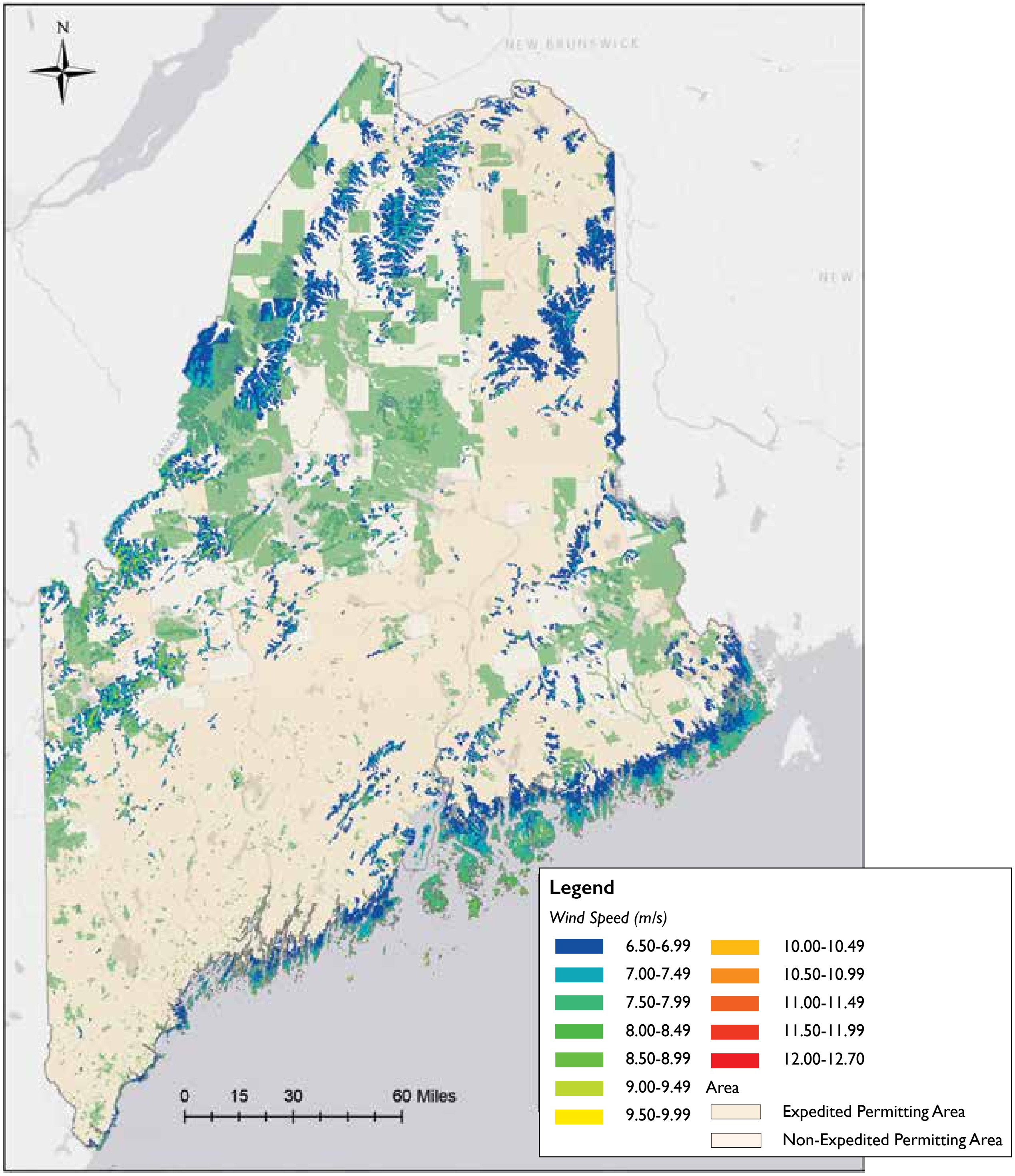


Figure 14. Conservation land where it overlaps 100m Wind Base.

Conservation Land and Wind Resources at 140m

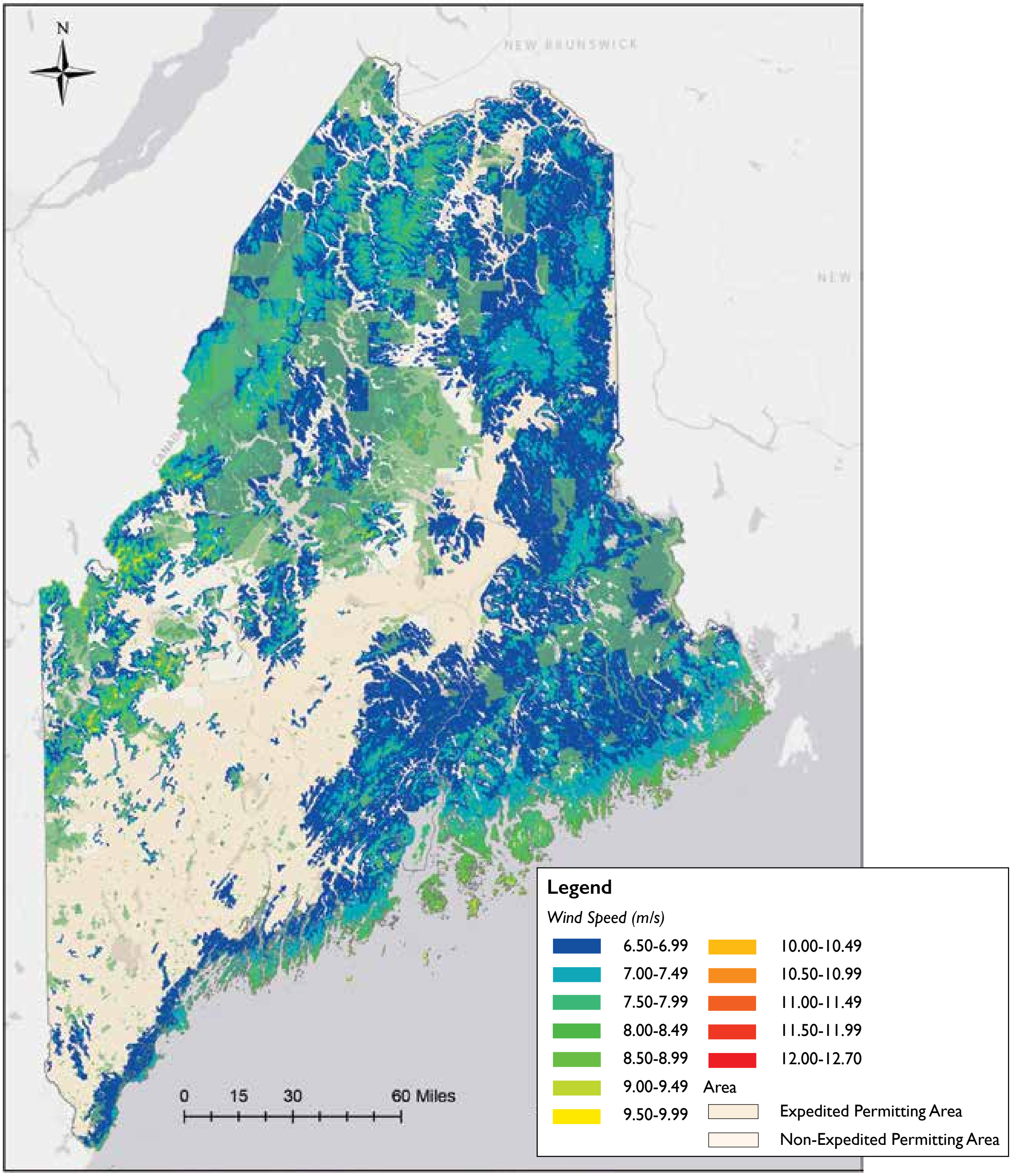


Figure 15. Conservation land where it overlaps 140m Wind Base.

Impacts of Wind Turbines for Birds and Bats

As described in this analysis, increasing wind turbine hub heights greatly expands the potential area for commercial wind energy generation, allowing developers to site wind projects away from the most sensitive wildlife areas. But wind turbines generally, and taller turbines specifically, come with risks to wildlife that may not be captured in this analysis such as collision risk for birds and bats. Increased turbine height may increase collision risk for birds; the higher the turbines and their rotors go, the more they enter the normal flight height for migrating birds. Additionally, when weather conditions deteriorate, migrating birds tend to reduce their flying height, thereby increasing their potential for collision with taller wind turbines. On the other hand, bat activity, for most species, tends to decrease with increasing height, so taller turbines may reduce bat collisions, although research is only just beginning on this topic.

And while location is a large factor in collision risk for birds and bats, it is not the only factor. The potential for bird and bat collisions with wind turbines, guy wires, or other structures also increases at night and in bad weather, when visibility is poor and structures are more difficult to avoid. Additionally, some birds and bats can be attracted to wind turbines due to type of construction, lighting, colors, and patterns, which developers can address through careful facility design.

Furthermore, many species avoid wind turbines rather than fly through a wind facility. For birds that are flying around arrays on daily foraging trips, or migrating birds on extreme energy rations avoiding one or more wind turbine arrays, there may be cumulative effects that lower fitness and survival.

This potential for increased risk of bird and bat collisions is not addressed in this analysis, because the wildlife variables analyzed in this study do not include bird or bat migration pathways. This is because such pathways are not well-known or mapped, and they may vary between species and with weather, time of year, and other factors. Because of this, and because even the datasets we did use are incomplete, site-specific wildlife and habitat information must be gathered early in the siting phase of any potential wind energy project. Areas with high concentrations of wildlife and wildlife habitats, migration corridors or pathways, and areas with rare or exemplary species or natural communities should be avoided.

By expanding the area that is potentially available for wind energy development, the potential for increased habitat fragmentation and cumulative effects of widespread development across the landscape also increases. Careful siting is still necessary for wind turbines and their associated infrastructure (transmission corridors, roads, etc.), and the cumulative effects of such development on wildlife and habitats should be investigated prior to wind energy project approval. As noted in this report[39], curtailment may be necessary to avoid harm to bats during low winds late in the year.

Conclusion

Taller turbines mean that more wind resources are commercially viable and accessible across Maine, creating ample opportunity to avoid high-value wildlife habitat while helping Maine meet its renewable energy goals. In fact, complete avoidance of Tier 1 and Tier 2 resources still leaves more than 2 million acres of viable wind at 100m hub height and more than 7 million acres of viable wind at 140m hub height. Maine Audubon recommends avoiding all areas with threatened and endangered species, and that every effort possible be taken to avoid other high-value wildlife habitat mapped in this analysis, especially where there are multiple wildlife resources and high concentrations of wildlife resources in the same place. If, despite all efforts, such resources cannot be avoided, impacts to wildlife and wildlife habitat should be minimized and/or mitigated, consistent with the recommendations in this report, found in the Mitigation section beginning on page 37. Additionally, while we used buffers to aquatic resources that are consistent with shoreland zoning laws, wider buffers—such as 100 ft. or more on perennial and intermittent streams—would provide better protection for these systems. Finally, other wildlife resources that are not already mapped—such as unknown locations of rare species or migratory pathways—need to be taken into consideration before finalizing any new wind power project.

[39] See page 30, Construction, Operation, Maintenance, and Decommissioning: Wind Considerations.

List of Endangered, Threatened, and Special Concern species in the DIFW GIS layer

Aeshna juncea
Sedge Darner

Alasmidonta varicosa
Brook Floater

Alca torda
Razorbill

Ammodramus caudacutus
Saltmarsh Sparrow

Ammodramus savannarum
Grasshopper Sparrow

Anax longipes
Comet Darner

Anthus rubescens
American Pipit

Aquila chrysaetos
Golden Eagle

Ardea herodias
Great Blue Heron

Arigomphus furcifer
Lilypad Clubtail

Asio flammeus
Short-eared Owl

Atrytonopsis hianna
Dusted Skipper

Bartramia longicauda
Upland Sandpiper

Boloria chariclea grandis
Purple Lesser Fritillary

Boloria frigga saga
Frigga Fritillary

Bucephala islandica
Barrow's Goldeneye

Callophrys gryneus
Juniper Hairstreak

Callophrys hesseli
Hessel's Hairstreak

Catharus bicknelli
Bicknell's Thrush

Catocala similis
Similar Underwing

Chaetaglaea tremula
Barrens Chaetaglaea

Charadrius melodus
Piping Plover

Chlidonias niger
Black Tern

Cicindela ancocisconensis
White Mountain Tiger Beetle

Cicindela marginata
Salt Marsh Tiger Beetle

Cicindela marginipennis
Cobblestone Tiger Beetle

Cistothorus platensis
Sedge Wren

Clemmys guttata
Spotted Turtle

Coluber constrictor
Northern Black Racer

Cordulegaster obliqua
Arrowhead Spiketail

Coturnicops noveboracensis
Yellow Rail

Emydoidea blandingii
Blanding's Turtle

Enallagma carunculatum
Tule Bluet

Enallagma durum
Big Bluet

Enallagma pictum
Scarlet Bluet

Epeorus frisoni
Roaring Brook Mayfly

Erynnis brizo
Sleepy Duskywing

Euphagus carolinus
Rusty Blackbird

Falco peregrinus
Peregrine Falcon

Fratercula arctica
Atlantic Puffin

Fulica americana
American Coot

Gallinula galeata
Common Gallinule

Glyptemys insculpta
Wood Turtle

Gomphus quadricolor
Rapids Clubtail

Gomphus vastus
Cobra Clubtail

Gyrinophilus porphyriticus
Northern Spring Salamander

Haliaeetus leucocephalus
Bald Eagle

Hemileuca maia maia
Eastern Buckmoth

Hesperia metea
Cobweb Skipper

Histrionicus histrionicus
Harlequin Duck

Ischnura hastata
Citrine Forktail

Ischnura ramburii
Rambur's Forktail

Ixobrychus exilis
Least Bittern

Lampsilis cariosa
Yellow Lampmussel

Lanthus vernalis
Southern Pygmy Clubtail

Lapara coniferarum
Southern Pine Sphinx

Leptodea ochracea
Tidewater Mucket

Leucorrhinia patricia
Canada Whiteface

Libellula needhami
Needham's Skimmer

Lycaena dorcas claytoni
Clayton's Copper

Lycia rachelae
Twilight Moth

Myotis leibii
Eastern Small-footed Myotis

Nycticorax nycticorax
Black-crowned Night-heron

Oeneis polixenes katahdin
Katahdin Arctic

Ophiogomphus colubrinus
Boreal Snaketail

Ophiogomphus howei
Pygmy Snaketail

Pantala hymenaea
Spot-winged Glider

Paonias astylus
Huckleberry Sphinx

Papilio troilus
Spicebush Swallowtail

Phalacrocorax carbo
Great Cormorant

Plebejus idas empetri
Crowberry Blue

Polygonia satyrus
Satyr Comma

Progomphus obscurus
Common Sanddragon

Rhionaeschna mutata
Spatterdock Darner

Satyrium edwardsii
Edwards' Hairstreak

Siphlonisca aerodromia
Tomah Mayfly

Somatochlora albicincta
Ringed Emerald

Somatochlora brevicincta
Quebec Emerald

Speranza exonerata
Barrens Itame

Stagnicola mighelsi
Bigmouth Pondsnail

Sterna dougallii
Roseate Tern

Sterna paradisaea
Arctic Tern

Sternula antillarum
Least Tern

Storeria dekayi
Northern Brownsnake

Strophitus undulatus
Creeper

Stylurus spiniceps
Arrow Clubtail

Sylvilagus transitionalis
New England Cottontail

Synaptomys borealis sphagnicola
Northern Bog Lemming

Terrapene carolina carolina
Eastern Box Turtle

Thamnophis sauritus
Eastern Ribbon Snake

Thorybes bathyllus
Southern Cloudywing

Tramea carolina
Carolina Saddlebags

Tramea lacerata
Black Saddlebags

Vertigo malleata
Malleated Vertigo

Vertigo morsei
Six-whorl Vertigo

Vertigo paradoxa
Mystery Vertigo

Williamsonia lintneri
Ringed Boghaunter

Xylena thoracica
Acadian Swordgrass Moth

Xylotype capax
Broad Sallow

Xystopeplus rufago
Red-winged Sallow

Zale lunifera
Bold-based Zale Moth

Zale obliqua
Oblique Zale

Zanclognatha martha
Pine Barrens Zanclognatha

Annotated Bibliography

Climate Change/General Renewable Energy

This annotated bibliography is a summary of the literature reviewed in the development of this report. It is not intended to be an exhaustive list of potential sources of information on the topic. Rather, we focused on review papers summarizing the current knowledge on each of the topics organized below as well as the most recent information available.

Allison, T., Root, T., and Frumhoff, P. 2014. Thinking globally and siting locally – renewable energy and biodiversity in a rapidly warming world. *Climatic Change,* 126: 1-6.

This is a brief overview paper highlighting the need to address climate change as a major priority, understanding that the development of renewable energy has costs to wildlife. The authors are concerned that the uncertainty around the risks to wildlife is limiting the pace and scale of renewable energy development, which could help address climate change. The authors recommend utilizing our current understanding of the effects on biodiversity to help site renewable energy development that will avoid or minimize the risk, knowing we cannot eliminate all risk or uncertainty. They argue forcefully that climate change is a substantially larger threat to biodiversity and that this should be considered in our evaluation of renewable energy projects. The take home message is that aggressive renewable energy development is essential.

Arent, D.J., Pless, J., Mai, M., Wiser, R.H., Hand, M.M., Baldwin, S.F., … Denholm, P. 2014. Implications of high renewable electricity penetration in the U.S. for water use, greenhouse gas emissions, land-use, and materials supply. *Applied Energy,* 123: 368-377.

This paper starts with the NREL Renewable Energy Futures Study (2012), which is an extensive look at all the aspects of incorporating renewables into our energy portfolio to reach 2050 goals, and adds an evaluation of land use, water use, greenhouse gas emissions, and materials supply.

Fernandez, I.J., Schmitt, C.V., Birkel, S.D., Stancioff, E., Pershing, A.J., Kelley, J.T., … Mayewski, P.A. 2015. *Maine's Climate Future: 2015 Update*. Orono, ME: University of Maine.

This succinct report details how climate change has affected and is predicted to affect Maine, specifically. It lays out the science and history of the climate, ties human activities to the dramatic changes, and then documents what it all means in general and particularly for Maine. There are numerous graphs and diagrams that bolster the case with very clear messaging.

Koppel, K., Dahemn, M., Helfrich, J., Schuster, E., and Bulling, L. 2014. Cautious but Committed: Moving Toward Adaptive Planning and Operation Strategies for Renewable Energy's Wildlife Implications. *Environmental Management,* 54(4): 744-755.
This paper uses three specific examples to highlight the feasibility and value of utilizing adaptive planning and management to move renewable energy projects forward rather than the usual and much more conservative precautionary principle. The focus is primarily on wind energy development and its effects on bats, but the concepts of adaptive management over the precautionary principle could be applied to any renewable energy project type.

Lazard's Levelized Cost of Energy Analysis Version 12.0. Retrieved from https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf
In this financial analysis the levelized cost of utility scale energy (i.e., the present value of the total cost of energy over the lifetime of the energy source such as a power plant) compares traditional (coal, nuclear, gas) to alternative (wind, solar, geothermal) energy sources. Depending on the scenarios examined, some forms of alternative energy generation already outperform conventional energy sources, based on the levelized cost of energy.

Mai, T., Wiser, R., Sandor, D., Brinkman, G., Heath, G., Denholm, P., … Strzepek, K. 2012. Exploration of High-Penetration Renewable Electricity Futures. *Renewable Electricity Futures Study*. VOLUME 1. NREL/TP-6A20-52409-1. Golden, CO: National Renewable Energy Laboratory.
This in-depth report is the first of four volumes examining the potential for renewable energy to comprise 80% of the U.S. electric market by 2050. This volume deals with the ability of the electrical systems to include the integration of renewable energy to meet the 80% goal. The authors find it is achievable, but will require significant changes to the existing electric power operation systems.

Peterson, T.C. and Vose, R.S. 1997. An Overview of the Global Historical Climatology Network Temperature Database. *Bulletin of the American Meteorological Society*, 78(12): 2837-2850.
This paper details the updates included in the dominant meteorological database, including information sources, timelines, data collected, etc. These data can be used in analyzing changes in meteorological data around the world over time.

Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., and Stewart, B.C. (Eds.) 2018. *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume 2.* Washington, DC: U.S. Global Change Research Program.
Volume 2 of the report described above details the climate change effects we can expect to see across the nation in the next few decades, depending on the emission scenario we follow. The report is broken into topics of concern (i.e., economic impacts, water, land use,

agriculture, human health, etc.), into regions of the U.S., and ways we can reduce or mitigate the expected effects. The Northeast is expected to see less distinction between its four seasons with milder and shorter winters, more extreme storms, and subsequent negative impacts to natural resources and the economies that depend on them.

Thomas, K. A., Jarchow, C.J., Arundel, T. R., Jamwal, P., Borens, A., and Drost, C.A. 2018. Landscape-scale wildlife species richness metrics to inform wind and solar energy facility siting: An Arizona case study. *Energy Policy,* 116: 145-152.
The authors use GIS to identify areas of high species richness based on GAP analysis data, and to ascertain if these data can help developers avoid wildlife habitats. They determined that this assessment of species richness can augment the information used by the state to assess the impacts of renewable energy projects in Arizona. As GAP analysis data are available nationwide, the authors recommend incorporating an evaluation of these data into standard review practices by developers and regulators so that renewable energy projects can avoid, minimize, and mitigate impacts to wildlife species and their habitats.

Van Zalk, J. and Berens, P. 2018. The Spatial Extent of Renewable and Non-renewable Power Generation: A Review and Meta-analysis of Power Densities and their Application in the U.S. *Energy Policy,* 123: 83-91.
This review article looks at the land-use cost of renewable energy compared to fossil fuels and other energy sources, and finds that renewable energy requires considerably more area to produce the same amount of energy, by several orders of magnitude.

Whitman, A., deMaynadier, P., Vickery, B., Cutko, A., Walker, S., Stockwell, S., Houston, R. 2014. *Climate Change and Biodiversity in Maine: A Summary of Vulnerability of Habitats and Priority Species.* Manomet Center for Conservation Science. Retrieved from https://www.manomet.org/wp-content/uploads/old-files/BwHSummary_021914.pdf
This pamphlet summarizes an assessment of the climate change vulnerability of hundreds of species, habitats, and natural communities of Maine. The authors determined that climate change puts one-third of all Maine species at risk, and half of the Species of Greatest Conservation Need and 10% of Maine habitats were ranked as highly vulnerable to climate change. The review offers strategies for conserving Maine's species and habitats in the face of climate change.

Wuebbles, D.J., Fahey, D.W., Hibbard, K.A., Dokken, D.J., Stewart, B.C., and Maycock, T.K. (Eds.) 2017. *Climate Science Special Report: Fourth National Climate Assessment, Volume 1.* Washington, DC: U.S. Global Change Research Program.
This report is a fairly exhaustive review of the state of the climate, updating the previous report published in 2014. All data support

continued rising temperatures and associated issues (increases in extreme weather, reductions in arctic sea ice, sea level rise, ocean acidification, etc.). A variety of modeled projections indicate that even halting emissions at the current level will still induce a significant global temperature increase. Mitigation options are becoming more limited as time goes on, but recommendations are still put forth to at least reduce the effects of human-caused climate change. Climate change, and its devastating effects, is already here; we are now in a frantic race to minimize the harmful effects to come.

Onshore Wind

American Wind Wildlife Institute (AWWI). 2014 Updated May 2019. *Wind Turbine Interactions with Wildlife and their Habitats: A Summary of Research Results and Priority Questions.* Washington, D.C. Retrieved from www.awwi.org**.**

This is a fact sheet, developed by an organization that facilitates the workings of an earlier group, the National Wind Coordinating Collaborative (NWCC) and its Wildlife Workgroup, that is intended to summarize knowledge of the adverse impacts of land-based wind power on wildlife in North America and how to mitigate them. Focus is on collision of birds and bats with rotors, so mitigation (curtailment, siting, ultrasonic transmitters, UV paint, etc.) is only related to that factor. Results suggest more research is needed, as many studies are inconclusive or contradictory, or simply very species-specific.

American Wind Wildlife Institute (AWWI). 2017. *National Wildlife Wind Research Plan*. Washington, D.C. Retrieved from www.awwi.org**.**

This is a general, 3-year research plan developed by AWWI to look at bird and bat fatality risks at wind energy developments and how to avoid, minimize, and mitigate them. They lay out the goals of each research focus (i.e., tabulate eagle collisions) , as well as the need for additional research outside the realm of this plan by this organization. The goal is to encourage the responsible growth of onshore wind.

Cetinay, H., Kuipers, F., A., and Guven, A. N. 2017. Optimal siting and sizing of wind farms. *Renewable Energy,* 101: 51-58.

This paper lays out multiple mathematical models that can be used to identify the best locations and sizes of potential future wind energy projects, taking into account the potential for integration into the electrical grid. They include information on available wind energy, wind direction and quality, and energy flow availability in transmission lines (capacity) to develop a profitable wind energy project. The authors then apply their models to Turkey as a case study.

Dai, K., Bergot, A., Liang, C., Xiang, W., and Huang, Z. 2015. Environmental Issues Associated with Wind Energy – A Review. *Renewable Energy,* 75: 911-921.
This is a fairly comprehensive review article covering the environmental effects associated with wind energy. The paper covers the negative impacts of wind farms on wildlife (birds, bats, and marine species in the case of offshore wind), loss of forest and soil erosion, human conflict in the form of noise, visual aesthetics, and electromagnetic fields (disruption of radio waves and radar). They also mention that wind farms can disrupt local weather and regional climate. They cover methodologies to mitigate effects of wind farms including siting, timing of construction, curtailment, blade design and speed, and recommend site-specific research looking at short- and long-term effects.

Enevoldsen, P. 2016. Onshore wind energy in Northern European forests: Reviewing the risks. *Renewable and Sustainable Energy Reviews,* 60: 1251-1262.
This is a rough paper looking at wind turbines constructed in forested areas in northern Europe where wind levels are high but available land is low. The effect of the forest on the wind energy captured by the turbines is significant and unpredictable because of the variability of turbulence created by the presence of trees. The paper tries to evaluate multiple risk factors in developing wind energy projects in the forests of northern Europe, but the factors are somewhat disparate and do not flow well. It also appears to be attempting to assess the amount of research conducted on a variety of related topics, but the value of this assessment is fairly low.

Erickson, W. P., Johnson, G. D., and Young Jr., D. P. 2005. *A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions.* USDA Forest Service.
This review article gathering information on a wide variety of anthropogenic bird mortality from collisions is often cited to note that bird mortality rates at wind turbines are insignificant. Buildings, power lines, and cats were estimated to be the largest anthropogenic sources of bird mortality in the U.S., with vehicles, pesticides, communication towers after that, with wind turbines comprising 0.003% of the estimated 1 billion birds killed annually in the U.S. from human causes.

Gartman, V., Bulling, L., Dahmen, M., Geibler, G., and Koppel, J. 2016. Mitigation Measures for Wildlife in Wind Energy Development, Consolidating the State of Knowledge – Part 1: Planning and Siting, Construction. *Journal of Environmental Assessment Policy and Management,* 18(3): 45pp.
This is a review paper covering a broad variety of topics associated with mitigating impacts of wind energy development on wildlife. This section focuses on the earliest stages of development—planning, siting, and construction—with ways to avoid, minimize, and mitigate impacts to wildlife associated with siting (macro and micro siting); facility characteristics such as size, color, rotor sweep;

and construction activities which can be mitigated through timing restrictions, reductions in land clearing, noise reduction, etc. Peer reviewed sources and grey literature were referenced and succinct tables show how much we know about each topic, based on the amount of literature associated with the topic, and whether it's based on research or observations, rather than simple recommendations.

Gartman, V., Bulling, L., Dahmen, M., Geibler, G., and Koppel, J. 2016. Mitigation Measures for Wildlife in Wind Energy Development, Consolidating the State of Knowledge – Part 2: Operation, Decommissioning. *Journal of Environmental Assessment Policy and Management,* 18(3): 31pp.
This is the second part of the review document consolidating what information is available on topics surrounding wind energy projects and impacts to wildlife. This part of the review focuses on the operation and decommissioning phases of a wind energy project. During operations, the primary focus is on keeping wildlife away from operating wind facilities, mostly to avoid collisions. This can be accomplished by managing the local and surrounding habitats to deter use of the space local to the wind facility or encourage use of space farther from the site, as well as use of acoustic, electromagnetic, or visual aids to deter wildlife from using the area. Collision rates can also be reduced through curtailment, or reducing operations during periods when wildlife—particularly birds and bats—would be moving through the area and thus most susceptible to collision. Decommissioning and repowering are addressed briefly, with most coverage associated with the replacement of small, older turbines with larger ones. These larger turbines can reduce risks for some species but increase them for others. The authors highlight the need for additional research, particularly into decommissioning as the industry grows.

Hutchins, M. and Leopold, B.D. 2016. Wildlife and wind energy: are they compatible? *Human-Wildlife Interactions,* 10(1): 4-6.
This is an introduction to a special issue of human-wildlife interactions focused specifically on wind energy and its effects on wildlife. It lays out the topics—climate change vs. impacts to birds and bats, future estimates of wind energy in U.S., habitat alterations, siting, mitigation, etc.—and provides an overview of the articles included in the issue. The feel of this brief introduction is that wind poses a profound threat which needs to be taken seriously.

Kiesecker, J.M., Evans, J.S., Sochi, K., Fargoine, J., Naugle, D., and Doherty, K. 2017. *Energy Sprawl Solutions: Balancing Global Development and Conservation.* Washington, DC: Island Press.
The authors here focus on the footprint size of wind energy projects and cumulative impacts of wind energy development on wildlife and wildlife habitats. They recommend steering wind energy projects to already developed portions of the landscape. They use an example of combining shale gas development and wind energy development together, which would occupy a large footprint, but bring energy and make efficient use of infrastructure for the two energy sources over one.

Kiesecker, J.M., Evans, J.S., Fargione, J., Doherty, K., Foresman, K.R., Kunz, T. H., … Niemuth, N.D. 2011. Win-Win for Wind and Wildlife: A Vision to Facilitate Sustainable Development. *PLoS ONE,* 6(4): e17566. doi:10.1371/journal.pone.0017566.
The authors argue that new wind energy development should be focused on areas that have been previously developed, in order to reduce the impact to biodiversity. Disturbed areas targeted in this analysis include cropland, oil and gas fields, and ridgelines adjacent to surface mining operations. They analyzed which states have enough wind energy and enough disturbed and developable land to support wind energy development to meet DOE renewable energy goals. This location on disturbed land would also facilitate energy infrastructure construction, as these disturbed areas usually already include roads and often transmission lines. They recommend the use of government incentives to encourage such development.

Kuvlesky, W.P., Breeena, L.A., Morrison, M.L., Boydston, K.K., Ballard, B.M., and Bryant, F.C. 2007. Wind Energy Development and Wildlife Conservation: Challenges and Opportunities. *The Journal of Wildlife Management,* 71(8): 2487-2498.
This is an earlier review article looking at the documented impacts of wind farms on wildlife, highlighting mortality to birds and bats through collision. They describe a wide array of mortality rates, while cautioning about the inability to compare them or take them at face value. They do, however, go into the detrimental effects of habitat loss and fragmentation associated with the infrastructure (i.e., roads) associated with energy development. The authors then focus on a proposed wind farm in California and suggest specific research needs still outstanding to assess the impacts. They close with a recommendation for policies (survey requirements with a plug to make research data public to help others, incentives, and mitigation) to direct wind project proponents in order to reduce negative impacts to wildlife.

Leopold, B.D. and Hutchins, M. 2016. Impacts of wind energy on wildlife: synthesis. *Human-Wildlife Interactions,* 10(1): 81-82.
This is a very brief overview of the wildlife issues associated with wind energy including impacts to birds and bats and the need for better data and data collected by independent sources, and the need for better siting and mitigation. The authors also push on the uncomfortable questions of how much mortality is acceptable compared to the impacts of fossil fuel energy sources, what are the long-term effects of wind farms on weather and climate, and that our current energy crisis is the result of overpopulation.

Maine Audubon. 2013. *Wind Power and Wildlife in Maine: A Statewide Geographic Analysis of High-Value Wildlife Resources and Wind Power Classes.*
This report details the results of a GIS analysis of the commercially available wind resources and their potential overlap with high-value wildlife resources across Maine. Based on this analysis, the author calculates whether the state contains enough commercially viable

wind resources in areas that don't overlap with high-value wildlife resources to achieve the state's goal of 3,000 MW of wind energy by 2030. The results of the analysis indicate that while there is a fair amount of overlap between wind and wildlife resources, there are sufficient wind resources in Maine to meet the state's 2030 goal only using areas that do not overlap with known high-value wildlife resources.

Maine Department of Inland Fisheries and Wildlife. 2018. *Maine Wind Power Preconstruction Recommendations and Turbine Curtailment Recommendations to Avoid/Minimize Bat Mortality.*
In creating this guidance document aimed at wind energy project proponents, MDIFW has provided potential wind energy developers with guidance on how to identify and avoid sensitive wildlife species and their habitats, and how to avoid and reduce harm to them. The document identifies individual species, habitats, and species groups (e.g., avian resources) and how to avoid or reduce harm to them, including specific wind turbine curtailment recommendations to avoid or reduce harm to bats.

Masden, E.A., Haydon, D.T., Fox, A.D., Furness, R.W., Bullman, R., and Desholm, M. 2009. Barriers to movement: Impacts of wind farms on migrating birds. *ICES Journal of Marine Science,* 66(4): 746-753.
This is an early review of the potential impacts of off-shore wind farms on marine birds, particularly the effects on fitness of avoiding large wind farms. The study showed no measurable impacts, but the authors suggest that further study is necessary to determine if this is indeed the case, and if their findings are supported in studies of other species.

Milbrandt, A., Heimiller, D.M., Perry, A.D., and Field, C.B. 2014. Renewable energy potential on marginal lands in the U.S. *Renewable and Sustainable Energy Reviews*, 29: 473-481.
This study evaluated the potential for renewable energy production utilizing marginal lands such as brownfields, landfills, abandoned croplands, etc. They found that the U.S. contains a substantial amount of marginal lands (11% of contiguous U.S. land) that could be used for energy production with PV solar having the highest potential, but also included wind, hydrothermal, geothermal, biomass, etc.

Nichols, B. and Racey, P.A. 2007. Bats Avoid Radar Installations: Could Electromagnetic Fields Deter Bats from Colliding with Wind Turbines? *PlosOne,* 2(3): e297.
The authors note that bats appear to avoid radar installations, suggesting the electromagnetic fields deter bats from the area, possibly associated with a risk of hyperthermia. An experiment exposing bats to varying levels of EM fields suggests that at higher levels and closer ranges, EM fields did in fact deter bats. The authors suggest this may be a method for deterring bats at wind turbines.

Phillips, J. 2015. A Quantitative-based Evaluation of the Environmental Impact and Sustainability of a Proposed Onshore Wind Farm in the United Kingdom. *Renewable and Sustainable Energy Reviews,* 49: 1261-1270.

This paper attempts to shift the evaluation of a potential wind project from a qualitative assessment to a quantitative one. A specific project, that was rejected under a qualitative scheme, was reviewed using the quantitative scheme, and was still rejected. The quantitative review also includes an assessment of the sustainability of the project. The results lead the author to question the motives behind the push for onshore wind projects in the U.K.

Pierre, J. P., Wolaver, B.D., Labay, B. J., LaDuc, T. J., Duran, C. M., Ryberg, W. A., … Andrews, J. R. 2018. Comparison of Recent Oil and Gas, Wind Energy, and Other Anthropogenic Landscape Alteration Factors in Texas Through 2014. *Environmental Management,* 61: 805-818.

Using GIS the authors estimate the change in land use of a large portion of Texas and categorize land use changes associated with energy production and non-energy production by ecoregion. Using buffers and an edge-to-alteration ratio, the authors also evaluate edge effects of these different land uses. Not surprisingly, they find that energy related land use is more fragmenting than urban and agricultural development. They offer suggestions for reducing the amount of land alteration associated with oil and gas infrastructure (such as co-locating wells on the same pads and developing near existing infrastructure.

Popa-Lisseanu, A.G. and Voigt, C.C. 2009. Bats on the Move. *Journal of Mammalogy,* 90(6): 1283-1289.

This review article describes what is known about how and why bats migrate, although the take-home message is that our understanding is incomplete. The authors cover the differences between bird migration and bat migration, one of the largest differences being that many bat species hibernate rather than migrate, and identify a number of theories for migration for temperate zone species (when hibernation is too risky in severe cold) and for tropical species (usually food or mate dependent). Physiological changes in anticipation of migration are not completely understood but have been theorized. Navigation is thought to be based on magnetic fields and the location of the sun at sunset, but how they learn to navigate, whether they migrate alone or in groups is also not understood. How to study bat migration as well as the potential future of migratory bats in the face of both climate change and wind power intended to mitigate climate change are discussed.

U.S. Fish and Wildlife Service. 2012. *Land-based Wind Energy Guidelines.* Retrieved from https://www.fws.gov/ecological-services/es-library/pdfs/WEG_final.pdf

This clear document lays out the appropriate steps a developer of onshore wind projects should follow to reduce impact on the environment and meet federal regulatory burden. The document lays

out steps in "Tiers" based on where in the project timeline you are—Tier One is the first step where you should look at landscape level impacts, Tier Five is post-construction monitoring associated with unexpected impacts.

Wang, S., Wang, S., and Smith, P. 2015. Ecological impacts of wind farms on birds: Questions, hypotheses, and research needs. *Renewable and Sustainable Energy Reviews,* 44: 599-607.
This is a review article about the effects of wind farms on birds which is then expanded to offer additional questions/hypotheses to be examined and detail further research needs. The authors basically argue that to reduce and mitigate the effects of wind energy production on birds we need to understand *why* and *how* birds are killed at wind facilities. They encourage more research into addressing these questions.

Offshore Wind

Allison, T.D., Root, T.L, and Frumhoff, P.C. 2014. Thinking globally and siting locally – renewable energy and biodiversity in a rapidly warming world. *Climatic Change,* 126: 1-6
This is a brief overview paper highlighting the need to address climate change as a major priority, understanding that the development of renewable energy has costs to wildlife. The authors are concerned that the uncertainty around the risks to wildlife is limiting the pace and scale of renewable energy development, which could help address climate change. The authors recommend utilizing our current understanding of the effects on biodiversity to help site renewable energy development that will avoid or minimize the risk, knowing we cannot eliminate all risk or uncertainty. They argue forcefully that climate change is a substantially larger threat to biodiversity and that this should be considered in our evaluation of renewable energy projects. The take-home message is that aggressive renewable energy development is essential.

Blau, J. and Green, L. 2015. Assessing the impact of a new approach to ocean management: Evidence to date from five ocean plans. *Marine Policy,* 56: 1-8.
The authors use existing ocean plans to identify how such plans can encourage rightly-sited offshore wind energy development and other offshore uses and balance conservation, economic opportunities, and other stakeholder needs at the same time. By developing ocean management plans, the jurisdictions studied were able to use large-scale planning to both encourage conservation and economic development in a more efficient and effective way, and the cost of developing such plans was fairly small. Developing these plans brings stakeholders together and reduces conflicts. This is a ringing endorsement for ocean management plans in order to increase the economic uses of the ocean while also protecting vulnerable areas.

Cranmer, A, Smetzer, J.R., Welch, L., and Baker, E. 2017. A Markov model for planning and permitting offshore wind energy: A case study of radio-tracked terns in the Gulf of Maine, USA. *Journal of Environmental Management,* 193: 400-409.

This study used a model to look at the potential effects of offshore wind energy development projects on Common and Arctic Terns in the Gulf of Maine. The Markov model used bird movement around a colony to estimate the risk turbines at varying distances from the colony posed to each of these species. The obvious result was that the risk diminished for both species the farther the turbine was from the colony. However, because Arctic Terns make shorter flights, in general, compared to Common Terns the risks were higher for Arctic Terns when turbines were <9km from colony, but higher for Common Terns >9km. The authors tout the benefits of using this model, preferably with more baseline data as inputs, along with site specific data to create exclusion zones, etc.

Dai, K., Bergot, A., Liang, C., Xiang, W., and Huang, Z. 2015. Environmental Issues Associated with Wind Energy – A Review. *Renewable Energy*, 75: 911-921.

This is a fairly comprehensive review article covering the environmental effects associated with wind energy. The paper covers the negative impacts of wind farms on wildlife (birds, bats, and marine species in the case of offshore wind), loss of forest and soil erosion, human conflict in the form of noise, visual aesthetics, and electromagnetic fields (disruption of radio waves and radar). They also mention that wind farms can disrupt local weather and regional climate. They cover methodologies to mitigate effects of wind farms including siting, timing of construction, curtailment, blade design and speed and recommend site-specific research looking at short- and long-term effects.

Dierschke, V., Furness, R. W., and Garthe, S. 2016. Seabirds and offshore wind farms in European waters: Avoidance and attraction. *Biological Conservation,* 202: 59-68.

This is a review paper looking at the effects of offshore wind farms in Europe to displace or attract various species of seabirds; unlike many other researchers, they did not look at collisions. They focused on longer term studies with some statistical strength to their results, and found that certain species may be more or less attracted to or more or less displaced by offshore wind farms. Groups that were attracted were ones that benefitted from the expansion of foraging areas opened up by having resting spots available or those for whom newly created reef habitat provided new food sources. Those displaced were ones whose food sources were negatively affected (i.e., fishing vessel castoffs) or who were disturbed themselves by the activities at the wind farms.

European Commission. 2015. *MaVREN – Environmental Impacts of Noise, Vibrations, and Electromagnetic Emissions from Marine Renewable Energy*. Final Study Report.
This is a fairly comprehensive review of the available literature into the environmental effects of noise, vibrations, and electromagnetic emissions during marine energy installation and operation (Marine Renewable Energy, Vibration, Electromagnetic fields and Noise = MaRVEN). Current standards around these issues were detailed, as were knowledge gaps and a proposed outline for further research and development on the topic.

Furness, R.W., Wade, H.M., Masden, E.A. 2013. Assessing vulnerability of marine bird populations to offshore wind farms. *Journal of Environmental Management,* 119: 56-66.
The authors based their assessments on the earlier work of Garthe and Huppop (2004), using the same approach and factors, but updating the earlier work with newer, more extensive data. They also separated out the risks due to collision from the risks of displacement, but used the same factors with changes made to the algorithms. The authors determined that large seabirds with low maneuverability, flying at turbine height and with late and low reproduction, were most vulnerable to collision, while smaller diving birds that are easily disturbed would most likely show avoidance. Specific future data sets availability are mentioned as having potential to refine the calculations or prove/disprove the results. Site specific and species specific studies are encouraged and the authors recommend research into macro- and micro-avoidance rates (avoiding the whole wind farm vs. entering wind farms and avoiding individual turbines) and how those vary among species.

Garthe, S. and Huppop, O. 2004. Scaling Possible Adverse Effects of Marine Wind Farms on Seabirds: Developing and Applying a Vulnerability Index. *Journal of Applied Ecology,* 41(4): 724-734.
The authors developed a wind farm sensitivity index (WSI) for seabirds taking into account the risks of seabirds colliding with wind turbines and/or being disturbed by wind farms. They used a number of different factors associated with different seabird species (i.e., flight maneuverability, altitude, time flying, population size, conservation status, etc.) to group the seabird species. Their studies indicated substantial differences between species, seasonal variations, and higher sensitivities closer to the coast. The authors recommend additional site specific surveys in addition to models and sensitivity indices.

Goodale, M. W. and Milman, A. 2016. Cumulative adverse effects of offshore wind energy development on wildlife. *Journal of Environmental Planning and Management,* 59(1): 1-21.
This is a very thorough review paper evaluating the effects of offshore wind energy development on a variety of wildlife species, and emphasizing the need to develop methods for analyzing cumulative effects. With the understanding that little is known, at this point, of the actual cumulative impacts of multiple offshore wind energy

developments, the authors stress that avoidance and minimization should be the primary goals for siting and development. The creation of ocean management plans is sited as a strong path forward in this regard. In order to develop guidelines around scoping for cumulative impacts one must identify the hazards, evaluate the species' vulnerabilities, and delineate the exposure in time and space. These factors will all vary by species, and have yet to be quantified. The authors also note the commonly highlighted fact that data surrounding the impacts of wind energy projects are at the moment considered proprietary by the developers and therefore inaccessible to researchers, agencies, and others for analysis of cumulative impacts. The authors strongly advocate for data sharing, strong siting policies, and continued research into the effects on wildlife over time and space.

Hoagland, P., Dalton, T.M., Jin, D., and Dwyer, J.B. 2015. An approach for analyzing the spatial welfare and distributional effects of ocean wind power siting: The Rhode Island/Massachusetts area of mutual interest. *Marine Policy,* 58: 51-59.
This paper analyzes the effects of offshore wind energy development through the lens of the shared ocean resources of Massachusetts and Rhode Island, and their MOU around developing offshore renewable energy sources there. The authors focus on both the ecosystem effects and the socio-economic effects of ocean management, with an emphasis on the socio-economic effects. They highlight the fact that the natural and human systems are linked, and perturbations in one can have unexpected ripple effects in the other in unexpected locations.

Kimmell, K., Blumkin, A., and Evans, R. G. 2010. Wind Energy Facility Siting in Massachusetts. *Natural Resources and Environment,* 25(2): 8-11.
The authors tout the achievements of the state of Massachusetts to address regulatory barriers that had been stymying wind energy development. They did so through the passage of the Wind Siting Reform Act to remove certain barriers for onshore wind development and changes to the 2008 Massachusetts Ocean Sanctuaries Act that included the requirement to develop an Ocean Management Plan to spur offshore wind development. The authors present a very positive face for renewable energy for the state of Massachusetts, and time has borne out this attitude as Massachusetts has been a progressive leader for renewable energy in the Northeast. However, the state has so far failed to approve any offshore wind projects including the very high profile Cape Wind project.

Kuvlesky, W.P., Breeena, L.A., Morrison, M.L., Boydston, K.K., Ballard, B.M., and Bryant, F.C. 2007. Wind Energy Development and Wildlife Conservation: Challenges and Opportunities. *The Journal of Wildlife Management,* 71(8): 2487-2498.
This is an earlier review article looking at the documented impacts of wind farms on wildlife, highlighting mortality to birds and bats

through collision. They describe a wide array of mortality rates, while cautioning about the inability to compare them or take them at face value. They highlight that collision rates at offshore wind sites are higher than those at terrestrial sites and that offshore wind farms have been found to divert migration routes of sea ducks, displace migrating and breeding waterfowl and shorebirds due to disturbance from construction and post construction maintenance, disruption of daily movements, and that additional energy expenditures could have cumulative negative effects. They close with a recommendation for policies (survey requirements with a plug to make research data public to help others, incentives, and mitigation) to direct wind project proponents in order to reduce negative impacts to wildlife.

Musial, W. 2018. *Offshore Wind Resource, Cost, and Economic Potential in the State of Maine.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-70907. Retrieved from https://www.nrel.gov/docs/fy18osti/70907.pdf
This is a report looking at the economic potential for floating offshore wind technology utilization in Maine.

Winiarksi, K.J., Miller, D. L., Paton, P.W.C., and McWilliams, S. R. 2014. A spatial conservation prioritization approach for protecting marine birds given proposed offshore wind energy development. *Biological Conservation,* 169: 79-88.
The authors propose using spatial distribution models of local marine birds from aerial surveys to identify high priority conservation areas within offshore areas in North America along the Atlantic Coast. Using these models offshore wind energy development projects can be sited to avoid high priority conservation areas in order to reduce the potential impact—direct and indirect—on marine birds.

Solar

Allison, T.D., Root, T.L, and Frumhoff, P.C. 2014. Thinking globally and siting locally – renewable energy and biodiversity in a rapidly warming world. *Climatic Change,* 126: 1-6.
This is a brief overview paper highlighting the need to address climate change as a major priority, understanding that the development of renewable energy has costs to wildlife. The authors are concerned that the uncertainty around the risks to wildlife is limiting the pace and scale of renewable energy development, which could help address climate change. The authors recommend utilizing our current understanding of the effects on biodiversity to help site renewable energy development that will avoid or minimize the risk, knowing we cannot eliminate all risk or uncertainty. They argue forcefully that climate change is a substantially larger threat to biodiversity and that this should be considered in our evaluation of renewable energy projects. The take-home message is that aggressive renewable energy development is essential.

Aman, M.M., Solangi, K.H., Hossain, M.S., Badarudin, A., Jasmon, G.B., Mokhlis, H., … Kazi, S.N. 2015. A review of safety, health, and environmental issues of solar energy systems. *Renewable and Sustainable Energy Reviews,* 41: 1190-1204.
This is an assessment of the overall health, safety, and environmental issues associated with solar energy systems. The authors examined solar energy because of its huge potential worldwide as a growing renewable energy source. Life cycle assessments are not as favorable as for wind or hydro, but significantly better than for fossil fuels. The land use needs are low for PV compared to wind, but high for USSE. Decommissioning and recycling are identified as issues for solar energy facilities, as PV cells include toxic materials such as cadmium, lead, and nickel.

Beatty, B., Macknick, J., McCall, J., and Braus, G. 2017. *Native Vegetation Performance under a Solar PV Array at the National Wind Technology Center*. Technical Report, Golden, CO: National Renewable Energy Laboratory.
This study was aimed at evaluating whether native vegetation in a grassland could be re-established after construction of a solar energy facility, and whether it could function as erosion control and habitat. The authors determined that while the presence of the solar panels did inhibit the growth of the grass mix planted at the site, it was not a substantial reduction in productivity and the grasses provided erosion control and wildlife habitat, at least anecdotally.

Bird, L., Gagnon, P., and Heeter, J. 2016. *Expanding Midscale Solar: Examining the Economic Potential, Barriers, and Opportunities at Offices, Hotels, Warehouses, and Universities.* Technical Report, Golden, CO: National Renewable Energy Laboratory.
This report analyzed the possibility of growing the mid-scale solar PV market by increasing the use of PV solar on offices, hotels, warehouses, and universities. The authors determined that significant increases in solar energy capture could be gained by expanding into these facilities if key barriers, such as financing challenges, education, and interconnection challenges were lifted.

Cardenas, L., Zapata, M., Franco, C.J., Dyner, I. 2017. Assessing the combined effect of the diffusion of solar rooftop generation, energy conservation and efficient appliances in households. *Journal of Cleaner Production,* 162: 491-503.
Renewable energy use is up, but not as much as the growth in the rate of electricity use. Solar expansion is the largest of the renewable energy sources, leading to reductions in cost. Energy efficiency was determined to be an insignificant contributor to reductions in electricity use. Policy is identified as a large driver for encouraging people to switch to renewable energy sources.

Comello, S., Reichelstein, S., and Sahoo, A. 2018. The road ahead for solar PV power. *Renewable and Sustainable Energy Reviews,* 92: 744-756.

The authors of this paper examine how solar PV power is positioned in the energy markets and where it will likely be in the future. Using the levelized cost of electricity (LCOE), they determine that the quality of the resource (i.e., how much insolation an area has) is a determining factor in the LCOE, putting northern locations at a disadvantage. They discuss the need for battery storage systems and that restrictions on net metering creates high prices. They conclude that PV-based solar electricity is cost-competitive in U.S. locations with good solar resources.

Denholm, P., and Margolis, R.M. 2008. Land-use requirements and the per-capita solar footprint for photovoltaic generation in the United States. *Energy Policy,* 36(9): 3531-3543.

In an interesting evaluation, the authors estimate the per capita solar electric footprint for individuals in each state, or the land area required to provide all the electricity used by solar PV. Comparisons were then made to the amount of land needed to provide all electricity by solar PV to the land used in agriculture and particularly in the production of corn ethanol. Suggestions for reducing the ecological effects of expanded solar energy development include siting solar PV on rooftops, brownfields, parking lots, and mixed with grazing land or other agricultural uses.

Dinesh, H. and Pearce, J.M. 2016. The potential for agrivoltaic systems. *Renewable and Sustainable Energy Reviews,* 54: 299-308.

This paper begins as a review paper on agrivoltaic systems with a discussion of the competitive land use needs in existence today, focusing on food production and energy production. The authors then create models to simulate both energy and crop production with a variety of solar and agricultural combinations. The highest economic yields for farmers came from converting from agriculture to solar energy production, but the cascading effects of food prices and food instability that would increase were not calculated. The preferred outcome was one in which solar panels are combined with shade crops to reduce energy costs while not causing an increase in food prices. Distance between rows should be optimized for equipment use, to minimize shading, and to optimize water loss prevention. The best PV module was a tilt model which should be used to vary shading throughout growing season, with the least shading during germination, higher when crops are bigger and temperatures are higher. Some of the factors that influenced the results included tilt angle, row spacing, acreage of farm, and types of crops.

Environmental Protection Agency. 2012. *Technical Resources – Siting Renewable Energy Projects on Contaminated Land, Hazardous Waste Consultant*, 30(3): 1.1-1.7.

The EPA has mapped >11,000 potentially contaminated sites and screened them for development of wind, solar, biomass, geothermal.

Using this information, they have developed a management plan – "RE-Powering America's Land Initiative Management Plan"—with three main goals: to provide incentives and technical assistance for siting renewables on contaminated land, to create a unified federal approach to promote renewable energy siting, and to improve communication and sharing of data on siting renewables on contaminated land. Contaminated sites are good options for the renewable energy developer because they cover large areas with few owners, and they often already have infrastructure in place. They make economic sense because the sites would otherwise have low real estate value and significant cleanup costs. Using contaminated sites for renewable energy production also reduces the development pressure on greenfields and agricultural land, returns shunned properties into uses that provide economic and community benefits, provides job opportunities, and have low real estate costs with existing or easily established zoning. Limitations can include liability, instability (i.e., shifting land under landfill caps may not be able to support weight of wind turbines). EPA estimates there are 490,000 sites and approximately 15 million acres of potentially contaminated properties in the U.S.

Hernandez, R.R., Armstong, A., Burney, J., Ryan, G., Moore-O'Leary, K., Diedhiou, I., … Kammen, D.M. 2019. Techno-ecological synergies of solar energy for global sustainability. *Nature Sustainability,* 2: 560-568.

This paper takes the basic concept of evaluating negative and positive impacts when siting and operating renewable energy development to a quantitative place. Ecosystem services are calculated in order to optimize land resources and minimize ecological impacts while maximizing solar energy production. The goal of the article is to provide a structure for incorporating these techno-ecological synergies into the development of solar energy projects globally through education, policy, and regulation to encourage smart "win-win" developments that benefit the ecological systems and the energy system.

Hernandez, R.R., Easter, S.B., Murphy-Mariscal, M.L., Maestre, F.T., Tavassoli, M., Allen, E.B., … Allen, M.F. 2014. Environmental impacts of utility-scale solar energy. *Renewable and Sustainable Energy Reviews,* 29*:* 766-779.

This is a good review article on the environmental impacts of utility scale solar energy. The authors looked at direct and indirect effects, both positive and negative. Negative impacts include those to biodiversity, water use, soil erosion, human health, land use and land cover change, and impacts of associated transmission lines and infrastructure. These negative impacts, however, seem to be downplayed in light of the benefits. Benefits include reduction in fossil fuel pollution and associated climate change, utilization of degraded lands and low quality agricultural lands, and reservoirs. The authors emphasize that the best way to reduce the negative impacts is through regulatory oversight.

Hernandez, R.R., Hoffacker, M.K., Field, C.B. 2015. Efficient use of land to meet sustainable energy needs. *Nature Climate Change,* 5: 353-358.
The authors determined that solar energy systems within the built environments have the lowest environmental and land-use and land-cover change impacts, they reduce energetic losses from and load on transmission, and are co-located with the energy needs of the growing populations. Utility Scale Solar Energy facilities have the advantage of economies of scale and may be compatible with many more sites, but they require a considerable amount of land.

Hoffacker, M.K., Allen, M.F., and Hernandez, R.R. 2017. Land-sparing opportunities for solar energy development in agricultural landscapes: a case study of the Great Central Valley, CA, US. *Environmental Science and Technology,* 51: 14472-14482.
Noting that energy production is one of the biggest drivers of land use change, and that energy production such as solar PV projects can compete with agriculture and conservation efforts for land, the authors evaluate the land-sparing potential of siting solar projects on four non-conventional land cover types in California: the built environment, salt-affected lands, contaminated land, and water reservoirs. Incorporating solar energy into the developed landscape was the best situation to reduce land use change for the solar arrays and it reduced the need for additional transmission and other infrastructure. Incorporating solar energy into pre-existing infrastructure (i.e., on buildings) on agricultural lands can also offset high energy needs for production of agricultural products without reducing productivity. Using contaminated sites is beneficial because such sites are usually near population centers and contain infrastructure. Floatovoltaics can minimize evaporation, reduce algal growth, maintain cool water temperatures, and improve the efficiency of the PV panels through cooling.

Ignanas, O. and Sundstrom, V. 2016. Solar Energy for Electricity and Fuels. *Ambio,* 45(1): 15-23.
This paper covers the very real limitations of solar energy (i.e., its intermittent nature and inefficiency) with potential solutions through technological advances. The authors advocate for new thinking on energy storage in forms similar to photosynthetic systems and improving inefficiencies by absorbing ultraviolet and infrared light as well as light in the visible spectrum. It has been argued by others that it is these two factors that make the costs of electricity from solar energy higher than that from fossil fuels, even as the cost for PV cells drops dramatically.

Kandt, A. and Romero, R. 2014. *Siting Solar Photovoltaics at Airports.* National Renewable Energy Laboratory paper. Retrieved from https://www.nrel.gov/docs/fy14osti/62304.pdf
This conference paper highlights the significant opportunity airports and airfields present for solar due to large amounts of open land. PV installations at airports cost a little more than elsewhere because

they have to coordinate with FAA, do glare studies, etc. But the FAA operates the Voluntary Airport Low Emissions program to help airports meet state-related air quality responsibilities under the Clean Air Act. This includes money to help buy and install solar PV. Airports are on places where wildlife are already actively discouraged due to the risk of collision with aircraft, so siting solar PV on airfields shouldn't pose risks to wildlife. Specific uses of solar PV on airports include runway deicing, solar generation on buildings, and for airport lighting.

Kiatreungwattana, K., Mosey, G., Jones-Johnson, S., Dufficy, C. Bourg, J, Conroy, A, … Brown, K. 2013. *Best Practices for Siting Solar PV on Municipal Solid Waste Landfills.* Golden, CO: National Renewable Energy Laboratory Technical Report.
This is an excellent technical review report identifying best practices for siting solar PV on municipal solid waste landfills. Landfills are suitable for solar because it is an economically viable reuse of sites with high cleanup costs and low real estate development demand, the environmental conditions are not suitable for residential or commercial development, it protects open space from solar development, landfills are located near roads and energy transmission infrastructure, zoning exists, it provides job opportunities, it can advance cleaner and cost-effective energy technology, and it reduces the environmental impacts of existing energy production. Landfills are particularly well-suited for solar energy development because they are near critical infrastructure (electricity transmission infrastructure and roads), are located near areas with high energy demand, are large areas with minimal grade, are lower cost than other land, and they can accommodate net metered or USSE solar, depending on the site. The report lays out the steps to take in evaluating a site including considerations of the landfill itself (age and condition of the landfill, useable acreage, slope, cap characteristics, maintenance requirements, liability, etc.), interconnection and other policies (net metering, community solar policies, pricing and incentives, etc.) and physical setting considerations such as solar resource available, surrounding land use and ecological condition, transportation and electric transmission infrastructure, etc. Technical design is covered—mounting structure, array orientation, tilt, energy prediction and economic considerations. And finally, additional feasibility factors to consider are listed which may include visual conflict, mitigation needs, weight considerations, wind/snow loading and frost protection, and remaining life expectancy of the cap.

Kim, S., Lee, Y., Moon, H. 2018. Siting criteria and feasibility analysis for PV power generation projects using road facilities. *Renewable and Sustainable Energy Reviews,* 81: 3061-3069.
The authors conduct a GIS analysis of the potential feasibility of utilizing specific unused highway interchange space (i.e., inside "cloverleaf" areas) in South Korea for electricity generation using solar PV. Site characteristics such as slope, angle, shade conditions (e.g., due to upper roadways), etc., were considered and project costs

were evaluated against energy produced. Results of the feasibility analysis indicated that feasibility is very site-specific: some land lease costs were too high in some areas, while other areas could be very cost-effective.

Macknick, J., Beatty, B., and Hill, G. 2013. *Overview of Opportunities for Co-Location of Solar Energy Technologies and Vegetation*. Golden, CO: National Renewable Energy Laboratory Technical Report.
A review paper from NREL describes the information available on co-locating solar energy production with agricultural or native vegetation. Solar energy generation requires a fair amount of land, and the traditional method of site development includes vegetation removal, grading, and general site clearing. The authors describe several projects that include vegetation co-location with solar energy developments that can reduce the land use conflict, including co-location with agricultural crops, grazing lands, and native low-lying vegetation that requires less management. Such co-location may require adjustments to a project to alter the PV post heights, distance between panels, site management protocols, etc., but the benefits may include reduced environmental impacts (and thus less mitigation needed), maintenance of agricultural productivity, soil and erosion protection, and easier end-of-life decommissioning.

Milbrandt, A., Heimiller, D.M., Perry, A.D., and Field, C.B. 2014. Renewable energy potential on marginal lands in the US. *Renewable and Sustainable Energy Reviews*, 29: 473-481.
This study evaluated the potential for renewable energy production utilizing marginal lands such as brownfields, landfills, abandoned croplands, etc. They found that the U.S. contains a substantial amount of marginal lands (11% of contiguous U.S. land) that could be used for energy production with PV solar having the highest potential, but also included wind, hydrothermal, geothermal, biomass, etc.

Ong, S., Campbell, C., Denhol, P., Margolis, R., and Heath, G. 2013. *Land-Use Requirements for Solar Power Plants in the United States*. Golden, CO: National Renewable Energy Laboratory Technical Report.
The authors gathered data from a number of utility scale solar projects from across the U.S. to estimate land use per energy unit for both ground-mounted PV projects and CSP projects. Calculations include both direct project impacts and land use from associated site preparation and infrastructure. Averaging the calculations from multiple projects with a range of 2.2 to 12.2 acres/MWac, the authors determined that direct land-use requirements for PV projects were 6.9 acres/MWac. They also found slight differences in the type of PV system, with 5.5 acres/MWac needed for fixed-tilt PV and 6.3 acres/MWac for 1-axis tracking PV.

Semeraro, T., Pomes, A., Del Guidice, C., Negro, D., and Aretano, R. 2018. Planning ground based utility scale solar energy as green infrastructure to enhance ecosystem services. *Energy Policy,* 117: 218-227.

Solar energy production sites were re-evaluated and used as productive sites for beneficial plants and pollinators to thrive in southern Italy. These sites were on previous agricultural land and brownfields, so any return to native plants that could increase native pollinators and produce beneficial plants increases the value of the renewable energy site. The goal of the project was to utilize the unused land around the PV panels to grow beneficial plants that will self-maintain in a fairly low state, reducing the need for intensive vegetation management. Such sites can then be marketed as projects that provide renewable energy but also beneficial plants and pollinators.

Stoms, D. M., Dashiell, S.L., and Davis, F.W. 2013. Siting solar energy development to minimize biological impacts. *Renewable Energy,* 57: 289-298.

This is a description of a GIS analysis used to identify areas in the southern California desert that would be most compatible with renewable energy projects (such as developed and fragmented sites, agricultural sites, sites with little native biological value, etc.) and least compatible (protected lands where energy production is not allowed, rare species habitat, intact landscapes, etc.). Using the GIS model, areas of high compatibility can be mapped for potential renewable energy projects, giving developers more certainty for less conflict and conservationists more confidence that highly valuable ecological sites will be avoided.

Szabo, S., Bodis, K., Kougias, I., Moner-Girona, M., Jager-Waldau, A., Barton, G., and Szabo, L. 2017. A methodology for maximizing the benefits of solar landfills on closed sites. *Renewable and Sustainable Energy Reviews,* 76: 1291-1300.

The authors use GIS to evaluate closed landfills in Hungary as potential sites for solar energy development. With the goal of encouraging reuse of brownfield sites for renewable energy production, the paper provides technical information on energy potential and the advantages and disadvantages to siting renewable energy projects on otherwise unusable lands. Landfills are targeted as beneficial renewable energy sites for a number of reasons including their existing infrastructure (roads and transmission lines), avoidance of natural areas, existing fencing and security, and distance from high quality wildlife habitats. Three different PV installation types are evaluated for different site characteristics and real examples are used to illustrate the points. The authors describe the outcomes as "win-win" situations.

Turney, D., and Fthenakis, V. 2011. Environmental impacts from the installations and operation of large-scale solar power plants. *Renewable and Sustainable Energy Reviews,* 15: 3261-3270.

The authors review the environmental issues, such as land use,

associated with large-scale solar energy project development. They identify 32 impacts, associated with development and operation of large-scale solar operations, categorized into land use, human health, plant and animal life, geohydrological resources, and climate change. Of the impacts identified, the vast majority are beneficial and none are found to be negative when compared to traditional power generation. The authors review potential impacts to five biomes: forests, grasslands, desert shrublands, true deserts, and farmland, and they determine that developing forest lands into solar plants creates a loss of carbon capture, but it is still better than energy generated by coal. In the final analysis, the authors determine that true deserts, or other places where solar insolation is high and wildlife is scarce, provide the best sites for solar power plants.

Transmission

Bernadino, J., Bevanger, K., Barrientos, R., Dwyer, J.F., Marques, A.T., Martins, R.C., … Moriera, F. 2018. Bird collisions with power lines: State of the art and priority areas for research. *Biological Conservation,* 222: 1-13.

This is a review article looking at the prevalence of bird collisions with transmission lines and factors associated with these collisions. While there is biological information associated with species most vulnerable to collisions with powerlines, the authors found a paucity of information linking powerline specifics (height, number of wires, etc.) to bird collisions or evidence to support recommended best practices. They recommend additional research into bird behavior and powerline structural features associated with bird collision hotspots.

Biasotto, L.D., and Kindel, A. 2018. Power lines and impacts on biodiversity: A systematic review. *Environmental Impact Assessment Review,* 71:110-119.

This is a review article focused on recent research looking at impacts of powerlines on abiotic factors (barrier effect, habitat conversion, fragmentation, edge effects, etc.) and associated biotic factors (impacts to organisms, population, and communities). Impacts to biodiversity were reviewed but lack of discernment between native and non-native biodiversity left the results inconclusive as to whether the results were negative or positive. The authors provide recommendations to project reviewers based on the existing knowledge base. The authors also note that the impacts on biodiversity identified in this review are common to other linear developments.

Eldegard, K., Totland, O., and Moe, S.R. 2015. Edge effects on plant communities along power line clearings. *Journal of Applied Ecology,* 52: 871-880.

The authors evaluated the effects of the existence of powerline clearings on plant communities. They found that ROWs showed differences in plant communities in clearing vs. edge of clearing and forest vs. edge of forest; species richness dropped from center of

clearing to edge and edge of forest to center of forest. For existing ROW, management plans should differentiate between clearings through high conservation value forests (limit edge effects), clearings that can act as replacement habitat for cultural landscape species (maintain open canopy), and 'business-as-usual' clearings.

Forman, R.T.T and Alexander, L.E. 1998. Roads and their Major Ecological Effects. *Annual Review of Ecology and Systematics,* 29: 207-231.
This important paper details the effects of roadways on wildlife and their populations. Roadkill, road avoidance, and barrier effects are described as are their impacts on wildlife populations. How hydrologic, chemical, and other ecological functions are disrupted by roads is explained and details of ways to reduce and avoid such impacts are described.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., … Winter, T.C. 2003. *Road Ecology: Science and Solutions*. Washington, DC: Island Press.
This seminal work on the science of road ecology creates the foundation for innumerable works on habitat fragmentation, hydrologic alterations, vegetation management, engineering, land use planning, and other topics related to the changes brought about through the creation and maintenance of roadways and associated infrastructure. The 14 coauthors include four transportation specialists, one hydrologist, and nine ecologists working together to convey information associated with the combination of transportation with ecology.

Hooshyar, A. and Iravani, R. 2017. Microgrid Protection. *Proceedings of the IEEE,* 105(7): 1332-1353.
This provides a descriptive review of microgrids and their values and limitations. A microgrid is a coordinated group of distributed energy resources (DER) that services a set of loads through a distribution system with the capability to: 1) Operate connected to regular power grid; 2) Operate islanded from macrogrid: and 3) Provide smooth transition between macrogrid-connected and islanded modes. A distribution system that operates as a microgrid brings sufficient generation close to the load and so can maintain power supply in event of macrogrid faults. Additionally, if a microgrid has extra generation capacity, it can provide the macrogrid with system recovery resources and decreasing frequency of outages. Microgrids can function in urban, rural, and off-grid settings.

Madison, C. et al. 2009. *Green Power Superhighways: building a path to America's clean energy future.* Joint publication of the American Wind Energy Association and Solar Energy Industries Association. Retrieved from http://www.tresamigasllc.com/docs/2016_02_19_US_FOSG_GreenPowerSuperhighways.pdf
This in-depth study lays out a vision for the future of energy transmission in the U.S. that is described as a collection of "green power superhighways." These superhighways would be carrying

electricity from remote to populated areas, using high-voltage rather than low-voltage transmission lines. They would be coordinated and efficient thanks to new technological and operating protocols. This increased efficiency would lead to greater flexibility for changes in the electricity supply and demand, could incorporate renewable energy resources, and would improve economic performance. The authors identify the outdated patchwork of policy and regulatory structures as the greatest challenges to realizing the goals laid out and the ability to take a big picture view. They claim green power superhighways will create interstate transmission systems to deliver remote renewable energy to population centers, and a more robust electric grid would allow plentiful domestic sources of renewable energy to be put to use, and would foster economic development in regions where it's needed. The authors argue that this vision would lead to large reductions in land use for energy and transmission lines, a more efficient and therefore cost-effective grid, less fragmentation due to the consolidation of infrastructure, and a reduced probability of power outages. This vision would require co-locating of lines and would focus habitat fragmentation in fewer areas and in low-value wildlife habitat before unfragmented habitats.

McMahon, J. 2018. *The Environmental Consequences of Forest Fragmentation in the Western Maine Mountains*. Occasional Paper #2, Maine Mountain Collaborative Retrieved from https://www.wildlandsandwoodlands.org/sites/default/files/2019-01-Environmental-Consequences-ForestFragmentation.pdf
This is an excellent paper that covers the concept of habitat fragmentation and associated detrimental effects from development of manmade linear features on the landscape. The use of western Maine to highlight the threat of such fragmentation provides real-life examples in what might otherwise be a simple concept paper. Connectivity, land use, wildlife mortality, habitat loss, edge effects, patch size, hydrology, invasive species, and impacts to scenic and recreational opportunities are all covered in depth and with real-world examples.

Strevens, T.C., Puotinen, M.L., and Whelan, R.J. 2008. Powerline easements: ecological impacts and contribution to habitat fragmentation from linear features. *Pacific Conservation Biology,* 14(3): 159-168.
This paper highlights the fact that while powerline easements occupy only a tiny proportion of the total area of a natural habitat, their combined direct and indirect effects may be great. Additionally, locating powerlines underground doesn't necessarily eliminate the need for powerline easements because of the need to maintain access to buried lines. The authors do, however, recommend avoiding putting ROWs in areas of undisturbed native vegetation, instead putting them alongside roads or areas of already modified habitat. They also recommend using more selective methods of vegetation management, for example, rather than total mowing or slashing, use selective removal of tall-growing species.

Yahner, R.H. 1988. Changes in Wildlife Communities Near Edges. *Conservation Biology,* 2(4): 333-339.
This is an earlier paper on the detrimental effects of habitat edges and forest fragmentation, written at a time when many ecologists viewed edges as beneficial due to the increased biodiversity found at transition zones. Much of the information contained in the article is well-known now, but was still fairly novel at the time in many land and wildlife management circles.

Zhang, W., Zhang, X., Huang, S., Xia, Y., Fan, X., Mai, S. 2017. Evolution of a transmission network with high proportion of renewable energy in the future. *Renewable Energy,* 102: 372-379.
The vision of a future transmission network with a high proportion of renewable energy will require an overhaul of the existing network to create simplification, efficiency, and flexibility. This framework for power system needs to consider: 1) Safety (i.e. capacity and stability); 2) Economy (reducing construction costs, power losses, network congestion); 3) Power generation access (always choosing nearest accessing point, which may require more planning): and 4) Public policy, especial if it includes increased costs for renewables. The uncertainty created by this new grid with renewable energy as a major source will be dependent on the number and characteristics of the power supply and energy storage equipment, the power grid network, and demand side response.

Zichella, C. and Hladik, J. 2013. Siting: finding a Home for Renewable Energy and Transmission. *The Electricity Journal,* 26(8): 125-137.
This paper lays out a systematic approach to attaining the transmission changes needed to achieve increased renewable energy goals. Smart planning is needed for the whole process, labeled "Smart from the start." This method relies on early and frequent communication between stakeholders, utilization of geospatial information to avoid land and wildlife conservation and cultural resources, and to target disturbed areas for development. This planning method should identify resource zones, incentivize resource zone development with priority approvals and access to transmission, renewable energy zones that optimize the use of the grid, maximize use of existing infrastructure (transmission and roads), "mitigation that matters", and smart siting. They recommend managing demand and taking advantage of the existing grid. You do this by optimizing the grid infrastructure, following the "Smart from the Start" criteria, improving governmental coordination, working closely with landowners, and working to support offshore wind energy projects. By optimizing the existing grid, money can be saved and resources can be better protected.

Compendium of Policies and Best Practices Utilized in Other States

Related to Siting Renewable Energy Projects and Wildlife

This is a brief overview of existing renewable energy-specific policies and guidelines used in nearby states to avoid, minimize, and mitigate impacts of renewable energy projects to wildlife and wildlife habitat. It is not intended to be an exhaustive list, rather it is intended to provide examples of existing policies and practices that could inform the development of similar Maine policies.

Existing policies in other states include siting guidance, but also some operational practices. As is the case with the entirety of the report (*Renewable Energy and Wildlife in Maine: Avoiding, Minimizing, and Mitigating Impacts to Wildlife and Habitat from Solar, Wind, and Transmission Facilities*), this document is specific to policies related to onshore and offshore wind facilities, solar facilities, and transmission infrastructure. Some of the listed policies address values beyond impacts to wildlife, such as noise or scenic impacts; this report does not address those values.

Existing Terrestrial Wind Policy

Most state siting guidance associated with onshore wind facilities center on avoiding high-value wildlife habitat, encouraging development on or near previously developed lands, such as landfills or agricultural lands, and requiring decommissioning. Some states also have policies aimed at reducing collision risk to birds and bats.

Maine

The Maine Wind Energy Act. The Act made wind development a permitted use within certain parts of Maine's unorganized, deorganized, and organized territories, known as 'Expedited Permitting Areas'. The Act specifically requires avoiding impacts to Bicknell's Thrush habitat. It also requires best practical mitigation to reduce impacts to wildlife resources to the lowest feasible level, which may include turbine and blade color, lighting, and curtailment. *See* The Maine Wind Energy Act, 35-A, §3401-3404 (2003).

Natural Resources Protection Act, Section 480-II. This section of the Act requires that construction and operation of small scale wind energy projects must use "best practical mitigation techniques for mitigating impacts to endangered and threatened species, essential wildlife habitat and other protected resources." It also requires decommissioning, including demonstrated financial capacity for decommissioning prior to receipt of permit. *See* Natural Resources Protection Act, 38, §480-II (2015).

Connecticut

The Connecticut Department of Energy and Environmental Protection encourages development of wind projects on contaminated sites by facilitating connections between municipalities that seek to site such projects with developers, offering financing and other monetary incentives, and providing technical assistance. *See* Connecticut Department of Energy and Environmental Protection (2019), *Siting Clean Energy on Connecticut Brownfields*. Retrieved from https://www.ct.gov/deep/cwp/view.asp?a=2715&q=607554&deepNav_GID=1626

Massachusetts

Massachusetts' Department of Environmental Protection Fact Sheet. This fact sheet encourages wind development (as well as other renewable energy development) on capped landfills providing detailed permitting guidance. *See* Massachusetts Department of Environmental Protection, Bureau of Air & Waste, Fact Sheet: *Developing Renewable Energy Facilities on Closed Landfills* (2016). Retrieved from https://www.mass.gov/files/documents/2016/08/nx/fslfenergy.pdf

New Hampshire

Energy Facility Evaluation, Siting, Construction, and Operation Law. This law requires the evaluation of cumulative impacts to a variety of values, including natural resource values. It also requires site decommissioning. *See* New Hampshire Public Safety and Welfare Act XII, §162-H (2014).

New York

New York Wind Energy Guide for Local Decision Makers, Section 5, Birds and Bats: Impacts and Regulations. This document, produced by NYSERDA (New York State Energy Research and Development Authority), provides guidance on avoiding, minimizing, and mitigating impacts to birds and bats and their habitats. NYSERDA advises that this can be accomplished through proper siting, minimal lighting, burying cables, curtailment, habitat restoration, decommissioning, etc. *See* New York State Energy Research and Development Authority, *New York Wind Energy Guide for Local Decision Makers: Birds and Bats: Impacts and Regulations* (2017). Retrieved from https://www.nyserda.ny.gov/Researchers-and-Policymakers/Power-Generation/Wind/Large-Wind/New-York-Wind-Energy-Guide-Local-Decision-Makers

Rhode Island

Renewable Energy Siting Guidelines. This technical paper, authored by Rhode Island's Department of Administration, Division of Planning, provides guidelines to avoid locations known to have high-value natural resources, minimize impacts to species and habitat, avoid fragmentation, use lights and coloring to reduce attraction to birds, and curtail or shut off turbine operations during periods of migration. *See* Rhode Island Department of Administration Division of Planning Statewide Planning Program, *Renewable Energy Siting Guidelines* (2012). Retrieved from http://www.planning.ri.gov/documents/LU/energy/Wind_Energy_FacilityGuidelines_June-2012_.pdf

Land-based Wind Siting Guidelines. These guidelines, authored by Rhode Island's Office of Energy Resources, provide background information and guidance for avoiding, minimizing, and mitigating siting and environmental impacts, with particular attention to bird and bat impacts. *See* Rhode Island Office of Energy Resources, *Rhode Island Land-Based Wind Siting Guidelines* (2016). Retrieved from http://www.energy.ri.gov/documents/landwind/WindSitingDoc_2016-1-6_FINALforPublicReview.pdf

Existing Offshore Wind Policy

Existing offshore wind development guidance aims to identify, locate, and describe offshore natural resources and provides requirements and/or guidance primarily to avoid critical marine habitat areas.

Connecticut

Department of Energy and Environmental Protection Request for Proposals. Connecticut's Request for Proposals requires that projects meet benchmarks for minimizing impacts to wildlife. *See Connecticut Department of Energy and Environmental Protection, Notice of Request for Proposals for Offshore Wind Facilities (2019).* Retrieved from http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/ccf12ec6cdf19ca7852584580072434d/$FILE/2019.08.16_Final.OSW.RFP.pdf

Massachusetts

Ocean Management Plan. The plan protects critical marine habitat and water-dependent uses and sets standards for new ocean-based projects in Massachusetts ocean waters. The plan's management framework is implemented within the state's regulatory structure, with the relevant agencies coordinating review and approval of proposed ocean projects. The plan includes an interactive mapping tool of various offshore resources for the purpose of avoiding direct and cumulative impacts to marine wildlife and fisheries. *See* Massachusetts Office of Coastal Zone Management, *Massachusetts Ocean Management Plan* (2015). Retrieved from https://www.mass.gov/service-details/massachusetts-ocean-management-plan

An Act Relative to Energy Diversity. This law identifies areas for offshore wind development where environmental and other impacts would be minimized. *See* Act to Promote Energy Diversity ch. 188, § 23M 1-17 (2016).

New York

New York State Offshore Wind Master Plan. This plan, developed by NYSERDA (New York State Energy Research and Development Authority), identifies areas that are appropriate for offshore development and areas that are not appropriate, for the purpose of protecting high-value marine resources. *See* New York State Energy Research and Development Authority, *NYS Offshore Wind Master Plan* (2019). Retrieved from https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Offshore-Wind-in-New-York-State-Overview/NYS-Offshore-Wind-Master-Plan

Rhode Island

Ocean Special Management Plan. This plan, approved by the Rhode Island Coastal Resources Management Council, includes spatial, regulatory, and planning guidance to avoid, minimize, and mitigate impacts to Rhode Island's coastal ecosystem. *See* Rhode Island Coastal Resources Management Council, *Rhode Island Ocean Special Area Management Plan* (2010). Retrieved from https://seagrant.gso.uri.edu/oceansamp/pdf/samp_crmc_revised/RI_Ocean_SAMP.pdf

Existing Solar Policy

Most existing solar energy siting guidance encourages rooftop, landfill, brownfield, parking lot, and other development locations that do not contain high-value wildlife habitat or high-value agricultural lands. Some also include pollinator-friendly plantings, wildlife fencing, and decommissioning.

Connecticut

The Connecticut Department of Energy and Environmental Protection encourages development of solar projects on contaminated sites by facilitating connections between municipalities that seek to site such projects with developers, offering financing and other monetary incentives, and providing technical assistance.

Massachusetts

Solar Massachusetts Renewable Target Program. The program uses financial incentives to guide siting of large-scale solar facilities, including "adders" for projects sited on brownfields, rooftops, parking lots, and other disturbed locations and "subtractors" for development of greenfields. *See* Massachusetts Department of Energy Resources, *Solar Massachusetts Renewable Target (SMART) Program* (2019). Retrieved from https://www.mass.gov/info-details/solar-massachusetts-renewable-target-smart-program

New York

New York State Solar Guidebook. This guidebook, developed by NYSERDA (New York State Energy Research and Development Authority), contains information, tools, and step-by-step instructions to support local governments managing solar energy development in their communities. In New York, municipalities must participate in a "State Environmental Quality Review" prior to developing solar, among other requirements that seek to balance environmental and agricultural resources with solar development. *See* New York State Energy Research and Development Authority, N*ew York State Solar Guidebook* (2019). Retrieved from https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Siting/Solar-Guidebook

Rhode Island

Solar Siting Information and Recommendations. The Rhode Island Department of Administration's Office of Energy Resources and Division of Statewide Planning, together with stakeholders, developed a presentation and recommendations to provide technical assistance and information to municipalities on the subject of solar siting. The materials provide general zoning guidance to promote renewable energy while protecting valuable natural resources, including recommending a decommissioning plan, pollinator-friendly planting, minimal soil disturbance, and wildlife-friendly fencing. *See Rhode Island Division of Statewide Planning Office of Energy Resources, Solar Siting Information (2019).* Retrieved from http://www.energy.ri.gov/documents/renewable/Solar_Siting_Information_Public_PPT_Feb_2019.pdf

Transmission Infrastructure Policy

Transmission siting is primarily regulated by each state's public utility commission (PUC), with some local environmental oversight in some areas. However, PUCs usually retain the ability to override local environmental constraints "for the public good." Many PUCs are charged with including environmental impacts as part of their review, but do not include specific siting requirements related to environmental impacts.

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