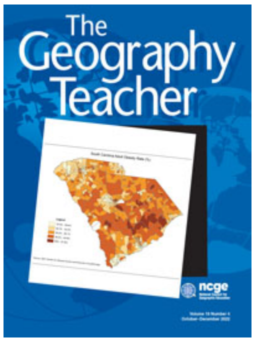

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LESSON PLAN

# Eagles and Wind Turbines: Using Maps to Protect Animals and Increase Renewable Energy Use

Douglas Leeson[a], Thomas C. Hammond[a], Kate Popejoy[b], Alec Bodzin[a], Michael Hardisky[c], and Sarah Lew[c]

[a]College of Education, Lehigh University, Bethlehem, Pennsylvania, USA; [b]PopejoySTEM LLC, Whitehall, Pennsylvania, USA; [c]School District of Philadelphia, Philadelphia, Pennsylvania, USA

## Introduction

Energy sources affect many systems, such as economics, politics and, of course, ecosystems. When considering energy sources' effects on ecosystems, the discourse typically focuses on emissions and climate change. Wind turbines can pose an additional risk, however. A study in the *Wildlife Society Bulletin* (Smallwood, 2013) estimated that more than 500,000 birds are killed by wind turbines in the United States every year. Among these birds are endangered or recovered species, such as the bald eagle.

In this lesson, students will examine the trade-offs between wind energy projects and bald eagle habitats in Pennsylvania. Students will identify a site for the construction of a new wind turbine that is effective and safe to wildlife, based on federally supplied data. Students will also have an opportunity to use ArcGIS Online (AGO), a tool used by geographers and other professionals, to collect and analyze data, study geographic patterns, and make planning decisions. We have provided publicly accessible versions of the learning materials using the embedded URLs, or teachers can request their own free AGO accounts for student use at https://www.esri.com/en-us/industries/education/schools/schools-mapping-software-bundle.

While this lesson is focused on Pennsylvania, educators in other parts of the country can easily adapt the materials to their own geographic areas, given that wind power is ubiquitous and that bald eagles are native to the entire continental United States. Alternatively, the lesson can be adapted to focus on other local bird species, all of which will have the same concerns regarding wind turbines.

## Learning Objectives

The student will:

- Explain the significance of wind turbines and distinguish between areas that are suitable or unsuitable for wind turbines based on average wind speed.
- Identify the spatial relationship of bald eagle nests to water.
- Select a point on a map suitable for a wind turbine based on average annual wind speed and the risk posed to bald eagles based on existing nesting locations.
- Evaluate the different designs of wind turbines in terms of their risk to bald eagles.

### *Next Generation Science Standards Connection*

HS-ESS3-1 Earth and Human Activity: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS-ESS3-2 Earth and Human Activity: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ESS3-4 Earth and Human Activity: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics Design: Evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

### *Grade Level*

High school, but the lesson can be adapted for middle school or even upper elementary.

### *Time*

Two 50-minute classes, each of which is split into two parts.

### *Materials*

Map, 4 story maps, linked here: https://storymaps.arcgis.com/collections/de8024adea934e538e05eb9158ea5ac6.

## Introduction to Online Mapping

We use an online geographic information system (GIS) because teachers may find it beneficial to incorporate geospatial thinking and reasoning skills into their curriculum. The interactivity and ease of use of maps displayed with online GIS allow for more student engagement and encourage exploration and investigation.

For introductions to using GIS, see Esri's guides at https://learn-arcgis-learngis.hub.arcgis.com/. For more information on what GIS is and what it can be used for, see Esri's introduction at https://www.esri.com/en-us/what-is-gis/overview.

**CONTACT** Douglas Leeson dml519@lehigh.edu College of Education, Lehigh University, 111 Research Drive, Bethlehem, PA 18015, USA.

## Teaching the Lesson

We teach this lesson over two sessions, with each session having two parts. The first day focuses on background information, first about bald eagles and then about the competing interests in protecting bald eagles and using wind turbines as a renewable energy resource. On the second day, students learn more about wind turbines and federal regulations, manipulate and interpret a web GIS map to make a site selection, and then annotate the map to report on their selection.

Because much of the analysis and the assessment in this lesson is based on web GIS, basic map literacy is necessary for student engagement. Before the lesson, students should be familiar with borders, basic map markup (for example, rivers), cardinal directions, and basic geospatial reasoning skills (such as direction and proximity).

### *Part 1 (Day 1): Introduction to Bald Eagles and Spatial Relationships*

In this first section, students will examine the history of bald eagles, observe their spatial relationship to water sources, and observe the proximity of some wind turbines to bald eagle nests. This information can be presented via slideware or ArcGIS StoryMaps (for example, https://arcg.is/1XCDy1) or another platform.

To take advantage of students' existing knowledge of bald eagles, we start with the use of the bird as a national symbol—the eagle appears on the presidential seal, the Great Seal of the United States, the seals of several branches of the military, and local Native American tribes (Lenni Lenape Archives n.d.). These uses of bald eagle imagery will be familiar to many students. In addition to these symbolic uses, the bald eagle is native to almost all of North America and, at one point, had a large population: Around 1700, the estimated population of bald eagles was more than 300,000 (Louisville Zoo 2021).

By the 1950s, however, there were only 412 nesting pairs of bald eagles in the forty-eight contiguous states of the United States (Wiese and Caven 2021). By the late 1970s, there were no more than three nesting pairs in Pennsylvania. During this period, bald eagles were considered endangered and were placed on the endangered species list in 1967. Many protections were put in place to protect bald eagles and their habitat, such as prohibitions on hunting and the banning of pesticides such as DDT (Grier, 1982).

Today, there are more than 100,000 bald eagles in the wild nationwide, and Pennsylvania has more than 300 active nests. By 1995, bald eagles were removed from the endangered list; they are currently considered a recovered species. Students can observe the recovery of bald eagles by viewing an AGO map of bald eagles' nests in Pennsylvania (Figure 1; map is accessible at https://arcg.is/0DSjiW). One way to begin this observation is by focusing on your local area. For example, in Philadelphia, there are five nests inside the city limits; Allegheny County, where Pittsburgh is located, has only three.

Once students begin examining specific nests, they should be prompted to identify the relevant spatial relationships—what seems to influence the location of bald eagles' nests? As students move about the map, they will observe that bald eagles' nests are all located on or near water. The Philadelphia nests, for example, are located along the Delaware River, and the nests near Pittsburgh are all on either the Monongahela, Allegheny, or Ohio Rivers. The entire length of the Susquehanna River is lined with eagles' nests; students can trace the river from where it enters Pennsylvania at the New York border all the way to where it exits on the Maryland border. Students may provide unexpected explanations for why eagles' nests are located where they are; if this happens, switching on the data layer "PA Rivers and Creeks" or "Susquehanna River" will provide a visual cue to draw students' attention to the correct pattern.

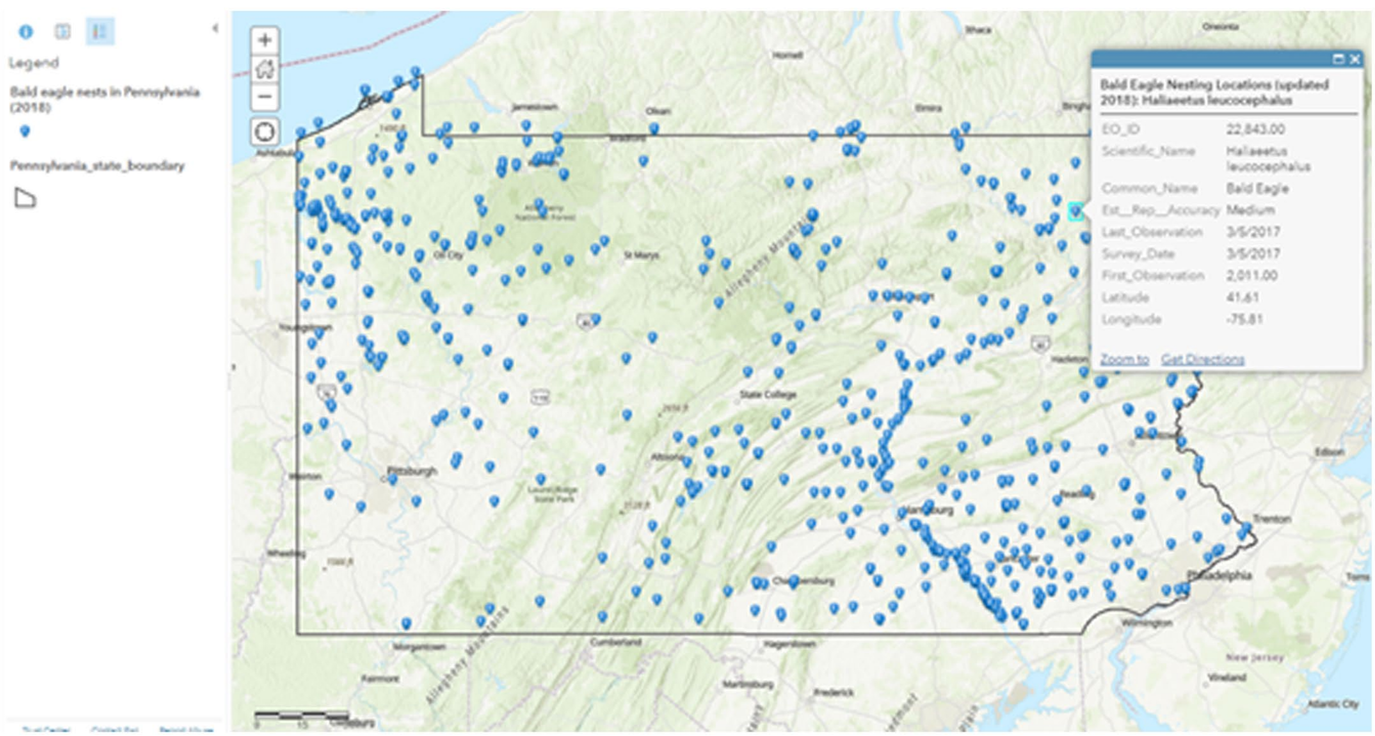


**Figure 1.** ArcGIS Map showing locations of bald eagle nests in Pennsylvania.

Once the students observe the pattern, they should infer causation: Why are these nests located near the water? The answer is access to food, as fish make up the majority of the bald eagle's diet. Clicking on specific nests will allow them to observe additional patterns and learn more about bald eagles. For example, the data on each nest include not just location but also when the nest was first surveyed, the date of the most recent observed use of the nest, and the last time the nest was checked. Some of the nests were first surveyed in the 1930s, such as the Pymatuning Reservoir on the western border of Pennsylvania, or the 1950s, as with some of the nests along the Susquehanna. Not all data points list a specific date of surveying but may just list a year. However, the nests with specific observation dates were observed in February through June, which is during the bald eagles' nesting season.

### *Part 2 (Day 1): Bald Eagles and Wind Turbines*

To draw a connection between eagles and wind turbines, we start by looking at eagles' foraging areas. According to the U.S. Fish and Wildlife Service, bald eagles need a foraging area of up to 6 square miles for a radius of approximately 1.4 miles around each nest. Students can either generate these boundaries themselves, using AGO's Analysis (via Use Proximity > Create Buffers), or the teacher can pregenerate these buffers as a separate layer. Next, we switch on the layer of wind turbines and either have students visually scan the map or use Analysis (via Use Proximity > Find Nearest) to locate wind turbines that are within the foraging area of a bald eagle nest.

In Pennsylvania, according to our data sets, only one wind power installation fits this constraint: a pair of turbines located on the east bank of the Susquehanna, southwest of Lancaster, within 1.4 miles of three nests, one of which has been used as recently as 2017 (Figure 2). These turbines were built in 2011 to supply power to a nearby factory that makes the Turkey Hill brand of ice cream (PPL Renewable Energy 2010). This wind power installation and its nearby nests presents the dilemma of two competing goods: Pennsylvania wants both to protect bald eagles and to expand its use of wind power and other renewable energy sources, with a goal of 40% of electricity coming from renewable sources by 2025 (Office of the Governor 2019). The next part of the lesson will engage students more deeply with strategies to pursue both goals.

### *Part 3 (Day 2): Learning about Wind Turbines*

The next session begins with more information about wind turbines, starting with the function of wind turbines. Wind turbines transform wind into electric power, so it is important that they

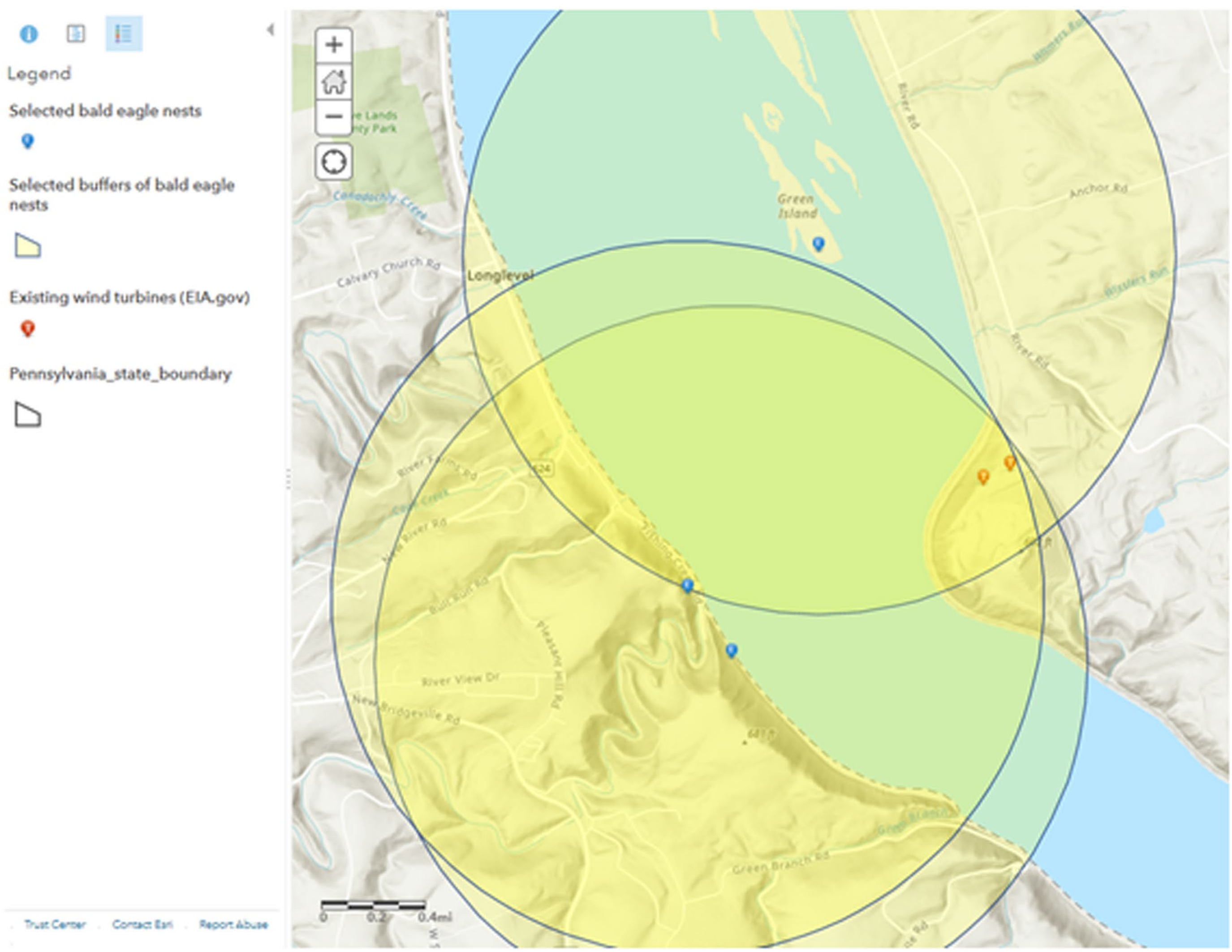


**Figure 2.** ArcGIS Map showing three selected nests and foraging zones that overlap with a wind turbine installation on the Susquehanna River.

are placed in an area with high wind speeds. We introduce students to either a simplified map, color-coding the United States into areas with average wind speeds above or below 14.3 mph, or a more granular map, dividing areas across seven different categories of average wind speed. Within Pennsylvania, students should be able to observe that the highest wind speeds correlate with where windmills are already placed, along the eastern edge of the Appalachian Plateau where the elevation is much higher than the lower-lying ridge and valley region.

Another consideration to the placement of a wind turbine is federal regulation. The U.S. Fish and Wildlife Service publishes a map layer that categorizes zones as having either high risk of impacts on eagles (in other words, areas with many eagle sightings) or low risk of impacts on eagles. Wind turbines are dangerous to birds: Nationwide, turbines kill approximately 250,000 birds annually, including 100 eagles (Bever 2022). Any new wind energy project has to meet requirements, depending on the proposed location's categorization. Before constructing a new wind turbine in a high-risk zone, the developer must first conduct a two-year impact study, assessing the proposed turbine's likely risk to eagles. Conversely, if the new turbine is to be in a low-risk zone, the developer can build right away.

One final consideration is the variety of turbine designs. In addition to the windmill style featured at the Susquehanna River location, there are also vertical turbines and spiral turbines, all of which are easier for birds to see and avoid. (For more specific information about wind turbine design, see https://www.eia.gov/energyexplained/wind/types-of-wind-turbines.php.) Even windmill-style turbines can be modified to improve bird safety—painting one blade black, for example, helps birds spot the blade and can reduce the number of bird deaths (Kinver 2020). After examining the map layers for wind speed and risk to eagles, students are now equipped with information for making a choice: Where can we place a new wind turbine that will expand Pennsylvania's use of renewable energy while also preserving our bald eagle population?

### *Part 4 (Day 2): Where to Place a New Wind Turbine in Pennsylvania*

The final part of the lesson requires students to work with the GIS tools themselves. If they do not have individual AGO accounts, they can manipulate the map, take a screenshot, and annotate this screenshot to show their site selection. If they do have accounts, they can do this annotation inside AGO and save the map for later reference. This final stage also provides opportunities for increasing the complexity of the spatial thinking, if so desired.

Students are now presented with the task of selecting a site for a new wind turbine. The new turbine should, of course, be located in an area of high average wind speed in order to generate as much power as possible. However, the turbine should also be located in an area of low risk to eagles, both protecting the existing eagle population and avoiding a costly delay of conducting the required two-year impact study. In order to make this selection, students will have to manipulate at least two layers: the eagle risk layer and an average wind speed layer. (Remember, there are two different versions of the average wind speed data, a simple one with two categories and a more complex one with seven categories.) We have set the eagle risk layer to a high transparency, allowing students to consider both variables at once;


**Figure 3.** ArcGIS Map showing average wind speed overlaid with risk to bald eagles and a pushpin representing a suitable location for a new turbine.

alternatively, students may choose to toggle the layers on and off as they consider different sites.

Once students have selected their site, they should mark it, either with a Map Note in AGO or by annotating a screenshot of their map. In addition to indicating their chosen site, they should also provide their reasoning: How does this site satisfy the constraints of both high average wind speed and low risk to eagles? They will also explain what style turbine they would build there and justify their choice. Students can enhance their answer with comments about their preferred design for the wind turbine: vertical, horizontal, or spiral. Figure 3 provides an example of a possible student response.

For an assignment with increased complexity, the teacher may introduce an additional spatial relationship to be considered: proximity to population centers. In general, electricity generation should take place close to where it will be used, reducing the need to transport or store the energy. If this is the case, students should either measure and record the distance from their proposed turbine to the nearest city or consult a population density layer for a more nuanced examination.

### Assessment

Teachers can assess students' work through a laddered criterion checklist: Did students make a site selection? Did the site selection address both constraints, just one constraint, or neither? Did they explain their choice? If desired, the inclusion of additional detail, such as the specific turbine design or proximity to population centers, could be counted as extra credit.

## Conclusion

This relatively brief lesson can serve many purposes for geography teachers. For example, the lesson provides an opportunity to introduce and/or explore GIS as a tool to develop important geography skills such as examining spatial relationships and patterns. The materials provided are all publicly accessible and no login is required. This lesson also exposes students to a concrete application of spatial thinking. The GIS allows them to observe spatial patterns, measure distances, and consider trade-offs when making a location-specific choice. Finally, and most importantly, the lesson engages students with a simple but authentic civic decision in which they must balance two competing goals: preserving the bald eagle population and increasing the use of renewable energy. The world that our students are inheriting is filled with increasingly complex choices, and the knowledge, skills, and tools of geography will be required to make these choices and communicate them to others.

## Notes on Contributors

***Douglas Leeson*** is a doctoral student and research assistant in Lehigh University's Teaching, Learning, and Technology program. He holds a BA in English from Pennsylvania State University and an MAT from the University of Mississippi. Douglas researches GIS and its applications for improving spatial thinking as part of a National Science Foundation–funded grant.

***Thomas Hammond*** is an associate professor in Lehigh University's Teaching, Learning, and Technology program. Prior to coming to Lehigh, he taught high school social studies for ten years and then completed his doctorate in Instructional Technology at the University of Virginia.

***Kate Popejoy*** is the owner of Popejoy STEM, LLC. Dr. Popejoy's research interests are technology-mediated science teaching and learning, environmental education, and teacher professional development.

***Alec Bodzin*** is a professor in Lehigh University's Teaching, Learning, and Technology program. His research involves the design of immersive learning environments and learning with spatial thinking tools including GIS.

***Michael Hardisky*** is an adjunct professor at Temple University's College of Education. He is also a Senior Career Teacher at Lankenau Environmental Science Magnet High School, teaching Biology, Chemistry, and Anatomy for the past twenty years in the Philadelphia School District. During that time, he obtained his doctorate in Educational Leadership and Management from Drexel University.

***Sarah Lew*** is a middle school teacher at Juniata Park Academy for eighth-grade science. Prior to coming to Juniata Park Academy, they taught high school students in chemistry for two years and completed their master's degree in Education at Temple University.

## ORCID

Kate Popejoy http://orcid.org/0000-0002-5184-5105

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