Appendix A
Lifecycle of a Wind Energy Facility
**The Lifecycle of a Project – A Brief Synopsis.**

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**Introduction**

To better understand the potential effects of a wind farm it is important to understand the components of the day-to-day work and general stages in the life of a utility-scale wind energy project. This document gives a broad overview of the steps that go into the development and operation of a typical wind farm project. The target audience is the U.S. Fish and Wildlife Service.

A wind farm has a lifespan of 20-30 years that starts with development and goes through construction, operation and ends with decommissioning or occasionally repowering, i.e., replacing old turbines with newer ones. For the purpose of this document this progression will be termed the Lifecycle of a typical wind farm. Wind energy development is driven by a stepwise process that is fueled by the available wind resource at any given location. Regardless of the land size, the geographic location or proximity to electricity demand, wind farms are limited by the quality character of the wind that blows through any project site. For this reason, the planning and development process of any wind farm is a dynamic process guided by the collection and modeling of wind data on site.

**Prospecting**

**Year 0-1**

Wind energy development is fueled by the available wind resource at any given location. The initial identification of a location, coordination of participating land owners, and conceptual design for a wind farm is typically done by the wind energy company. However, often times the prospecting activities may be conducted by smaller wind development companies or agents who are most familiar with the local conditions prior to the involvement of the wind energy company that will eventually complete the development activities. Once the framework for a conceptual design\(^1\) is put together by these entities, it is then offered to wind development companies to purchase and develop formally. The condition that the conceptual design is in when offered to wind development companies varies, but essentially has the following components to it.

1. One or more temporary meteorological-towers (met-towers) erected within the project area and collecting wind data for approximately one year.
2. Project boundary
3. List of participating and potential land owners that have contracted into land lease agreements.
4. Documentation of any environmental assessments or surveys that have been performed to date and correspondence with agencies.
5. Routes for transmission lines that exist for connecting the wind farm to the grid.
6. List of possible utility companies that will purchase power
7. Map showing preliminary turbine locations
8. Initial feasibility studies to support an interconnection to the grid.

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\(^1\) Conceptual design refers to the initial ideas intended for development of the wind farm prior to having enough information for more detailed design layouts. After more information is gathered from the site the concept for the wind farm is molded into an engineering design that will optimize the performance of the operation.
If there is sufficient information for the wind energy development company to manage the risk of the conceptual proposed project there may be several purchase options. If the project is initially scoped and defined by a local developer or agent without the means to execute the project, it would typically be offered for sale to a larger wind developer or utility.

1. Purchase the entire project for an agreed upon price and take full ownership of the project.
2. Enter into a contract partnership between the independent agents and the wind energy development company that outlines the interaction and working relationship of both parties through development at a price that is based on megawatt energy produced at build out.
3. Form a separate company that has Principals from both parties and is legally separate from both the independent company and energy development company. This is one reason why wind farms have separate names and do business under that name.

Siting/Development
Year 1-3 (sometimes up to five years)
Once the prospecting period is over and a suitable project area is identified, the owner/developer takes a lead role in the continued development and formalization of the conceptual design. This is when the professional resources are brought to bear by the development company and staff technical specialists begin the various evaluations processes required to take the conceptual design to a finished and economically optimized form to get the project ready for construction. However, typically a wind energy company will not invest significant resources in studies or engineering until they enter into a Power Purchase Agreement (PPA) with a utility or other entity that will purchase the electricity generated by the wind farm. From the time a wind energy company enters into a PPA, they typically have 2-4 years to begin operations of the project.

The process begins with the assignment of a project manager (developer) who will be in charge of all the components of taking the conceptual design through the environmental and regulatory planning process. An interdisciplinary team of in-house and consultant staff will be charged with evaluation of the conceptual design and refinement of the final proposed project. The interdisciplinary team is comprised of technical specialist from all over the world in the following (not limited to) fields:

1. Civil engineering
2. Mechanical engineering
3. Transportation engineering
4. Electrical engineering
5. Meteorological modelers and wind assessment technicians
6. Biologists
7. Permitting specialists
8. Wetland scientists
9. Geologists
10. Archaeologists
11. GIS technicians
12. Financial analysts
13. Attorneys
14. Environmental planners
15. Telecommunication and radar technicians
16. Surveyors

Invariably, one of the most important aspects of the proposed wind farm is the wind resource. Meteorologists evaluate the quality of the wind data to-date and optimize the placement of existing and subsequent met-towers based on topography, initial wind characteristics, and the proposed turbine layout. Over the course of the next one to two years, the modeling that is performed on the wind data will help refine the placement and operation of the wind turbines for optimal output given the climatic conditions of the site. Because the placement of the wind turbines is determined by the modeling of the wind resource, the exact location of the wind turbines is not known until the last few months of development when decisions will be made regarding the optimal choice of turbine. If the exact location of turbines is not known, study corridors will be used for the environmental assessment so that the planning process can continue and allow more weather data to be collected to refine the exact placement of the turbines.

Once the exact location of the turbines has been refined from the conceptual design, the individual turbine locations will be evaluated against resource surveys performed for potential impacts to key resources such as wetlands, raptor nests, breeding areas, shadow flicker on nearby homes, noise to nearby residents, archeological sites, or sensitive plant locations. If there is an issue of the turbine impacting a known resource, in most cases the turbine will be moved until it is no longer impacting the identified critical resource. The adjustment can be several feet, several hundred feet, or elimination of the turbine all together. This stage of turbine adjustment is called “micro-siting” and is done for all resources.

The conceptual design is compared against local, state, and federal requirements, and if inconsistencies occur, either design changes or mitigations may be implemented. Not all states have the same planning requirements for wind energy development. Some states have very strict laws that apply to wind farm development while others have very limited oversight and may only include a permit for construction which can be obtained from the county building department. Most projects will be required to submit application for a Conditional Use Permit (CUP) for the county they propose a project within. The project managers and environmental staff work with the county planning department and the county attorney to draft a development agreement consistent with county, state, and federal codes and policies. Once this has been drafted it is presented to the county planning commission for approval. This approval is subject to public review and input prior to a final approval being issues. If the approval is appealed by any member of the public or interested party, the CUP may be elevated for hearing and approval by the County Board of Supervisors. This may result in denial of the project subject to design modification or resolution of any dispute raised in the appeal. It is the responsibility of the developer (project manager) to make sure that all local requirements are complete and that a project has no risk to operation from missing steps or avoiding planning requirements. In some cases where a local ordinance does not account for the characteristics of wind farms, i.e., maximum height restrictions or setbacks from property lines, variances are applied for through a local permitting process to make provisions for the wind farm.
Each step of the development process is evaluated at milestone stages for a risk evaluation. If the internal review identifies any issue that is not within regulatory or company standards, the issue is resolved before the project can continue to the next milestone. The development phase does not end until all applicable permits or approvals including the FAA, USFWS, SHPO, ACOE, Water Quality Control Board, etc. are in hand. The end result of the development process is a Conditional Use Permit or Land Use Permit (LUP) issue and enforced by the County or local government. The issued CUP or LUP will contain the details that the developer must abide by to construct the proposed project.

In cases with a federal nexus, NEPA regulations may warrant an environmental documentation process subject to public review. As necessary, federal agencies are involved in the planning process in accordance with NEPA guidelines. As projects are proposed, the potential impacts to resources regulated by federal agencies such as Federal Highway Administration, U.S. Fish and Wildlife Service, Army Corps of Engineers, etc. are identified to determine the appropriate level of coordination.

**Construction/Commissioning**  
Year 3-4

Once the CUP or LUP is issued, the conditions for the permit and the final approved design are then handed to the construction to team to implement. The transition from planning to construction takes months of coordination before the right mix of technical expertise is gathered for engineering, procuring long-lead items are identified and procured and the information needed for ground breaking is disseminated. The following steps will be required to construct a typical utility-scale wind farm. Once construction starts it will typically take 8-10 months to complete.

1. Contractors hired to perform:
   a. Grading plan and estimated earth work volumes for roads, turbine pads and equipment movement.

   b. Construction of electric cables from the wind turbines to the substation. On-site-Collection system cables can be placed underground beneath or adjacent to the roads that are constructed or placed on power poles adjacent to the roads. Typical placement is beneath the existing or constructed road bed. This is done with equipment that is driven along the designed collection system route and lays and buries the wires as it moves. Collection system lines get larger as they carry more power and get closer to the sub-station. Cables will have the largest diameters at the sub-station (2”) and smallest at the turbines furthers from the substation (1/2”).
      i. Collection lines can be placed under wetlands and streams via directional drilling.
c. Construction of roads – Existing roads will be used to the fullest extent possible so as to avoid unnecessary impacts. Each turbine will need a road built up to the base of the turbine. Roads will have a typical design.
4 Road Graveled and Seeded with Native Veg.

i. Roads will typically be 16’ wide compacted earth with a gravel base either raised or built with drainage features according to prescribed pollution elimination and run off elimination standards.

ii. Initial roads will be widened to accommodate the crane used for construction. This crane typically has a 30’ width and the road edges or shoulders are widened and leveled to accommodate it. The surfaced roads are not widened to 30’. The tracks of the crane are driven such that one is on the constructed road and the other track rides off the road on an area that has been cleared and compacted for safe travel. Once the crane work is done, soil is replaced (if it was removed) and the area is revegetated as required back to the standard road width.

iii. The turning radius of the roads is evaluated to accommodate the long trailers that will be transporting turbine blades, towers, and turbine bodies to pad locations. Some earth removal, straightening, and widening of roads may be necessary to allow trucks and trailers safe turning room.

d. Design and Construction of turbine pads- Turbine pads are constructed of concrete and rebar that are designed and poured based on the conditions of the soil and the turbine manufacture standards. The actual turbine pad at the base is 50’ x 50’ and is reinforced concrete. Additionally, an area for placing the crane is cleared around the turbine typically 50 m x 50 m and is compacted and covered with gravel.
5 Pouring a Foundation

6 Rebar Frame

7 Concrete Foundation Poured
e. Construction of transmission lines—these lines are variable in size and must be run above ground on poles. These lines carry electricity from the on-site substation to an off-site substation or transmission line where it feeds the electric grid. These newly constructed transmission lines can be several miles in length. Transmission lines must be constructed above ground. Electrical losses from burying transmission lines under the ground is too great and the ability to maintain these buried lines should problems arise is extremely difficult.

i. Poles supporting transmission lines can be either double “H” shape or single mono poles. Construction materials can be wood, concrete, or metal.

ii. Typical right-of-way is 125’ to each side of the lines. This can vary by county or local ordinance and by voltage of the line.

iii. Pole holes are excavated with an auger and then strung in runs with appropriate gauge wire.

iv. Poles are spaced to span critical resources such as water ways or wetlands.
v. Transmission lines are typically constructed to Avian Power Line Interaction Committee guidelines for electrocution and collision reduction.

10 Drilling Power Line Post Hole

11 Laying Power Poles along the Route

f. Construction of permanent met-towers- Once the project is constructed most if not all the temporary met-towers are taken down and replaced with a single permanent (sometimes 2) met-tower. These towers can be 80-95 m in height depending on the ability to model the wind for optimal turbine operation. Permanent met-towers are typically un guyed.
g. Assembly of turbine towers and generators- This requires a crane to lift the tower sections in place and men to manually bolt them together as it is constructed. Work will be performed during low-wind hours of the day, which is usually early morning. Crane work is avoided for safety reasons during windy periods of the day. Typical construction time is 4-5 turbines constructed per week.

i. Turbine towers are typically 80-95 m tall and are constructed by stacking three sections of rolled steel tubes and bolting them together. Some newer designs for larger turbines require concrete towers that will have to be poured on site.
ii. The crane is 30’ wide and is positioned to make all the lifts required with minimal relocation. The crane operates on ground within what is termed a “crane pad”. This pad provides a compact and level surface that supports the weight of the crane evenly and reduces the chance of the crane tipping from uneven or soft earth.

iii. Once the tower is constructed the nacelle is lifted to the top of the tower and bolted in place. These nacelles can weigh upward to 154 tons but typically weigh 70 tons.

iv. Once the nacelle is in place the blades lifted and bolted onto the hub or the hub and blades are bolted together on the ground and then lifted as a unit and bolted in place.
h. Construction of a sub-station - this area will be cleared and the earth compacted. Gravel will be spread deep enough to eliminate vegetation growth. A chain link fence will be built with barbed wire to deter entry to the electrical components. The dimensions will vary, but will be approximately ¼ acre.
Biological and Cultural monitors will work with construction crews in areas of critical or important resources such as wetlands, cultural sites, or locations of sensitive species to avoid impacts from construction equipment.

**Operation**

Year 4-20,30

Once the project has been built operation begins once power is delivered to the grid. On-site staff manages the wind farm on a day-to-day basis. Not all wind developers continue on to operate the wind farm once it is constructed; therefore, many wind developers sell the wind farm once it is constructed. There are only a few companies in the U.S. that develop, construct, and operate the wind farm though it’s lifecycle.

There are approximately 12 full-time staff that rotates shifts (for 90 – 200 MW size wind farm) so the wind farm is monitored 24 hours/day. The monitoring of performance for each turbine is done via remote SCADA system (SCADA stands for *Supervisory Control And Data Acquisition*. It generally refers to an industrial control system: a computer system monitoring and controlling a process). This system is on-site in the Operation and Maintenance building. The SCADA system reports any anomaly in the system so that immediate repair or maintenance can be performed.
Wind turbines are visited every couple of days for visual inspection of areas around the turbines to identify any erosion or non-mechanical maintenance that may be needed. Turbine pads are kept free of debris and rodents are controlled if burrowing activities are observed around turbine pads. Areas that have been revegetated or seeded are monitored for erosion and any need for erosion control or maintenance. Speed limits are posted on all roads within the project site and staff are expected to operate vehicles within the limits and weather conditions at all times.

Project requirements will vary in regard to post-construction monitoring. These activities are carried out with the supervision of the environmental staff of the operator.
Turbines operate at a fixed or variable rotational speed that generates a rated electrical output for each turbine. Rotations speeds that the turbine is rated for is maintained for any given wind speed automatically by the turbine. Each turbine has weather instruments that adjust the pitch of the blades so that as wind speeds change, the blades stay at a constant RPM. Rotational speed ranges from 14-22 RPM depending on the turbine manufacture. *It should be noted that current models of wind turbines do not rotate fast enough to “blur” the blades. The units are large enough and the components massive enough as to see them at all wind speeds.* Modern turbines stop turning when winds exceed safe velocities of approximately 25 m/s. This is termed cut-out speed. The turbines do not start turning until the wind reaches approximately 3/4 m/s (although this will vary by turbine type). This is termed cutin speed.

![Wind farm](image)

Wind farms are developed and optimized for their output and returns on investment on a 20 or 30 year model. Most costs in the lifecycle are capitalized and built into projects pro-forma during operations. Open ended operational restrictions such as curtailment may impact the ability of projects to get financing.

**Decommissioning**

Year 20 or 30

As the end of the useful life of the equipment is reached there are two options for an operator. One is to decommission the existing wind farm and remove the equipment and sell it for scrap and the other is to repower the existing array with new technology (still would sell the old stuff for scrap). Decommissioning is done by dismantling the turbines and towers and selling the raw components for scrap. Buried collection lines are left in the ground. These components are the steel and copper in lines and towers. Concrete pads are removed below the surface of the ground by jack hammer or explosive and then the remaining concrete is covered with soil. Once the foundation is removed and covered, the gravel around the pad is removed and the compacted earth is ripped and seeded. In areas of cultivated
fields, reseeding may be omitted to allow for crops to be planted. The concrete removed is disposed of in appropriate manner depending on the local need for this material and disposal locations.

Buried collection lines are left in place and not removed as they are buried 3-4 feet below the ground surface. All above-ground wires and components are removed and sold as scrap. Unnecessary roads are ripped and seeded if appropriate and or left for local land owner use. These are at the discretion of the landowner and agreed upon by the operator.

**Repowering**
The alternative to only decommissioning is to repower the project with current technology. This would still require decommissioning old equipment in preparation for newer turbines. We are seeing many of the older California wind farms being repowered with new turbines. As many as 20 old turbines can be replaced by a single turbine built with existing technology. Repowering may initiate the permitting process again in some areas, but not necessarily. Regardless, repowering will be a very viable option and technological advances even 10 years from now will produce turbines that are more efficient resulting in few turbines at and more electricity out of wind farm sites.