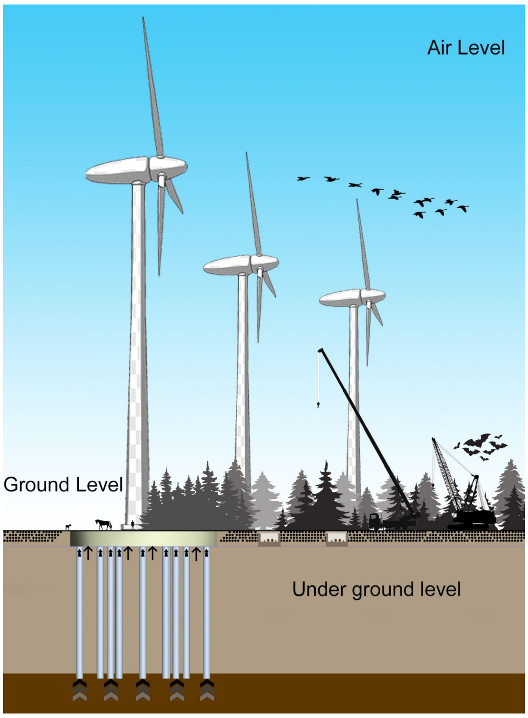
Wind energy and environmental impacts of

wind turbine projects

Vindenergi och miljöpåverkan av vindkraftsprojekt

Chadi Kattach



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Swedish University of Agricultural Sciences, SLU
Department of Landscape Architecture, Planning and Management
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Wind energy and environmental impacts of wind turbine projects

Vindenergi och miljöpåverkan av vindkraftsprojekt

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“Of all the forces of nature, I should think the wind contains the greatest amount of power” Abraham Lincoln

Abstract

My goal in writing this paper was to become more familiar with with wind farm planning and its relationship to the landscape, as a strong and bold intervention in the existing landscape.
I examined some of the side effects of onshore wind farms in general, By studying different research on the effects of wind turbines on the surrounding key species such as humans, terrestrial mammals, bats and birds. Which can be dangerous in some cases.
Then by putting them together from a landscape perspective with the time aspects of the life of the turbines starting with the manufacture, transportation, installation, operation and ending with dismantling. And discussing how to avoid the negative effect through proper project planning. To give a comprehensive view of the problem and to work on a sustainable wind energy project.

We aspire to have clean electricity without the use of fossil fuels and their negative effects on the climate and thus the landscape. However, we want to do this in a way that does not harm the environment in general or biodiversity in particular. Wind energy is one of the most effective ways to reduce these negative effects.

Research findings are primarily based on literature reviews and in addition to simulation programs (Simscale) when studying wind resources and their effects. And (Revit) when studying the movement of the sun and the effects of wind turbine shadows. Additionally, I added diagram drawings that will be the highlight of my thesis write-up and used them as a reward for a hard day of work.

Foreword

As a designer of high-rise buildings, I always had a question when I was standing at the height of hundreds of meters above the ground. Why do we study the tower's resistance to wind and not how to benefit from it? And why do we generate electricity from wind turbines in rural areas and not work on finding a way to develop it in urban areas? If wind power is so effective, why do we not use it more in other places in the world? These questions prompted me to study different disciplines, starting with landscapes, passing through wind and its resources, and ending with wind turbine technology, design and planning

As we know there is enough wind energy available to meet all the world's energy needs if appropriately harnessed. Additionally, wind energy will never run out like oil, gas, or uranium. It is essentially free as long as the turbines are set up and maintained properly. Compared to other energy sources, such as nuclear power, which generates radioactive waste, coal-burning power plants produce smoke and smog. Compared to fossil fuels, wind energy produces no greenhouse gases and does not contribute to global warming. Compared to other power sources, such as nuclear, wind energy is very cost-effective. Those who are anti-wind energy tend to exaggerate the turbines' ugliness, disruptiveness, and noise. The number of birds killed by turbines is negligible compared to those killed by cell towers and radio towers. In addition, there are billions of birds killed by domestic cats.

It made sense to broaden my knowledge of landscapes. My previous education and work experience were as an architect, so I think my understanding of landscape architecture before and after the program is quite different.
Before starting the study, my concept of landscape architecture can be summarized as improving the aesthetic appearance of a building, by planning the space outside or around the building and designing this environment with the help of natural elements such as stones, bricks, water, terrain...etc. As a landscape architect, the definition may be much deeper. It is a science through which environmental and ecological expertise is applied in planning, assessing, analyzing and resolving practical landscape issues, designing habitats and improving landscapes. In which the landscape architect also receives expert advice from multiple disciplines on

landscape operations, landscape ecology, habitats, and vegetation. We may one day see other types of turbines that are not affected by air turbulences (like a vertical wind turbine) in urban areas and in different shapes than current designs, shapes with much smaller sizes and zero noise.

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1. Introduction

The oil crises of the 1970s caused panic in the industrial world, which in the 1980s was reinforced by accidents at the nuclear reactors at Harrisburg and Chornobyl, where some countries began to search for new sources of energy. Through the development of renewable energy sources such as solar energy, biofuels, hydropower and wind energy, a new energy industry developed. Then came the Rio de Janeiro conference in 1992, where calls for a transition to renewables were more frequent, and shifted the focus to alternative sources of clean energy production.

There seems to be a strong connection between energy and environmental policy. Burning fossil fuels to produce energy is the primary source of ever-increasing greenhouse gas emissions that threaten to change the climate on a global scale. Several governments, including those in Sweden, Germany, the United Kingdom, the Netherlands, and the United States, then began investing money in research and development. A large energy company and the aircraft industry were tasked by the governments to develop wind energy (Wizelius, 2015).

Denmark was a leader in the development of wind turbines and the installation of wind energy connected to the grid. The country was at the forefront of wind energy development from the 1970s to the early 1990s. It provided 39 per cent of the country's total electricity consumption in 2014. The coal-fired power plants that generate this energy require about 255 million tons of coal, 255,000 railcars, or 12 million trucks, and emit about 530 million tons of carbon dioxide (Wizelius, 2015).

No fuel is transferred to wind turbines - and therefore does not pose any danger to the environment - nor does it pollute the air, and it does not generate hazardous waste. But there are other forms of pollution that have been tested during operation such as noise, transportation and manufacturing operations. We may also experience other effects after a few years, after the end of the life of the currently operating turbines and their dismantling. Also how to deal with the materials resulting from the dismantling.

The process of producing energy by wind turbines is a clean process, and it is one of the cheapest types of energy sources available. The sun's radiation causes differences in temperature and air pressure which cause the winds to move. The wind is the fuel for wind energy. The availability of wind resources varies over time and place like other natural energy sources. There are "gold mines", with high and stable wind speeds, and areas poor in wind resources where the winds are too weak and/or turbulent to be used cost-effectively (Brower, 2012).

But there are several challenges facing this industry as a source of energy. The wind is always different, when the wind slows down or stops, the power must be produced by other power plants. In addition to the fact that wind turbines are artificial structures constructed in natural ecosystems with balanced biodiversity, where all living things will experience different effects, depending on the location of the addition. Humans may also suffer side effects from these farms.

My goal with this thesis was to study the side effects of onshore wind turbines (horizontal axis) to reduce them, by looking at wind farm planning from a comprehensive perspective. This is on a general level without a specific location because each location has its own characteristics in the cases of studying the shadow and the movement of the sun, in order to answer specific questions:

1- What are the factors to consider when choosing a site and planning a wind farm within it?

2- How do onshore turbines affect the surrounding key species of this site, whether on fauna, flora and humans?

3- What are the procedures through which: Minimizing or adapting to the side effects of these turbines?

2. Methods

Wind turbine effects have been discussed in many detailed but separate previous papers, from the points of view and research of researchers in various sciences, from zoologists, botanists, biologists and meteorologists to physicists and planners. This paper is a literature study where I link research from different disciplines to get a holistic knowledge about the interrelationship between turbines and their surrounding key species: humans, terrestrial mammals, birds and bats. Proceeding from this paper, taking advantage of my background as an architect and my studies in landscape architecture. I will link this different knowledge and then analyse them to answer the main questions of the paper. I work on figures as part of my methods, not just as a link, but to illustrate and understand key points and ideas for both myself and the readers.

I will divide the site surrounding the turbine into three levels during the life stages of the turbine, starting with planning, implementation and operation, ending with stopping and dismantling.

1. The first level is the air space surrounding the turbine blades where birds, raptors and bats interact with the turbine blades
2. The second level is where plants, animals and humans interact with the turbine in general.
3. The third level is a level below the natural ground: the foundations and power cable ducts.

3. Result

To reach the goal, it was critical to have all the essential tools on hand. These tools were knowledge. In-depth knowledge of wind turbines, their types and parts, how they work, and how wind farms are planned. To achieve this, it was necessary to understand the main factor, which is wind, its types, how they form and where they are best available. After studying these two factors, the process of reaching the goal and analyzing side effects was more clear and easy.

3.1 Historical background

It may be impossible to know when man started using wind and exploiting its energy, but, according to Wizelius, some types of windmills were used in China and Japan about 3000 years ago (Wizelius, 2015). In Persia, close to the Afghan border, the first well-documented windmill dates back to AD 947. During this period, windmills were used by the Persians to grind grains. Reed or wood bundles were used as sails on these vertical-axis machines (Sathyajith, 2003). See (Figure no.01).

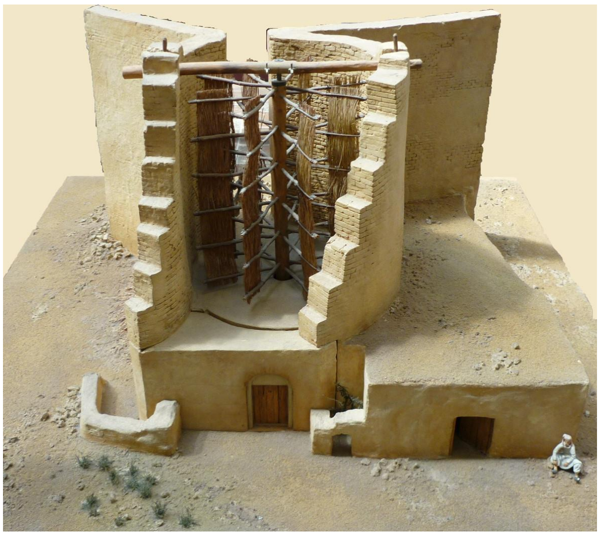


Figure no.1 Model of an Iranian windmill housed in the German Museum in Munich.

It is also unclear where the technique of using wind for mechanical power came from. In ancient Babylon, the technique may have originated. As part of his ambitious irrigation project during the 17th century B.C., Babylonian emperor Hammurabi planned to use wind power (Sathyajith, 2003). In most of Europe, grain grinding mills were popular in the 13th century. This technology was adopted by the French by

1105 A.D.and by 1191 A.D., it had been adopted by the English. Unlike Persian mills with vertical axes, European mills had horizontal axes (Kishore, et al., 2014). These mills were pioneered by the Dutch, under the design of Jan Adriaenszoon. Holland used windmills not only for grinding grain but also for draining marshy lands.

In different periods of history, there have been some other types of horizontal-axis windmills (mainly in the Occident): Post windmill (the 1100s), Wipmolen Dutch (1400s), Dutch smock mill (1500s), Poltrock mill (1600s), and Gallery smock mill (1700s) (Kishore, et al., 2014).

Historical wind turbines were not as popular as the American farm windmill (also known as the Western mill). Through Dutch settlers, these windmills reached America in the mid-17th century. In North America, these windmills were developed to provide drinking water for people and cattle during the mid-19th century. Additionally, they were used to provide water for locomotives during the westward expansion of railways (Sathyajith, 2003). See (Figure no.02).

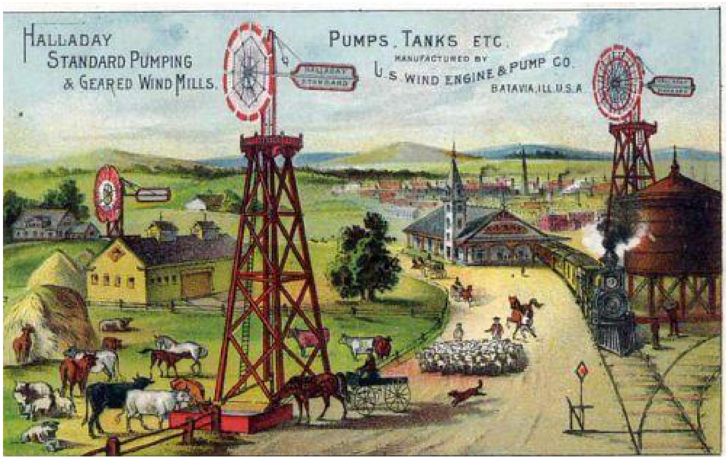


Figure no.2: An advertisement by U.S. Wind Engine & Pumping Co., developer of American windmills.

Water-pump windmills are still considered one of the most successful applications of wind power. The American multi-blade wind turbine first appeared in wind energy history in the mid-1800s. From 1850 to 1930, over six million units were installed in the US alone (Kishore, et al., 2014).

The era of wind electric generators began in the early 1900s. Danish engineers built the first modern wind turbine in 1890 specifically for generating electricity. During the same period, a large wind electric generator with a 17 m rotor was built in Cleveland, Ohio. By 1910, several hundred such machines were supplying electrical power to villages in Denmark. By about 1925, electric wind generators became commercially available in the American market (Kishore, et al., 2014).

3.2 Wind resources

Wind resources are the process of estimating how much fuel is available for wind power turbines during their useful lives. Ultimately, this step determines how much profit the turbine will earn for its owners and how much energy it will produce (Brower, 2012).
There are different definitions of wind, all of which have the same meaning, but they differ in wording but agree on the fact that wind is moving air. Wizelius (2015) sees it as moving air, and wind turbines convert the kinetic energy of the moving air into electrical energy or mechanical work. Karl Nilsson and Stefan Ivanell (2010) expressed it as the air current, that moves relative to the Earth's surface.

Newton's first law states that a body remains at rest or in motion without acceleration as long as it is not affected by any external forces (Nilsson & Ivanell, 2010). Accordingly, some forces affect the air to generate wind, some of which affect the air mass horizontally, namely: Pressure gradient forces, Coriolis, Turbulent drag, Centrifugal and Advection. Some are vertical: Gravitational force, and Pressure gradient force (the vertical).

Item	Name of Force	Force direction	Horiz. ⇶ or Vert.↑↑↑↑
1	Gravity	↓↓↓↓↓↓↓↓	↓↓↓↓↓↓↓↓
2	Pressure gradient	H ⇶ L	↑↑↑↑↑↑ + ⇶
3	Coriolis	90° to right (left) of wind in Northern (Southern) Hemisphere	⇶
4	Turbulent drag	Td ⇇ ⇶ W	⇶
5	Centrifugal (apparent)	away from center of curvature	⇶
6	Advection (apparent)	(any)	↑↑↑↑↑↑ + ⇶
7	Friction	F ⇇ ⇶ W	⇶

Table no.1: Horizontal and vertical forces (Stull, 2017).

3.2.1 Horizontal Forces

- **Pressure gradient forces**

A pressure gradient is the only force that causes winds to blow horizontally. All other forces are dependent on wind speed, so they can only change the existing wind's speed or direction. A pressure gradient is the only force that can start winds blowing from zero (calm). There is a force from high to low pressure when the pressure changes with distance (i.e., a pressure gradient). Normally, this force is at right angles to height contours or isobars on weather maps, going from high to low pressures directly (Stull, 2017). See (Figure no.03).

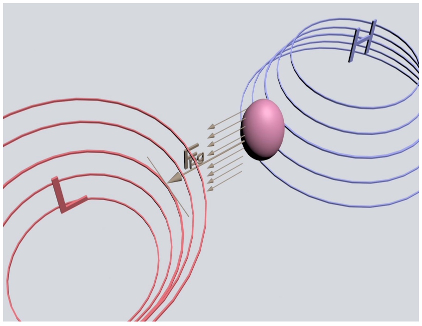


Figure no.3:

The horizontal pressure gradient forces.
The brown arrow shows the direction of pressure-gradient force F_{PG} from high (H) to low (L) pressure. This force is perpendicular to the isobars.

- **Centrifugal forces**

An air parcel moves in a straight line due to inertia. A force that must be applied in a different direction for its path to turning. The centripetal force pulls toward the inside of the turn. A force opposite the centripetal force is called the centrifugal force. It points outward from the center of rotation. The magnitude of centrifugal force is proportional to the square of the wind speed (Stull, 2017). See (Figure no.04).

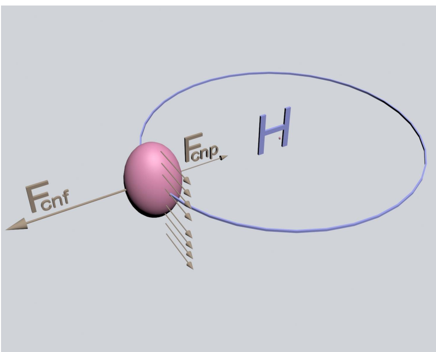


Figure no.4:

The horizontal centrifugal forces.
Centripetal and Centrifugal forces are equal and opposite.

- **Friction force**

Friction occurs when air sweeps over the ground. Due to this friction, a friction force is created in the opposite direction of the wind moving. It depends on wind speed and roughness length, which measures how much the ground surface, retards the wind speed at a specific location. A high roughness length retards wind speed more than a low roughness length. As a result, the frictional force is greater in areas with high roughness length, such as dense forests, than in areas with low roughness length, such as open waters. Roughness lengths are typically used in their classified form, the roughness class (Wizelius, 2015). See (Figure no.05). The roughness classes were divided into five classes:

The first one is 0 which is the water body described as Flatwater.

Then class 1 is a sparsely vegetated landscape with few buildings characterized by flat to hilly terrain.

Class 2 is a mix of open areas, vegetation, and buildings in the countryside, and is described as terrain that ranges from flat to hilly.

Class 3 is about several farms, woods, and obstacles that can be found in small towns or the countryside, and is described as the terrain from flat to hilly.

Cities or dense forests with large populations are classified as Class 4, and they cover a range of terrains from flat to hilly terrain (Wizelius, 2015).

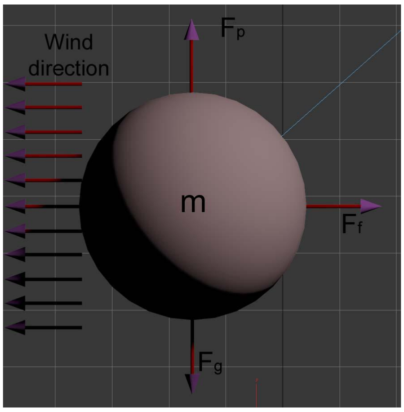


Figure no.5:

Three forces affect this mass of air, F_f the horizontal frictional force is opposite to the direction of the wind, it works to reduce the wind speed in the plate near the surface of the earth.

- **Turbulent-Drag Force**

There is a layer of air between 0.3 and 3 km thick at the bottom of the troposphere called the atmospheric boundary layer (ABL). Due to its position at the bottom of the atmosphere, the ABL is referred to as the bottom boundary of the atmosphere. It lowers the wind speed M throughout the entire ABL due to the mixing of slow near-surface air with fast air in the ABL caused by turbulence in the ABL. As a result, the air in the ABL is subjected to a drag force that is normally experienced by air. The direction of the wind is always opposite it (Stull, 2017). See (Figure no.06).

A wind-blocking surface element, such as a pebble, blade of grass, crop, tree, or building, interferes with airflow around them and interferes with wind direction. A combination of these elements over a ground surface slows airflow by creating resistance. It is called drag when there is this resistance (Brower, 2012).

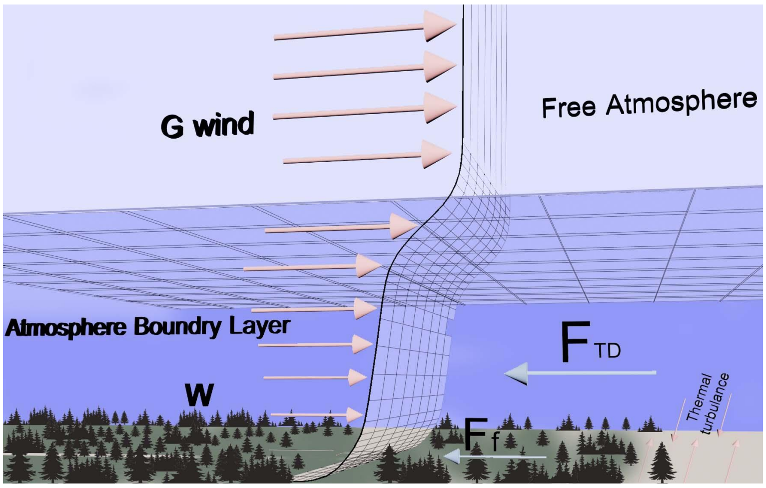


Figure no.6: Wind speed W is slower than geostrophic G because of turbulent drag force in the atmospheric boundary layer.

- **Coriolis force**

High-pressure winds will move clockwise in the northern hemisphere due to the Coriolis force, while low-pressure winds will move counterclockwise. In the southern hemisphere, the opposite is true (Wizelius, 2015). It is the force that makes the wind bend off from a straight line, and that makes the trade winds blow towards the equator from the northeast and southeast instead of in a perpendicular direction. In addition to being perpendicular to the direction of motion, the Coriolis force is proportional to the speed of the wind. It also varies with latitude. At the equator, it is zero and it increases towards the poles (Stull, 2017).

When observing motions from the earth as a reference frame, we experience the Coriolis effect. At the equator, the earth's surface rotates faster around its axis than it does near the poles. Surfaces beneath objects moving freely toward the equator accelerate toward the east if they are free to move toward the equator. As seen from the surface, the object appears to be turning westward. The direction the wind comes from is used to indicate wind direction. In the case of southerly wind, the air is moving toward the north (Brower, 2012). See (Figure no.07).

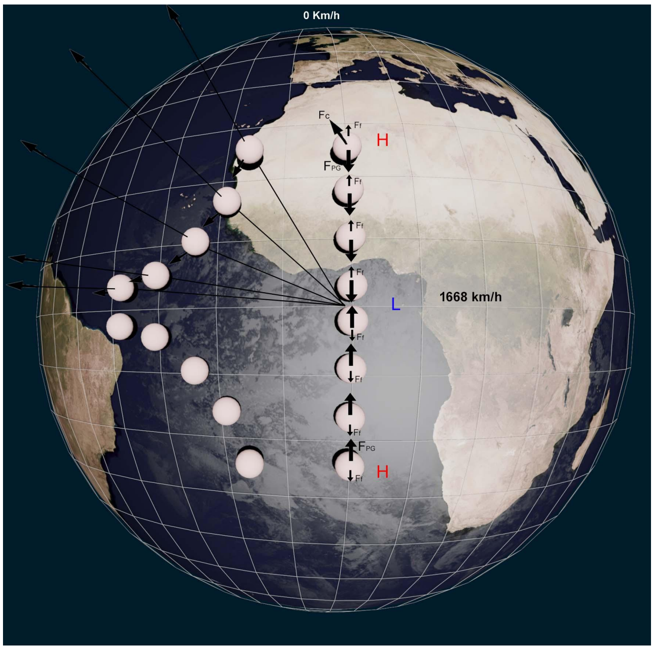


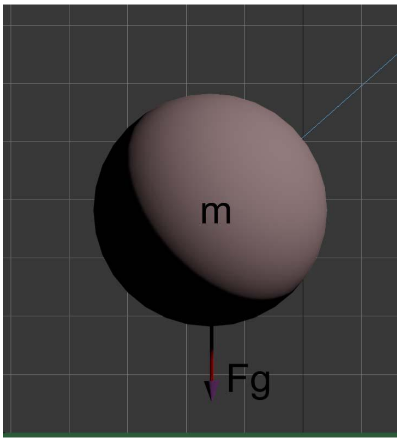
Figure no.7: Coriolis force diagram
An object's speed depends on its distance from the axis of rotation since the Earth is a rotating sphere. At the North Pole, since the axis of rotation intersects the Earth's surface, you are not moving due to the Earth's rotation. The fastest speed on Earth can be found at the Equator, farthest from the axis of rotation.
The speed of a vehicle is determined by the distance travelled divided by the time spent travelling. A circle's circumference is equal to its radius times two. According to the Earth's radius, someone standing on the equator would be moving at 40,0030 km / 24 hours = 1668 km/hr. And we don’t even notice! Yet someone standing at the South Pole would not be moving.

3.2.2 Vertical Forces

- **Gravitational force**

An object with mass is pulled toward another by gravity or gravitational force. Gravity is usually the first thing that comes to mind when we think about Earth. Our bodies are kept on the ground by this force. However, all objects with mass exert a gravitational force on each other. All objects around us are subject to gravitational forces! Larger masses result in a greater gravitational force between two objects. Because of this, we are able to feel the gravitational force between us and the Earth, but not between us and smaller objects. Distance between two objects also affects the gravitational force between them. Distance between objects reduces the force between them (Hofmeister, et al., 2012). See (Figure no.08).

Air parcels have a mass of m, this mass combined with the gravitational constant g defines the gravitational force. In this case, the force is downward (Wizelius, 2015).



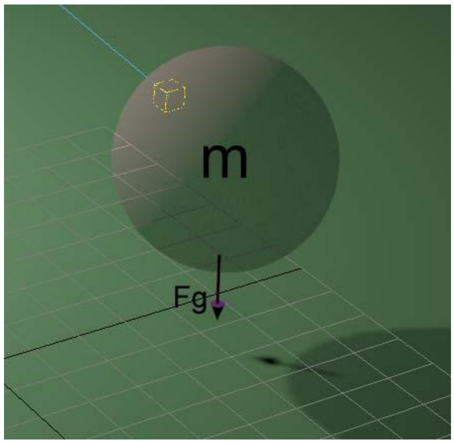


Figure no.8: Gravitational force
The Arrow represents the gravitational force (F_g) directed towards the ground.
The Sphere represents an air parcel with mass (m).
According to Newton's second law: Force equals mass times acceleration ($F_g = m \cdot g$)
When gravity pulls objects toward Earth, it always causes them to accelerate at a rate of 9.8 m/s^2

- **Pressure gradient force**

The sun's radiation will not be evenly distributed over the earth's surface because the earth revolves around the sun and rotates on its axis at the same time. As a result, the temperature will vary around the world due to differences in the amount of energy per square meter due to solar radiation. This also depends on the angle at which the sun's rays hit the earth. The sun's rays that hit the earth perpendicularly at the equator will affect a specific area smaller than the area that the same rays will hit but at the Tropic of Cancer. Because of this, the sun's energy is greater per square meter and the temperature is higher at the equator. A certain amount of solar energy strikes the two surfaces at the same angle. As a result, the energy will be smeared over a wider area at the Tropic of Cancer, resulting in less solar energy per square meter, and thus a lower temperature. In addition, the air temperature in the atmosphere will vary as a result (Wizelius, 2015).
Heat expands the air parcels, creating high-pressure areas. High-pressure air seeks equilibrium and moves towards low-pressure areas. Pressure differences cause the pressure gradient force (Brower, 2012). Winds begin to form when the air begins to move from areas of high atmospheric pressure to areas of low pressure (Wizelius, 2015). When the surface warms, the air above it expands and rises, and the pressure falls. When the surface cools, the reverse process takes place and the pressure rises (Brower, 2012). See (Figure no.10).

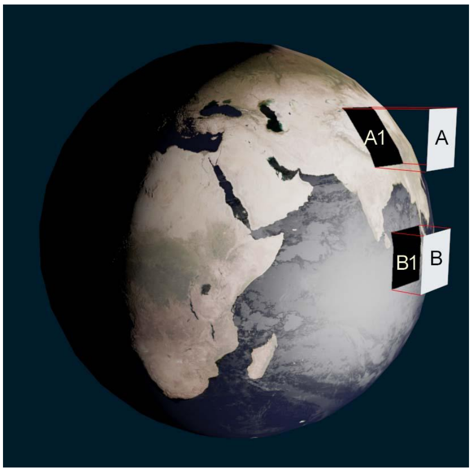


Figure no.9:
Area B = Area A
But area B1 is smaller than A1
Because of the earth's shape, the amount of heat it receives in B1 equals the heat it receives in A1.
The heat received for a square meter in B1 is greater than the heat is receives for a square meter in A1.
This causes a temperature difference between the two surfaces A1 and B1.

The Earth's surface is heated by solar radiation because the Earth is round and solar radiation strikes the Earth at varying angles. As the Earth rotates on its axis, radiation varies during the day and at night. Different parts of the Earth experience different temperatures, which leads to different atmospheric pressures. There is an association between these and the movement of air from high to low-pressure areas. Wind happens in this way (Wizelius, 2015).

So winds are created by differences in atmospheric pressure that in turn are caused by differences in temperature. See (Figure no.09).

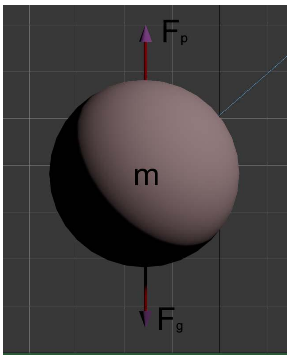


Figure no.10:

The vertical gradient pressure force is pressure, which opposes the force of gravity. The movement of air is from high to low-pressure areas.

<u>What I bring with me for the planning discussion</u>

There are two types of forces that affected the wind 8 in total, 6 horizontal and 2 vertical. The horizontal and vertical pressure gradient forces are responsible for the wind blowing horizontally, which move from high-pressure areas to high-pressure areas, which is what turbines need to generate electrical energy from the kinetic energy of the wind. Other forces affect the direction and speed of the current wind.

3.3 Conversion of Wind Energy

A lot of power is contained in the winds that blow above our heads. For this to be used as a source of energy, it must be captured and transformed into a form that can be used. Using a turbine, the wind can rotate an axis that is connected to a millstone, water pump, or electrical generator, turning an axis that can rotate a turbine. The rotor blades are inclined with the wind. As a result, the moving air pushes against them, causing them to move in one direction while the air moves in the other (Nilsson & Ivanell, 2010). To convert this kinetic energy within the wind into mechanical power, then electrical power, we need a tool, this tool is a wind turbine.

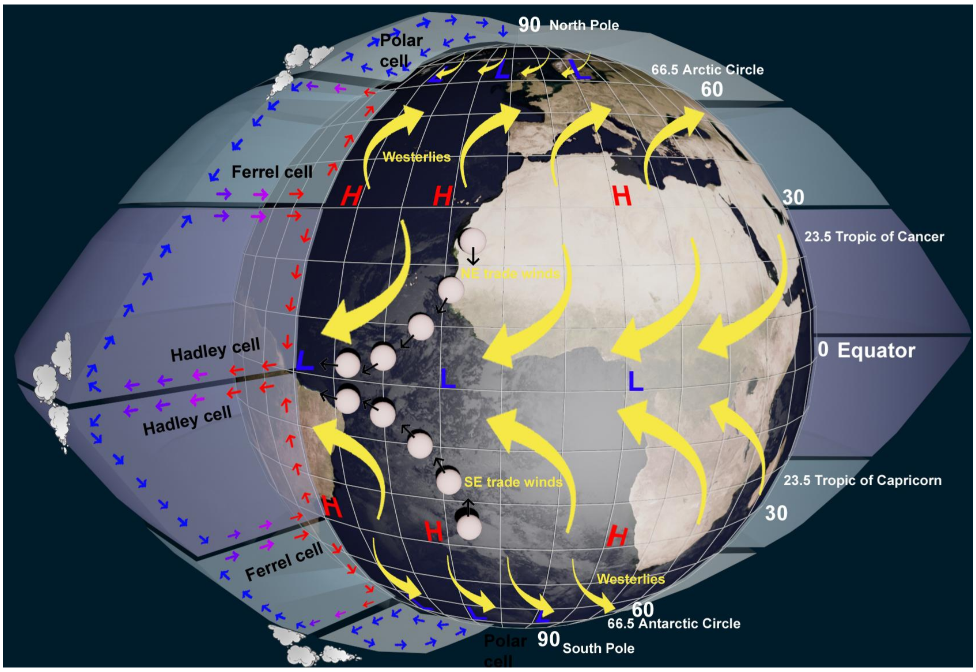


Figure no.11: permanent wind systems.

I created this figure to clarify the formation of prevailing winds and the difference in weather and precipitation according to location and latitude, hence the difference in the types of landscapes around us as a result of those differences.

Also, the Coriolis force results from the Earth's rotation on its axis.

I relied on the NWS (the national weather service in the USA) as a main reference.

Hadley cell: Low latitude air movement toward the equator that rises vertically with poleward movement in the upper atmosphere as it warms. Tropics and subtropics are characterized by this type of convection cell.

Ferrel cell: During the 19th century, Ferrel named the Ferrel cell to describe the mean atmospheric circulation at mid-latitudes. This cell is characterized by poleward and eastward airflow near the surface and equatorward and westward airflow at higher altitudes.

Polar cell: The air rises, diverges, and travels toward the poles. Polar highs are formed when air sinks over the poles. Polar highs diverge outward at the surface. The surface winds in a cold cell are easterly (polar easterlies) (NWS, nd).

3.4 Wind types

Wind turbines rely on the wind that blows horizontally to generate electricity. I will study only horizontal winds and the forces that affect their speed and direction.

3.4.1 Horizontal wind

When air accelerates, winds are created, and wind speed affect by wind forces. During the acceleration process of the wind caused by all the changing forces, feedback is often observed. This eventually results in a wind that is balanced between all the forces. There is no acceleration when there is zero net force. Such a final equilibrium state is called a steady state (Stull, 2017):

Item	Name of Wind	Forces	Specifications
1	Geostrophic	1- Pressure-gradient 2- Coriolis	Heading parallel to isobaric lines with low pressure to the left of the wind. It is most noticeable aloft in regions where the isobars are nearly straight
2	Gradient	1- Pressure-gradient 2- Coriolis 3- Centrifugal	similar to geostrophic wind, but following curved isobars. Clockwise around Highs, counterclockwise around Lows. It is most noticeable aloft in regions where isobars are curved.
3	Atmospheric boundary layer	1- Pressure-gradient 2- Coriolis 3- Drag	similar to geostrophic wind, but crosses isobars at a small angle toward Low pressure. It is most noticeable near the ground in regions where isobars are nearly straight.
4	Atmospheric boundary layer gradient	1- Pressure-gradient 2- Coriolis 3- Drag 4- Centrifugal	similar to gradient wind, but crosses isobars at a small angle toward Low pressure. It is most noticeable near the ground in regions where isobars are curved.
5	Cyclostrophic	1- Pressure-gradient 2- Centrifugal	It is most noticeable in tornadoes, waterspouts (& sometimes in the eye-wall of hurricanes).
6	Inertial	1- Coriolis 2- Centrifugal	anticyclonic circular rotation. It is most noticeable in ocean-surface currents.

Table no.2: wind types and its specification (Stull, 2017).

3.4.2 Vertical wind

Vertical winds generally occur in a thermosphere, which is also in a horizontal motion. Between about 85 km and 600 km (Smith, 1999).

3.5 Wind turbine types

3.5.1 Horizontal Axis wind turbines (HAWT)

A horizontal-axis wind turbine is known as HAWT. Traditionally known as windmills, these turbines look like a large propeller attached to a long pole or tower. Turbine blades spin on a horizontal axis, so they need to be pushed out far enough from the mast so that high winds won't bend them back in. Typically, this type of turbine faces forward into the wind. Generally, these types of turbines incorporate a tail fin to keep the blades facing the wind. Turbulence from the mast is also avoided by doing this. Strong winds can easily be observed from a tall tower. It is possible to place a tall tower on uneven ground or offshore. In the forest among large trees, it can be set up. They are mostly self-starters (Layne, 2021).

There are some disadvantages as it is difficult to operate in ground winds. It is also difficult to transport and has negative effects on the environment and landscape. Installing it requires skilled operators and cranes, with negative effects on the environment (Layne, 2021). There are some negative effects on the environment and they are difficult to maintain. Longer blades and taller turbines generate more electricity. At present, nearly all wind turbines are horizontal-axis (EIA, 2022).

3.5.2 Vertical Axis wind turbines (VAWT)

Vertical axis turbines have shafts and blades connected vertically to the ground. The main components of the system are located close to the ground. Lift-based wind turbines and drag-based wind turbines are two types of vertical-axis wind turbines. In comparison to drag or paddle-based designs, the lift design is more efficient. Unlike horizontal axis turbines, vertical axis turbines have blades attached at the top and bottom of a cylindrical rotor (EIA, 2022).

VAWTs have the advantage of not needing to face the wind, as the blades spin regardless of the direction of the wind. As a result, they are ideal for areas with less predictable wind directions. A VAWT system is generally less efficient and requires more maintenance than a HAWT system because of the additional torque on the axis. Due to the fact that the rotor housing does not have to be hoisted high up in the air, these types of turbines are easier to maintain. Running it requires energy and has a low starting torque (Layne, 2021).

Figure no.12: Darrieus wind turbine.

Figure no.13: Giromill wind turbine.

Figure no.14: Twisted Savonius wind turbine

Figure no.15: Savonius wind turbine.

There are two VAWT brands: Darrieus ("egg beater") and Savonius (type S). These two brands stem from multiple forms of low cost, and the ability to take advantage of winds from all directions without the need for a steering mechanism:

- Darrieus wind turbine: This type of wind turbine resembles a whisk with slender curved blades. See (Figure no.13).
- Giromill: A straight-bladed version of the Darrieus. See (Figure no.14).
- Savonius wind turbine: In this turbine, scoops replace blades, and drag is used instead of wind lift. There is less resistance on one side of the scoop than on the other, so the scoops spin. The result is less efficient, but it can be applied in areas where cost and reliability are more critical. Caravans and buses often use these types of turbines for ventilation. See (Figure no.15).
- Twisted Savonius: It is possible to improve efficiency by reducing drag by changing the shape of the scoops into solid blades that twist around the axis. For fixed HAWTs, changing directions can be a problem in urban wind energy generation (Wizelius, 2015). See (Figure no.16).

What I bring with me for the planning discussion

There are two types of wind turbines, horizontal and vertical. These are classified according to the axis around which the blades rotate, and the focus will be on the horizontal type, which is common around us.

3.6 Wind turbines and Landscape

There is a difference between landscape impacts and visual impacts, but they are related. Changes in the fabric, character, and quality of the landscape are considered landscape impacts. Changes in the available views of the landscape and their effects on people are considered visual impacts. A landscape impact does not necessarily correspond to a visual impact. There is always confusion between the two definitions. We can consider that the visual effect is part of the group effects of turbines on the landscape. Wind turbines are a difficult issue, as they are a novel element in the landscape. This adds pressure to them and adds a new challenge to these landscapes, due to their large size and problems associated with energy transfer, noise and shading (Brower, 2012).

Emmanuel Contesse (2017) argues that landscapes are the result of human intervention in their environment and that the European Landscape Convention does not protect "valuable" landscapes from wind turbines. Instead, it suggests a way to manage landscapes with wind turbines by transforming the landscape in a coherent and compelling way while preserving its elements. Assessing whether wind farms enhance or diminish the landscape in which they are located is more difficult.

There is no hiding place for wind turbines. Wind turbines are particularly visible in the landscape due to their sheer size and the large areas required to construct them. As the principle of landscape integration cannot be applied to land-use planning for wind turbines, the basic aim is to integrate wind turbines into the landscape, taking into account the specificities of the host landscape. Landscape planning can be enhanced or spared by wind turbines. In the same way as any other type of infrastructure, wind turbines must be considered as part of a landscape project (Wizelius, 2015).

I divided my study into three levels to study the effects of wind turbines on landscapes: the air level surrounding the turbine, where bats and birds suffer a bit during installation and operation; the natural ground level, where humans, terrestrial mammals, and plants suffer a bit during transportation, installation, operation, and maintenance; and the underground level, where there is a clear trace from the foundations and underground cables.

3.6.1 Air level

At this level, the effect will be on birds, bats and raptors according to the location of the wind farm. The wind energy industry is expanding day by day in many parts of the world. There will be some adverse effects on birds and bats as a result of this expansion. These impacts include collision mortality, habitat loss and disruption from displacement (Rydell, et al., 2012). There are many factors to consider, such as species, season, and location, which makes it difficult to generalize (Powlesland, 2009).

- **Birds**

Sweden has so far recorded 486 bird species. Of these, about 250 species breed annually in the country and another 70 are regular visitors, moving between their summer and winter seasons. The number of breeding pairs of birds in the country is estimated at 70 million. This means that at least 140 million birds are in the country at the beginning of each breeding season (Rydell, et al., 2012).

For wind farms to be effective, they must be located in open, exposed areas with high average wind speeds. This means that they are often proposed in upland, coastal, and offshore habitats, potentially affecting critical habitats for breeding, wintering, and migrating birds. In addition to the specifications of the development, the topography of the surrounding land, the habitats affected, and the number and species of birds present, the effects of wind farms on birds are highly variable. As there are so many variables involved, each wind farm's impact must be assessed individually (Langston & Grewitt, 2006). Below are the main areas of concern for birds. In some cases, these potential effects can interact, either increasing or decreasing the overall impact on birds (for instance, habitat loss may lead to a reduction in birds using an area, reducing the risk of collision) (Wizelius, 2015).

A. Construction and Decommissioning

By dislodging birds from wind farm areas due to visual intrusion and disturbance, habitat loss can be effectively achieved. Wind farms may experience displacement during both construction and operation. This may be influenced by the presence of the turbines themselves through visual, noise, and vibration impacts, or by vehicle and personnel movements associated with site maintenance. Site- and species-specific factors influence the scale and degree of disturbance, which must be assessed site-by-site (ESTA, 2022).

It is normal for wind farms to cause a high degree of disturbance during construction. It depends on several factors, such as the project's scale, the terrain and the climate, and how long it takes to construct a wind farm (Wizelius, 2007). It is likely that some of this time will coincide with birds breeding, due to the fact that construction typically takes 9–18 months. Following the development of roads, the concrete foundations for the towers are excavated and poured. Typically, trenches are dug and underground cables are buried where soil conditions permit. Substations and other buildings are built next, followed by the assembly and testing of turbines. It usually takes one day to erect a turbine (Hötker, 2006).

Because most wind farms are fully automated, human disturbance at the site after construction is complete is minimal, so only a few employees are occasionally needed on site (Hötker, 2006). Activities associated with turbine decommissioning could also disturb birds at the site. Although wind energy is considered "clean and environmentally friendly", waste is generated at all stages of a turbine's life cycle (construction, operation, and decommissioning). Potential pollutants include various lubricants used in turbines, such as gear oils, hydraulic fluids, and insulating fluids. These materials pose a low risk to birds if handled properly, but contamination can occur if fluids are spilt during routine maintenance or if turbines are not inspected regularly (Langston & Grewitt, 2006).

Decommissioning generates a lot of waste because all turbines must be dismantled, all above-ground piping removed, and all other equipment and waste removed from the site and disposed of appropriately, this results in human activity, movement of multiple vehicles and trucks, and thus the birds leaving this area (Wizelius, 2007).

B. Collision mortality

Direct mortality at wind farms results from birds striking spinning rotor blades, towers, nacelles, and associated power lines and weather poles. There is also evidence that birds are violently thrown to the ground by turbulence behind the turbine caused by the moving blades (Powlesland, 2009). Wind turbine collisions have been associated with relatively low levels of mortality in most studies. Perhaps this is largely due to the fact that most wind farms studied are located away from large bird populations. Additionally, many records rely only on corpse finds, without accounting for corpses overlooked or removed by scavengers. A variety of factors contribute to collision risk, including bird species, numbers, and behavior, weather conditions, topography, and the nature of the wind farm itself. Generally, large birds with poor maneuverability (such as swans and geese) are at greater risk of colliding with structures, Wind turbines are less likely to be detected and avoided by species that fly at dawn, dusk, or at night. The risk of collision can also vary for a particular species, depending on its age, behavior, and stage in the annual cycle. It is evident that the risk is greater in areas regularly used by a large number of feeding or roosting birds, or along migratory and local flight paths, especially where they are intercepted by the turbines (Langston & Grewitt, 2006).

Bird movement and behavior can be strongly influenced by the physical features of the landscape. Diurnal migrants, for example, follow coastlines, shorelines of lakes, rivers, ridges and other linear features. While nocturnal migrants are migrating over large bodies of water during the day, peninsulas and islands can serve as essential resting and feeding grounds during layover periods. A similar phenomenon can be observed in crops (plantations), which can concentrate migrants in otherwise hostile environments (Hötker, 2006).

In a study, two wind farm areas were considered synonymous with collision deaths: Altamont Pass in California and Tarifa in southern Spain. Large numbers of raptors collided with turbines at these sites, including large numbers of golden eagles (*Aquila chrysaetos*) in Altamont, and Griffon's vultures (*Gyps fulvus*) in Tarifa, both long-lived species with low breeding production. The number of collisions with each turbine was relatively low, less than one bird per turbine per year, but as a result of a large number of turbines (7,000 turbines in Altamont and about 700 turbines in Tarifa), the total number of collisions was high (Powlesland, 2009). The main reason for this was that both sites provide abundant food resources that attract raptors, resulting in raptors feeding within the impact hazard zone of the turbines. Thus, these two sites were not suitable as sites for wind farms due to the behavior of these types of birds. These are large birds that fly at high altitudes with poor maneuverability. In both regions, the scale and location of wind farms are unsuitable due to species behavior (large, upland species with poor maneuvrability for flight), which makes them vulnerable by colliding with the turbines and this causes a slight increase in the mortality rate. While there were very low collision rates (<0.1/turbine/year) at highland sites in the UK indicating the generally low densities of birds found in these areas (Powlesland, 2009). According to the available literature, where bird collisions have been recorded, the average number of collisions per turbine ranges from 0.01 to 23 per year (Langston & Grewitt, 2006).

In wind farms, bird deaths are caused by six main factors:

1. Density of birds and turbines: There are more opportunities for birds to collide with turbines when birds are abundant or frequent movements move them. This does not mean that the high density of birds or the frequency of movements necessarily translates into greater deaths of birds. However, the density of turbines on the site increases the chances of collision (Powlesland, 2009). Bird mortality is not related to the scale of a wind farm. Small, poorly sited wind farms may kill more birds than larger farms. However, large facilities may kill many birds in total, affecting the population at large, especially when threatened species are involved. Even relatively small increases in mortality rates may be significant for populations of some birds, especially long-lived species with low productivity and slow maturity, especially when the species are already rare, such as the blue duck (*Hymenolaimus*

malacorhynchos) and the kaka (*Nestor meridionalis*). It is critical to consider the average effect of each turbine, as well as the cumulative impact of the total number of turbines and associated structures like overhead power lines, and meteorological masts, when analyzing potential impacts (Powlesland, 2009).

The potential for adverse effects, other than fatalities, also increases with the area of the farm (turbine density remains constant). Large farms may cause more bird habitat loss or endangerment, due to birds avoiding these large sites while foraging and thus increasing flight distances and time (Powlesland, 2009). Since the size of the rotor determines the size of the wind wake, the distance between turbines is measured in rotor diameters. Generally, if turbines are arranged in one row, they should be placed five rotor diameters apart. In larger installations, such as wind farms. There is usually a seven-rotor diameter distance between rows in this case (Wizelius, 2007). On the other hand, when Manuela de Lucas tries to predict the impact of a proposed wind farm on the birds, it is insufficient to assume that collision mortality will increase with bird abundance. Rather, he proposes that differences in mortality are equally or more related to species-specific flight behavior and morphology, weather, and topography in the vicinity of the wind farm (2008).

2. Species of birds: Certain species or groups of birds seem to be particularly susceptible to collisions with structures. These groups include pelicans, ducks (*Anseriformes*), birds of prey (*Accipitridae*), especially large upland species, owls (*Strigiformes*), and night-migrating passersby (Powlesland, 2009).

3. Landscape features: Certain landforms on wind farm sites, such as hills, steep slopes, saddles, and valleys, may increase the degree of interaction between turbines and birds (Powlesland, 2009).

4. Foul weather: In many locations, collisions with nocturnal migrants tend to occur during episodes of foul weather with poor visibility (Powlesland, 2009). In some studies, it has been shown that birds are more likely to collide with structures when fog or rain impairs visibility. In such conditions, flight activity may be reduced to some extent, which may offset this effect (Langston & Grewitt,2006).

5. Wake effect: Wind turbines will always cast a wind shadow downwind. Where the turbine behind produces a long path of wind that is very turbulent and slow, compared to the wind coming in front of the turbine. It's called the waking wind (Nilsson & Ivanell, 2010), and this turbulent wind is capable of harming small birds (Powlesland, 2009). See (Figure no.16,17).

Figure no.16 Wake effect

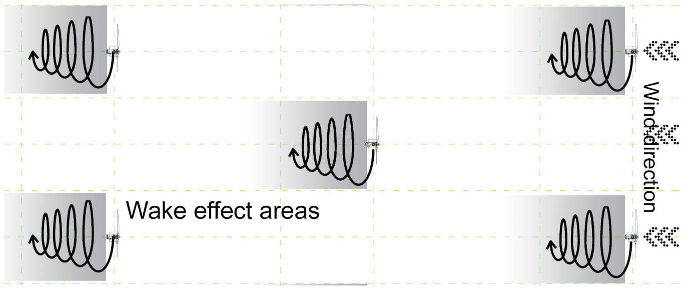


Figure no.17 Wake effect area behind 3 lines of turbines

6. Warning lights: The effects of lights are poorly understood in these circumstances. However, large numbers of migrant birds have been seen colliding with illuminated structures, especially during overcast nights with drizzle or fog (Langston & Grewitt, 2006).

The lights are normally medium-intensity obstruction lights and must be installed and operated to minimise their visibility at ground level. Therefore, low-intensity red continuous lights are used, directed upwards (shielded downwards) and installed on top of the nacelle. Illuminated turbines can attract birds, potentially increasing the risk of collision, especially in poor visibility. There have been large mortality events at a variety of lit structures in the US. This is a result of nocturnal migratory birds becoming disoriented by lights when forced by rain and fog to fly at low altitudes. Solid or flashing red lights seem to attract birds more than white flashes that flash every 1-3 seconds (Powlesland, 2009). A single bright point source is less likely to disorient birds than using lights on the outer turbines only, which could result in diffuse lighting (Langston & Grewitt, 2006). The problem of these lights attracting or confusing nocturnal migratory birds and causing them to collide with turbines has worried wildlife authorities. This needs to be considered in detail during risk assessments (Powlesland, 2009).

C. Habitat loss

The development of wind farms will result in habitat loss for birds and will affect bird densities in the area. The land is occupied by turbine bases and access roads, and secondary effects such as changed hydrology are possible (Powlesland, 2009).

Under certain conditions, areas must be cleared of trees and water drainage secured. On the other hand, if the wind farm is located in wild, forested areas, new roads may fragment the entire area, which could have worse effects than the direct impact of existing or building. However, the most significant type of habitat loss is probably the indirect one. If birds avoid the immediate vicinity of a wind turbine, this area may become unattractive to birds in the long term (Rydell, et al., 2012).

Typically, only two to five per cent of a development's total area is lost to habitat loss. Proper placement of turbine pedestals and rerouting of access roads, together with proven restoration techniques, can ensure that losses are minimised. However, the cumulative loss or damage to sensitive habitats can be significant, particularly when several large settlements are located in locations of high bird use. In addition, direct habitat loss may contribute to displacement. The extent of habitat loss, along with the availability and quality of other suitable habitats that may house displaced birds, and the conservation status of these birds determine whether or not there will be negative impacts on populations. The possibility that wintering birds might become accustomed to wind farm structures has been suggested, but there is little evidence and few studies of sufficiently long duration to show this. Behavioural differences between residents and migrants have been observed in some studies but not in others (Powlesland, 2009).

D. Barrier effect

Barrier effect means that an obstacle such as a wind turbine creates a barrier for flying birds, causing them to avoid the vicinity of the obstacle and take a different flight path. This behavior obviously leads to a lower risk of collision, but at the same time, the birds would have to travel a longer distance, possibly increasing energy consumption during transport between feeding, breeding and resting areas. The evasive behavior may consist of a slight adjustment in flight course with insignificantly increased energy consumption, but it could also result in a larger area behind the obstacles being effectively avoided. The size of the area avoided depends on the size and construction of the facility and its location in relation to the surrounding bird habitat. The additional distance birds have to fly to get across an offshore wind farm is probably negligible in most cases, but because birds sometimes fly very long distances and can pass many wind farms on their way, the cumulative impact on their Energy consumption may be noticeable (Powlesland, 2009).

While the studies by Elizabeth Masden (2009) and others showed that birds avoided the wind farm and flew around it instead of flying between the turbines. They discussed that the extent to which avoidance is considered an impact depends on: The type, the size of the wind farm, the spatial arrangement of the installations, and the type of movement, ie local movements between foraging, nesting and roosting areas, or annual migrations and the energy costs involved, and in the extreme the energy costs of avoidance behavior and increased distance travelled would reduce the mass and condition to the point where breeding success is adversely affected.

- **Bats**

The story of an unlikely hero who had a global impact. Just as the sun sets, a new day begins. Over 50 million years have passed since bats first appeared on Earth. It is the second most diverse order of mammals, with over 1,400 species dispersed across six continents. Globally, bats consume insect pests, pollinate plants, and disperse seeds, making them essential to ecosystem health. Bats are facing unprecedented threats today due to climate change, habitat destruction, invasive species, and other factors. In the absence of concerted international action, their populations will continue to decline, resulting in the extinction of many species.
In January 2016, a research review by Amy Mathews Amos found that wind turbines are the largest cause of bat mortality globally. In addition to running into spinning blades, these flying animals can experience barotrauma. Body tissues are damaged by barotrauma when the air pressure changes. A wind turbine's blades cause nearby air pressure to drop when they move. This drop in air pressure can damage the lungs of a bat if it flies too close to a turbine.
Because birds' lungs are compact, and rigid and do not expand excessively,

barotrauma is not a problem for them.
According to Cris Hein, (2016) a biologist with Bat Conservation International, if wind turbine installation continues as it is, bat populations, already in decline thanks to the fungus, will collapse. Due to their natural ability to control pests, bats are worth billions to the agriculture industry.
Despite saving farmers billions of dollars in pest control every year, they are relatively underappreciated. It is still unclear how bats are attracted to wind turbines. In contrast, birds don't usually flock to wind turbines, but simply collide with them.
Why are Bats Attracted to Wind Turbines?
9 hypotheses about the attraction of bats to wind turbines are discussed. I will review the most significant of these hypotheses:

- In museums seeking bat specimens, long poles have been used to attract bats, knock them down, and then collect them. It is possible that bats are attracted to wind turbines due to the audible "swishing" sound they produce. It is not known whether these bats were attracted by the audible "noise," the movement of the pole, or both factors.
- Bats may be attracted to the heat emanating from the nacelles of wind turbines because they seek warm roosts.
- Migrating tree bats could be attracted to wind turbines because they are the tallest structures in the landscape along migratory routes. This may serve as a meeting place for mating.
- Wind turbines generate complex electromagnetic fields that can cause bats in the immediate vicinity to become disoriented and fly further into the vicinity of the turbines.
- As flying insects may be attracted to wind turbines, perhaps due to their prominence in the landscape, their white colour, the light sources or the heat emitted by the nacelles, it makes sense that bats would be attracted to concentrations of prey.

In addition to collision and barotrauma mortality, wind farms can affect bats in the following ways:
Several studies in Sweden have provided insight into what bats do when they visit wind turbines. A variety of tools have been used, including ultrasound detectors, spotlights, thermal image cameras, or combinations of these. These studies show that some species of bats visit wind turbines actively to feed on insects that

accumulate around turbine towers and rotor blades. The vortices behind the rotating blades often suck up bats when they fly close to the blades and turn and dive quickly. This is usually associated with catching flying insects. (Cryana, et al., 2014).

Observations have also shown that bats behave in wind turbines the same way regardless of whether the rotor is moving or not. This means that magnetic fields, heat or ultrasound created by turbines, or Doppler effects produced by the same movements cannot attract bats to turbines. A white or red warning light on top of a wind turbine does not attract bats, and the sound produced by the turbine does not affect them (Rydell, et al., 2012).

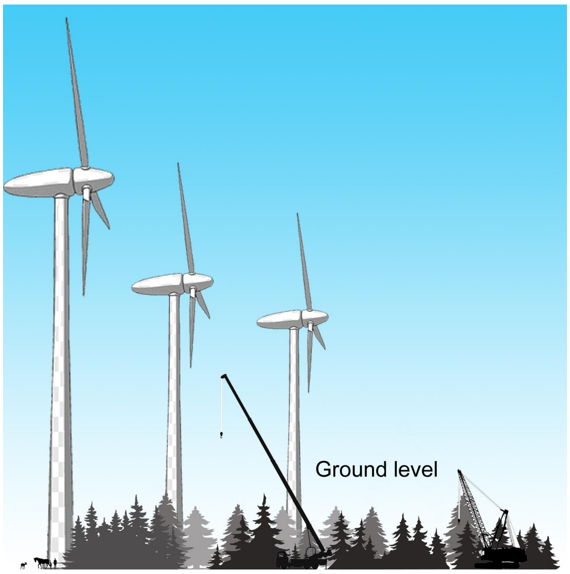
On two wind farms in the Baltic sea, 10 kilometres from land, bats exhibit exactly the same behaviour as they do when feeding on land-based wind turbines. There are insect accumulations around the turbine towers in both cases. It appears that the insects were drifting or migrating across the Baltic Sea. Occasionally, bats may remain at sea until the following evening, searching for suitable roosts in the towers or ball houses of offshore wind turbines after eating (Gaultier, et al., 2020).

Bats are killed at wind turbines primarily in August and September, as has already been mentioned. However, even within this period, accidents vary dramatically from day to day and this variation is clearly related to weather conditions. A wind speed of fewer than 4 m/s (measured at the height of the nacelle) correlates with the highest bat activity at wind turbines and the most fatalities. While bat activity decreases between 4 and 8 m/s. Additionally, high numbers of dead bats occur several days after rainstorms (cold fronts), when high air pressure, low humidity, and slow winds, usually from the north, prevail. In warm weather, more bats were killed, but there was a weak relationship with temperature (Rydell, et al., 2012).

<u>What I bring with me for the planning discussion from this level</u>

The turbines affect birds during the stages of transportation, implementation, operation and dismantling. This is because of human activity and the movement of machines within the site and because of the presence of the turbines themselves. This leads to different effects, such as displacement, mortality collision and loss of habitat, and also the effect on the bats by collision with turbine blades during operation and at low wind speeds with high air pressure, low humidity, in addition to and barotrauma mortality.

3.6.2 Ground level



At this level, the impact will be on terrestrial mammals and humans as well as on plants, depending on the location of the wind farm. There will be audio and visual pollution as well as environmental impact. Terrain mammals will be pushed temporarily away from the site by human activity, the sounds of mechanisms and drilling, and the rejection of these structures by some humans due to visual distortion or side effects.

- **Transportation of wind turbine**

Some must have wondered, when watching the wind turbines and their blades, how these giant pieces were transported from the factory to the site, especially in areas with difficult terrain or dense vegetation cover. It is very difficult to transport wind turbine components due to multiple factors, including their large and heavy dimensions that are difficult to transport. The difficulty of accessing the site is because of the vegetation cover. The transportation route is usually planned based on options, first the speed of access and then the lowest cost. Any modification to this path requires an increase in cost, time, and effort. The transportation of a 150-megawatt wind farm, for example, can require 650 truckloads, 140 railcars, and eight ships (LMC, 2017). See (Figure no.18).

A route survey is conducted prior to planning the transportation of wind turbine components to the site. This is done by taking into account the correct sizes of the turbine components and the volumes of freight vehicles. The route survey begins at the plant loading point and continues along the proposed highway to the site. It also includes the access path to the site and the site roads. To prevent overturning or damage to automobiles or turbine components. Or besieged in the areas of strong bends. Road surfaces are also maintained to prevent damage to trucks, trailers, cranes and other vehicles. Also, street tendencies are adjusted by no more than 10 percent (ESTA, 2022).

Figure no. 18: According to (dailymail, 2017) CIMC Vehicles was assigned the task of transporting 90 wind turbine blades to the top of Yunnan province's 2,900m-tall (9,500ft) Baoding mountain. As they make their perilous journey, three are pictured here.

There are also cases where new lanes and streets are created to access the wind farm site. When planning transportation, planners may have to widen the streets by cutting trees and changing the ground cover in addition to removing street coverings. Wind farms may affect terrestrial mammals differently. Mammals can be disturbed by traffic and outdoor activities. Despite the loss of natural habitats, these methods alter habitats in a way that does not necessarily harm animals. See (Figure no.19,20). Animals can be prevented from freely moving across the landscape by roads, or they can be facilitated by roads. Wildlife and reindeer have been affected by the roads, but other livestock (except horses, which are affected more by traffic than cattle or sheep) may be less affected. In most pastures, access roads already exist, so adding a road for wind turbines shouldn't be too difficult (ESTA, 2022).

Figure no.19 Cornering is one of the most difficult issues during the transportation of turbine parts which requires prior study.

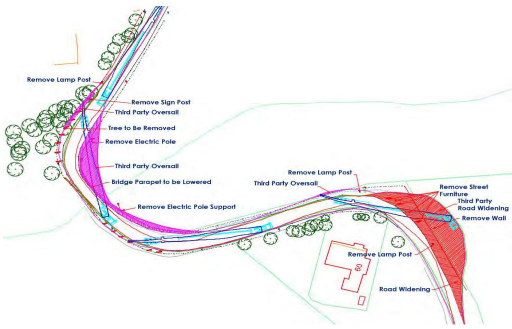


Figure no. 20 The scheme includes the removal of: electric poles, signs, and trees. The bridge parapet shall be low, lamppost, exposing the street. remove a wall.

- **Human**

According to WHO, health is not just the absence of disease, but also a state of well-being (WHO, 1948). Human well-being may be affected by the presence of turbines near the residence, which may cause noise, shadows, and reflections in addition to the visual impact.

A. Wind turbine noise

When wind turbines are placed near residential areas, the noise may be loud enough to disturb people, causing irritability, negativity, and cognitive disturbances, potentially adversely affecting wakefulness and sleep. It is critical to distinguish between sound emission and sound immission when measuring noise (Ryberg, et al., 2013).

The sound emission of a turbine is the sound it emits. Manufacturers declare the sound emission value that is used to calculate noise levels at different distances from the turbine, which is calculated based on the sound emitted from the centre of the rotor at a height of 10 metres above the ground when the wind speed is 8 m/s, and the roughness class is 1.5 (roughness length 0.5). At a specific distance from the turbines, the sound immission is measured (or calculated). The sound immission at different distances from the turbine can be calculated if the sound emission and hub height are known. For this, there is an international standard method, ISO9613-2 (Davy, et al., 2020).

There are two main types of wind turbine noise: mechanical and aerodynamic. The mechanical noise is tonal in character and is generated by various machinery components in the wind turbine (Deshmukh, et al., 2018). As air flows over blade surfaces, it interacts in different ways with the surfaces, generating different aerodynamic noise sources.

- Mechanical noise sources: There are several moving components in a wind turbine nacelle, such as gearboxes, generators, cooling fans, and other auxiliary devices, that generate mechanical noise. Human ears perceive mechanical noise primarily as tonal, which means that it peaks around certain frequencies and is harsher than broadband noise. However, mechanical noise can be minimised by properly shielding the nacelle, using sound-absorbing materials, and suppressing vibrations. Due to this reduction, aerodynamic noise has become the dominant noise source in wind turbines.

- Aerodynamic noise sources: Noise caused by flow structures interacting with blade walls is called aerodynamic noise. There are two types of aerodynamic noise produced by wind turbines: inflow turbulence noise and airfoil self-noise (Vermont, 2017).

Examples of sound at different dBA levels	
dBA level	Example of sound
20	Very, very quiet bedroom, nighttime
40	Week radio music
60	Office, loud speaking
80	Goods train or heavily traffic highway 15 m away
100	Motorcycle
120	Launching jet plane, 60 m away
140	Pain threshold, close to launching jet plane

Table no.3 Sound emission according to different calculation models for different spaces and mechanical (Ryberg, 2013).

Sound is measured using dBA (decibel A), which measures sound at different frequencies, adjusted to the sensitivity of the human ear to sound at different frequencies (Ryberg, et al., 2013). The dBA unit measures the sound that the ear perceives. The sound level of normal speech is around 65 dBA, of a modern refrigerator 35–40 dBA, of a city street about 75 dBA, of a nightclub around 100 dBA, and of a quiet bedroom about 30 dBA. It is possible for a wind turbine to emit sounds between 95 and 110 decibels (Vermont, 2017).

During the manufacturing process of modern wind turbines, sound-absorbing materials have been used in the nacelle, better precision has been achieved in the manufactured components, and damping has been used to eliminate mechanical noise. Mechanical sounds are usually heard only when a component fails. In general, wind turbines emit sound in the range of 95 to 105 dBA, which can be found in the technical specifications for the machines (Deshmukh, et al., 2018).

ISO 9613-2	Denmark	Holland	Sweden
34.1 (dBA)	35.5 (dBA)	36.0 (dBA)	35.5 (dBA)

Table no.4 Sound emission according to different calculation models for a wind turbine with 50 m hub height and a sound emission of 100 dBA; sound immission 500 m from the wind turbine (dBA) (Wizelius, 2015).

Wind turbines will be heard only between 3-4 m/s and 8 m/s, and the maximum sound level can only be reached at 8 m/s at 10 m high (Wizelius, 2015).

dBA	ISO 9613-2	Denmark	Holland	Sweden
35	465 m	525 m	555 m	525 m
40	305 m	325 m	325 m	325 m
45	205 m	195 m	185 m	195 m

Table no.5 Distance (m) to 35,40,45 dBA for a wind turbine with 50 m hub height and a sound emission of 100 dBA (Wizelius, 2015).

Emission	Immission		
	45 dBA	40 dBA	35 dBA
105 dBA	350 m	575 m	775 m
100 dBA	200 m	350 m	575 m
95 dBA	120 m	200 m	350 m

Table no.6 Sound level from wind turbines/distances (m) in general (Wizelius, 2015).

B. Shadow flicker

When the sun passes behind the rotor at certain times of the day and year, a shadow may be cast over neighbouring properties. During blade rotation, shadows flicker on and off; this effect is called "shadow flicker". There are several factors that affect shadow flicker effects:

The path of the sun in the sky is based on the location of the wind farm development, the time of year, the influence of the terrain, size and orientation of the receiver (window or other opening), the distance between each turbine and receiver, turbine shaft height, turbine rotor diameter, width of the turbine blade, and cover of clouds. See (Figure no.21 & 22).

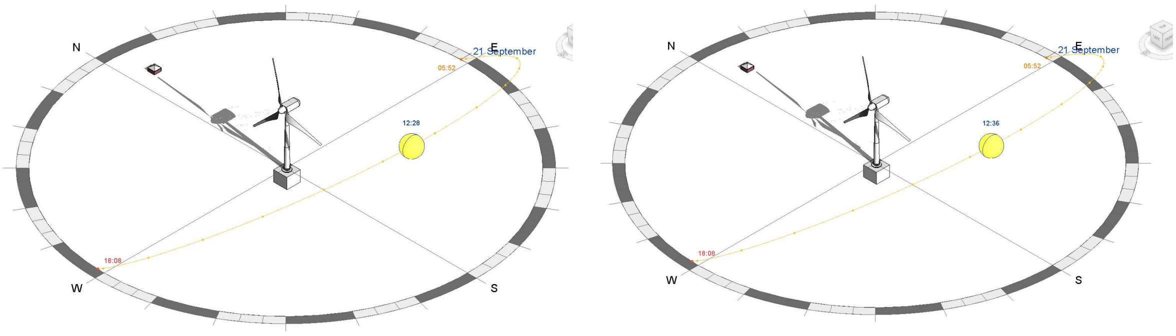


Figure no.21 A simulation of a scenario of the impact of a turbine shadow on a house 220 meters away from it, on September 21. The duration of the effect is from 12,28pm to 12,36pm.
The duration of effect on a 10 meter wide elevation is only 8 minutes daily.

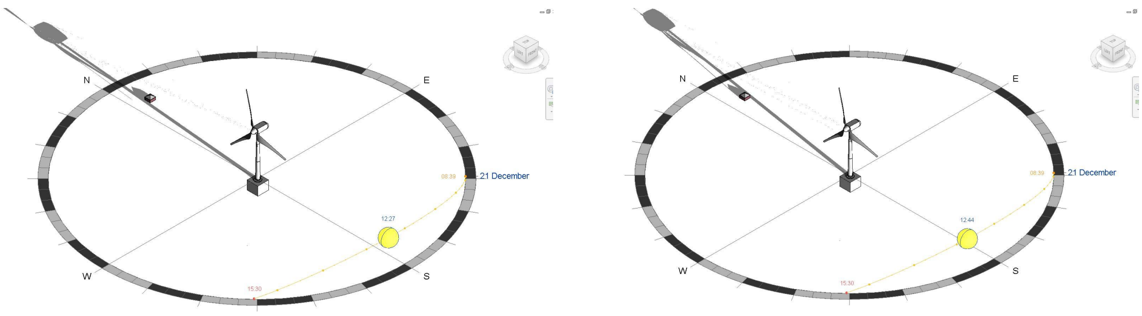
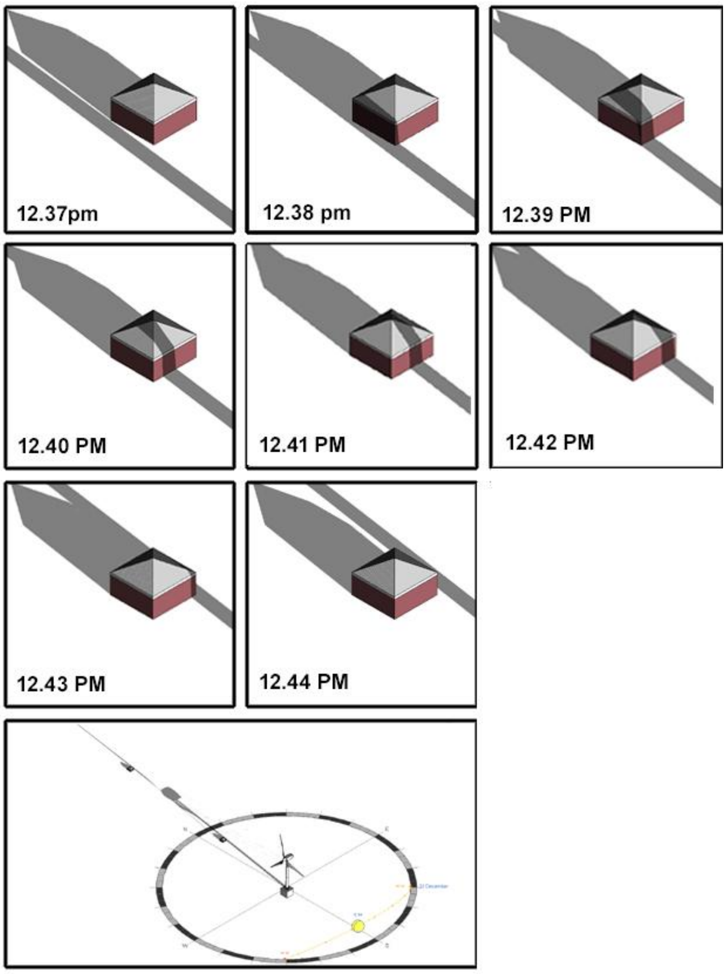


Figure no.22 A simulation of a scenario of the impact of a turbine shadow on a house 220 meters away from it,on December 21. The duration of the effect is from 12,37pm hours to 12,44pm.
The duration of effect on a 10 meter wide elevation is only 7 minutes daily.(the worst scenario)

The overall expected impact throughout the year is influenced by factors such as cloud cover and wind direction. An ideal approach would consider both of these factors when determining whether or not there will be an effect: The worst-case scenario would be sunny conditions with the widest area of the blade facing the sun. Figure no.21 and 22 shows a scenario based on the likely weather conditions (wind and cloud cover) in the area.

The turbine casts its longest shadow during the day on December 21st at 8:33 AM and 15:30 PM. These shadows will vary in the event of a slope in the ground, increasing or decreasing in length according to the degree and direction of the slope. See (Figure no.23).



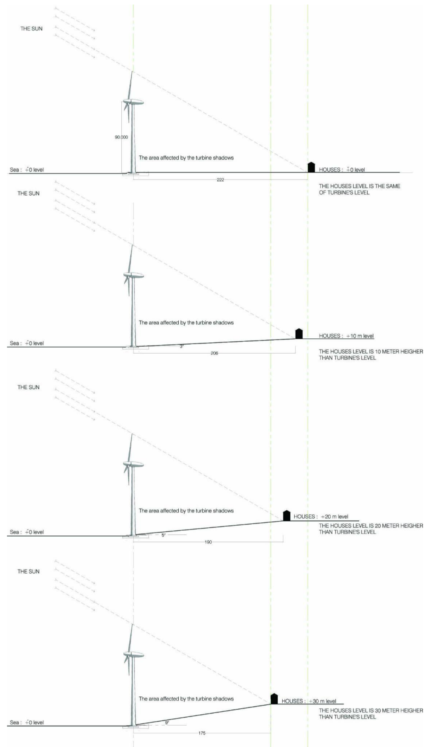


Figure no.23

A simulation of a scenario of the impact of a turbine shadow on a house 450 meters away from it, on December 21. The duration of the effect is from 12,38 pm hours to 12,43pm.
The duration of effect on a 10-meter-wide elevation is only 5 minutes daily.

C. Visual impact

Similar to factories, power lines, highways, and other structures, wind turbines are visible objects that have an impact on the landscape. Because they have a rotating rotor and are tall, they may attract the attention of passersby more than other structures. Thus, wind turbines have a relatively large impact on how a landscape appears (Cothren, et al., 2013). The visible impact can be discussed during two phases, the construction phase and the operating phase:

During the construction phase, the effects will be temporary, ending at the end of the implementation phase. The impact will be local within the scope of the farm and result from human activity and the machines used in transportation, excavation and installation. It may also affect the surrounding area due to excavations of floor channels (EWEA, 2005).

During the Operation Phase: Some commonly used techniques, called ZTV (area of theoretical visibility) maps, identify areas from which all or part of a wind turbine can be seen, as dictated by the topography (EWEA, 2005). ZTV zones can be defined as follows:

Zone I - Visually Dominant: Turbines are seen to cover a large area and blade movement is evident as the immediate scene changes. This area covers up to 2 km from the turbine. See (Figure no.24).

Zone II - Visual Intrusive: Turbines are important landscape elements and are clearly perceived. The movement of the rotating blades is clearly visible and attracts attention. Turbines are not necessarily a dominant feature of a landscape. The distance in this area is between 1 and 4.5 km in clear visibility conditions. See (Figure no.25).

Zone III - Palpable: Turbines are clearly visible, but not obtrusive. The wind farm can be seen as part of the landscape. The movement of the rotor blades is visible in a clear view, but the turbines look small in the overall picture. The distance in this area is between 2 and 8 km in good visibility conditions. See (Figure no.26).

Zone IV - element in the distant landscape: the apparent size of the turbines is very small, they are like any other element in the landscape, and the movement of the blades is generally imperceptible, the distance is more than 7 km (WindFacts, 2009). See (Figure no.27).

Figure no.24 The sight of the turbines at a distance of 1000 meters with good weather conditions and flat ground.

Figure no.25 The sight of the turbines at a distance of 4000 meters with good weather conditions and flat ground.

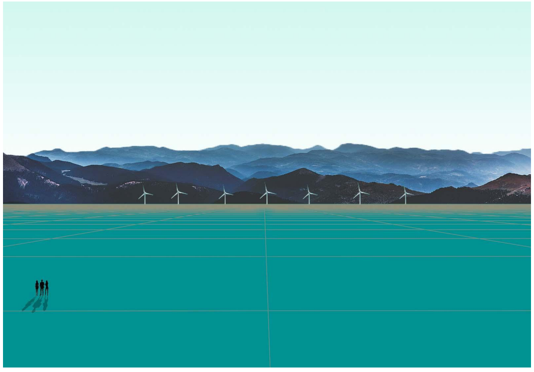


Figure no.26 The sight of the turbines at a distance of 6000 meters with good weather conditions and flat ground.

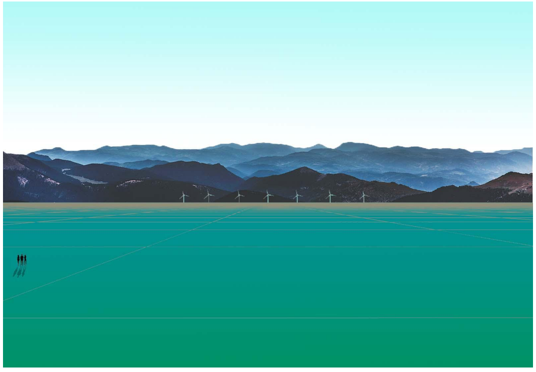


Figure no.27 The sight of the turbines at a distance of 10000 meters with good weather conditions and flat ground.

There are some who consider wind turbines to be ugly machines that turn the environment into an industrial area. However, others view them as slender sculptures that visualize the power of the wind, or as a clever way to utilize the free energy provided by nature. Natural resources are usually used efficiently by farmers, and the surrounding environment is considered a production landscape. Additionally, they have to earn a living from it (Abromas & Grecevicius, 2015).

Landscapes are often viewed by tourists and holiday cottage owners as 'postcards' that convey aesthetic and similar experiences. Wind turbines are considered natural and valuable components of the landscape after some time, since opinions and experiences tend to change over time. Considering that the experience of a landscape's values is subjective and different people have quite different opinions about it, it is difficult to determine how wind turbines affect the landscape. There are certainly some turbines that are situated in problematic places, as well as turbines that suit the landscape well (EWEA, 2005).

There are, however, no general rules for how the most effective way to site turbines in the landscape should be determined. To ensure that the wind turbines produce as much power as possible, the developer carefully selects the site. There should be no obstructions, such as buildings, trees, or other obstacles, in the area around the turbines. A high-quality site is usually aesthetically pleasing from an aesthetic standpoint as well (Wizelius, 2015).

- **Terrestrial mammals**

The construction phase of wind turbines requires increased traffic, ground works, and in some cases, deforestation and other human activities in the area. This may affect animal behaviour and spatial distribution. For large land mammals with extensive homelands, all of this infrastructure can lead to immediate and permanent habitat loss and fragmentation. The increase in people associated with wind farm construction also has the potential to disturb wildlife, especially during sensitive times such as the breeding season. this can increase the risk of fatalities from collisions with vehicles on roads (Da Costa, et al.2018).

The few studies on the construction phase show some effects, albeit temporary. However, it should be emphasized that when developing large wind farms, the construction phase lasts for several years, so some effects of this phase may persist for a long time (at least along the main corridor) (Renaud, et al., 1999).

Preliminary results from a 2011 (Álvares, et al., 2011) study of wolves at wind farms in Portugal showed that wolves avoided the area for some distance during construction, but the impact was limited to one year. After construction was completed, some decided to leave the area. This project consists of 49 turbines. Animals living near wind turbines may be affected by the noise of turbine operation. This is because the noise disrupts the animal's vocal communication or interferes with the animal's ability to hear an approaching predator.

A systematic review in 1999 concluded that there was no evidence that EMF caused poor animal health, decreased productivity or fertility, or changes in animal behaviour (Renaud, et al., 1999).
Road infrastructure is a major reason for habitat loss from wind farms. Wind farm access pathway networks can affect land mammals in different ways. Traffic and outdoor activities can be disruptive factors. Roads cause habitat loss. Roads can create obstacles for animals, fragmenting the landscape, but also facilitate movement. The passage of each turbine can cover more than 1.5 hectares of land (assuming a road length of 800 m and a pavement width of 20 m), while a single turbine would require another 0.5 hectares (Rönnqvist 2011).

Loss of natural habitat is considered permanent, but overall these areas represent only a small fraction of the overall landscape. This means that for most large land mammals that regularly move over large areas, this loss of habitat is likely not to be significant (Arnett et al. 2007).

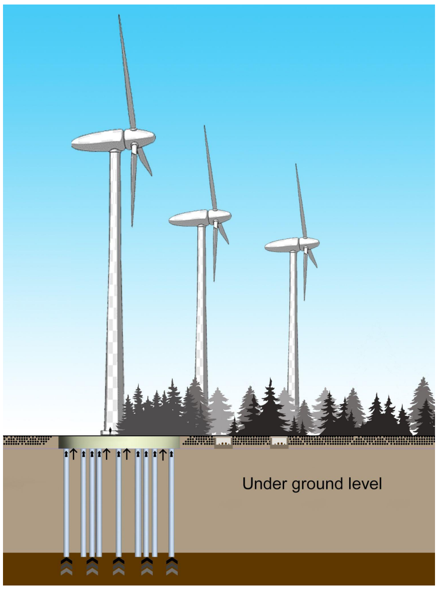
Helldin et al. (2010) suggest that all land mammals experience high-traffic roads as barriers to movement. There are, however, significant differences in the functional and structural characteristics of roads built or adapted for wind power in forests. Rather, they should be compared to low-traffic roads or forest roads, except that they do not follow the terrain as closely. There are wider side areas and higher cuttings and embankments on forest roads as well as minor forest roads. The roads in wind farms are thus structurally intermediate between forest roads and paved roads.

<u>What I bring with me for the planning discussion from this level</u>

The process of transporting the components of the turbine is a difficult and costly process and requires long planning in advance because it affects the vegetation cover and terrestrial mammals. The distance between the plant and the chosen site plays an important role in mitigating it. The effects on the human during operation are human well-being may be affected by the presence of turbines near the residence, which may cause noise and shadow in addition to the presents of the turbines themself. So some people consider wind turbines as ugly machines that turn the environment into an industrial area. As for terrestrial mammals, the effect will be permanent habitat loss and fragmentation. Increase the risk of fatalities from collisions with vehicles on roads, also animals living near wind turbines may be affected by the noise of turbine operation.

3.6.3 Underground level

On the third level, turbines can only impact the foundations, as well as the underground cable channels. This effect begins with the production of building materials and the resulting emissions that continue during the implementation and pouring of concrete, and the resulting transport operations and machines in addition to human activity. It decreases to the lowest level during maintenance operations during operation.



- **Foundation**

Wind power is currently generated with large turbines in many parts of the world. A large turbine requires substantial foundations depending on structural and geotechnical considerations (Bodamer, 1999). Foundations are used to prevent overturning and vibration, as well as to distribute the weight of the turbine over a wider area. Based on the turbine location and site conditions, a foundation design should be selected. Typically, onshore wind turbines use reinforced concrete foundations (spread or piled) (Berndt, 2004).

The most significant types of foundations used in the construction of turbines are:

A. **Spread foundation** (or a slab foundation)

Large onshore turbines typically use slab foundations. Slab foundations have a large area for spreading loads. Slab foundation dimensions are determined by geotechnical conditions and structural requirements. Strong and stiff soil with relatively low settlement is a suitable candidate for this type of foundation.

- Shallow foundation: There is a common practice of footing a spread foundation on the ground, or just below. There is little excavation and refilling required for this type of foundation.
- Gravity foundation: Compared to concrete-based foundations, this type requires excavation and refilling, but reduces the amount of concrete (Svensson, 2010). See (Figure no.28).

For a 1 MW turbine, the slab foundation would be approximately 15 m in diameter and 1.5 - 3.5 m deep. For turbines in the 1 to 2 MW range, 130 to 240 m3 of concrete are typically used. Typically, multi-pile foundations are used in weak ground conditions and require less concrete (Berndt, 2004). See (Figure no.29).

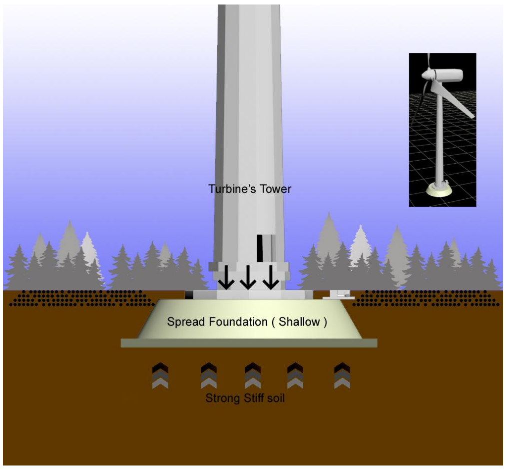


Figure no. 28 Spread foundation - Shallow

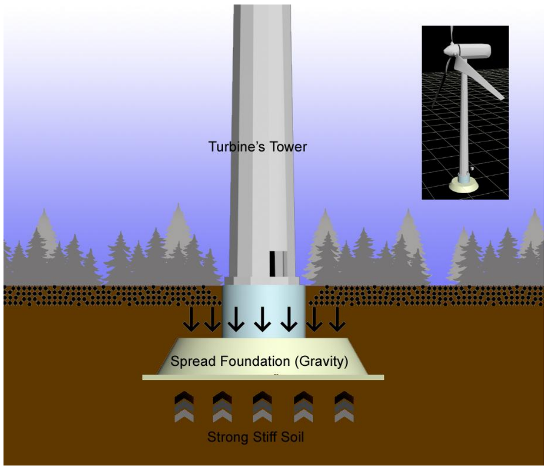


Figure no. 29 Spread foundation - Gravity

B. Piled foundation:

For soils that are not suitable for footing the foundation on the ground, pilings can be installed to transfer the load to better soil that is deeper underground.

- Piling to bedrock: If the bedrock is at a reasonable depth and of high quality it can be a suitable solution to drive piles to the bedrock. See (Figure no.30).
- Piled-raft foundation: This technique is a combination of the two methods described above i.e. spread foundation and piled foundation. The spread foundation ensures load distribution in the upper layers of the soil, and the piles transfer the load to deeper layers of the soil (Svensson, 2010). See (Figure no.31).

In comparison with other energy sources, such as electricity from coal-fired power stations, operating wind turbines reduces C02, SO2 and NO emissions. The average coal-fired plant in the UK emits 860 grams of carbon dioxide per kWh, 10 grams of sulphur dioxide per kWh, and 3 grams of nitrogen dioxide per kWh (BWEA, 2003).

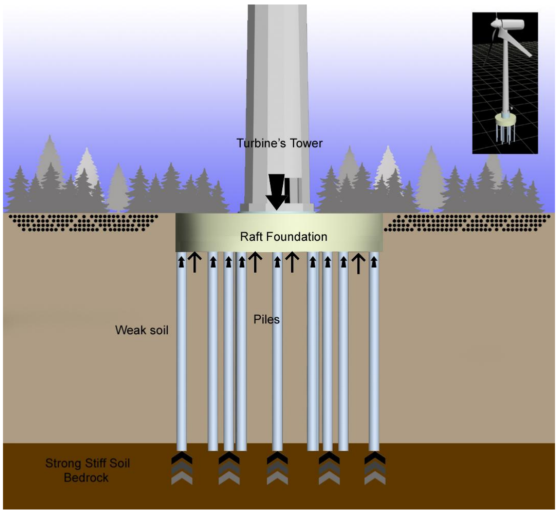


Figure no. 29 Piled foundation - Piled-raft

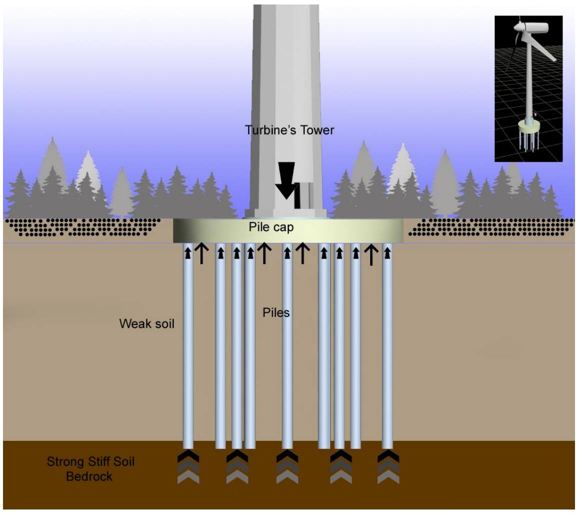


Figure no. 30 Piled foundation - Bedrock

Using a turbine with a rated capacity of 1.3 MW, annual emissions would be reduced by <u>2938 tonnes</u> of carbon dioxide, <u>34 tonnes</u> of sulphur dioxide, and <u>10 tonnes</u> of nitrogen oxide (Berndt, 2004). When considering the emission benefits of wind power, it is also necessary to take into account the CO2 involved in producing the materials required for reinforced concrete foundations. Concrete typically used as foundations for large wind turbines requires a substantial amount of cement, along with sand and aggregates (A'itcin, 2000).

According to the Department of Energy USA, the production of cement is energy intensive and involves the production of significant amounts of CO2. In fact, cement production accounts for approximately 8 percent of global CO2 emissions. It is estimated that 60 percent of CO2 emissions from industrial processes in the US are attributable to cement manufacture. This is because the direct release of C02 containing 11.4 million tonnes of carbon equivalent into the atmosphere was associated with US cement production in 2001. Cement manufacturing releases approximately one tonne of CO2 per tonne of cement manufactured (A'itcin, 2000). A significant amount of steel is also required for reinforcing concrete foundations. According to the US Environmental Protection Agency in 1994, iron and steel production emitted 39.9 million metric tons of carbon dioxide. Based on 1994 data, approximately 0.55 tonnes of C02 are produced per tonne of steel in the US.
Cement, water, steel, sand, and aggregates are natural resources. Depending on the strength and durability required, structural concrete typically contains 300-450 kg/m3

of cementitious material. For an onshore 1.3 MW turbine, a 240 m3 concrete foundation may require 72-108 tonnes of Portland cement, resulting in 72-108 tonnes of CO_2. CO_2 emissions are at least 5.5 tonnes per tonne of reinforcing steel in the same foundation (Berndt, 2004).

- **Cables**

Below are a few points that describe the impact of underground cables:
Remove soil from a large trench by excavating it, perhaps several kilometres long, and levelling it approximately 30 metres wide. See (Figure no.32). After that, bring heavy cable drums to the site, along with other equipment.
Lastly, cable fires and their impact on the environment. It covers the entire life cycle of the cables, from original manufacture to on-site commissioning and disposal at the end of their useful life. Open-cut trenching is the most frequently used construction method for cable installation (Basec, 2019). However, for crossing watercourses or motorways, for example, a trenchless technique such as directional drilling may be used. Works at each section commonly consist of the construction of a haul road, the excavation of the cable trench by mechanical excavators, the storage of excavated material cable laying, sand and native material is backfilled into the trench and the surface is reinstated.

A typical cable installation rate is up to 160m per week, depending on the terrain. Underground cables are marked on service maps provided to other utilities and are installed with surface marker tape to warn of their presence below the ground. During operation, annual maintenance checks on foot are common. The cable route will also be kept clear of any high-growing vegetation. In the unlikely event that there is a fault along the cable, the area around the fault is excavated and the fault is repaired or a new section of the cable is inserted as a replacement (SPEN, 2020).

Most cable products consist of a conductor, jacket and insulation, while some may also include a bed and armor wire. Conductors, bedding, and steel armored wire can all be recycled easily, but jacketing and insulation can present some challenges. Cable products are traditionally covered with PVC. PVC is not only easy to recycle, but also has excellent durability and chemical resistance. However, PVC is known to emit smoke and corrosive gases when burned (Basec, 2019). When the line is out of service, the cable can be left in place or removed manually by unlocking the floor (SPEN, 2020). See (Figure no. 32 & 33).

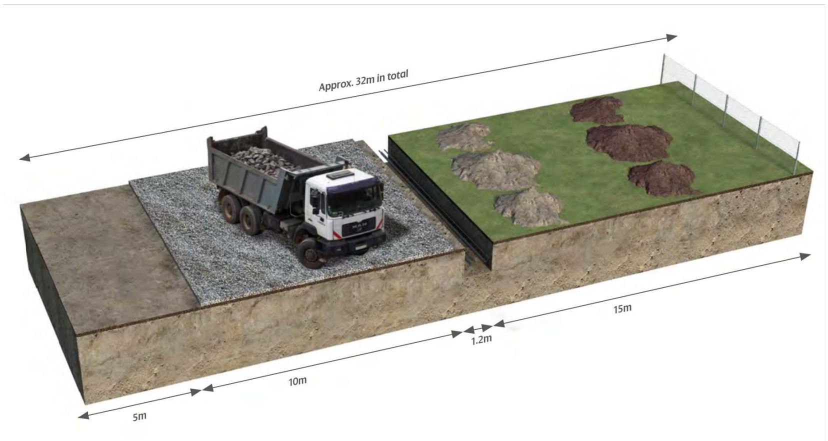


Figure no. 32 Underground trench cables, where the width of the ground levelling reaches 32 m.

Figure no.33 Connecting the turbines to the substations and from there to the national grid through underground cables.

Figure no. 34 Cable laying process after levelling.

<u>What I bring with me for the planning discussion from this level</u>

It is necessary to take into account the CO_2 involved in producing the materials required for reinforced concrete foundations, in addition to the excavation and filling operations also human activity, also the resulting fragmentation.

4 Discussion

After analyzing the wind, its resources, the process of its formation, and the forces that affect its direction and speed, I think it is possible to discuss and choose the location and the possible effects of a turbine on the surrounding environment.

4.1 Wind as a source of energy

The Earth's surface is heated by solar radiation because the Earth is round and solar radiation strikes the Earth at varying angles. As the Earth rotates on its axis, radiation varies during the day and at night. Different parts of the Earth experience different temperatures, which leads to different atmospheric pressures. There is an association between these and the movement of air from high to low-pressure areas. Wind contains a lot of energy. A wind turbine converts the kinetic energy of moving air into electricity or mechanical power. Since air has mass, the wind has kinetic energy (the weight of air is a bit more than one kilogram per cubic metre). Eight times more power is generated when the wind speed doubles (Wizelius, 2015).

To generate electricity from the wind, there are 3 main factors:
Turbines, perfect wind resources, and an ideal location for a wind farm. It is simple and possible to combine the three factors. However, how these factors integrate, and how they affect and are affected by their surroundings varies according to the geographical location on the earth's surface. Therefore, I will discuss these factors in more detail.

4.2 Aspects that determine an adequate location

To clarify, the air surrounding us has weight, which compresses everything it touches. In the Earth's atmosphere, atmospheric pressure is the force exerted by air molecules on surfaces. Most of the gases are diatomic nitrogen and oxygen, with small amounts of argon helium carbon dioxide and other trace gases mixed with varying amounts of water vapour. All of these gas particles have mass and are pulled towards the Earth by gravity. At sea level, NASA estimates that the air density is 1.222 kilograms per cubic metre.
It varies depending on location and elevation above sea level. As altitude increases, atmospheric pressure decreases (Pbs, 2000).

In fact, the weight of the particles in a column of gas above each of us applies a force that we experience as atmospheric pressure. This force is simply the weight of a column of gas above a specific area. **Air pressure** is greatest at the ground and decreases with altitude both because the column of air gets shorter with increasing altitude. In addition, the density of the gas particles decreases with altitude meaning there are less gas particles per unit volume at high altitude compared to ground level. Simply put, density is the mass divided by the volume of anything, including air. Scientists typically use kilograms per cubic metre to measure density in the metric system (Williams, nd). For instance, at a height of 6,190 metres, Denali, Alaska, is the highest point in North America. Compared to Honolulu, Hawaii, the United States, which is at sea level, has about half the atmospheric pressure. This is according to National Geographic. On the other hand, pressure decreases, and oxygen availability decreases. As a result of low atmospheric pressure and a lack of oxygen, you can get sick and even die at high altitudes.

Thus, the weather is influenced by atmospheric pressure. Clouds, wind, and precipitation are usually brought on by low-pressure systems. High-pressure systems are usually followed by fair and calm weather. Air density depends on three factors: air temperature, air pressure, and the amount of water vapour in the air. In the case of dry air, the density will be affected by temperature and pressure. In the case of moist air, the density will be affected by temperature, pressure, and the amount of water vapour in the air (Williams, nd).

Given the above, <u>in the first case:</u> A cubic meter of completely dry air is composed of about: 78% nitrogen molecules, each of which has a molecular weight of 28 (two atoms - N_2 - with an atomic weight of 14). Another 21% of the air is oxygen, with each molecule having a molecular weight of 32 (two atoms - O_2 - with an atomic weight of 16). The last ratio is a mixture of other gases, which you don't have to worry about (Williams, nd).

It could be argued that molecular collisions occur at extremely high speeds between molecules of nitrogen, oxygen, and other gases that make up air. As the temperature rises, molecules move faster. The molecules in the air move faster when it is heated, so they push harder against their surroundings as a result.

For instance, the expansion of a balloon is caused by warming the air, while shrinking is caused by cooling the air. The heated air will push away the surrounding air if it is surrounded by nothing but air. Consequently, if the air in a box is free to escape, the air inside it decreases when it is heated.
As air is heated, its density decreases (Williams, nd).

Air density is affected by the pressure in the opposite way. As pressure increases, the density increases as well. Increasing altitude. Around 18,000 feet, the air's pressure drops to 500 millibars from 1,000 millibars at sea level. There are only about 10 millibars of pressure in the air at 100,000 feet above sea level (Williams, nd).
A high or low air pressure system also affects the density of the air, but not nearly as much as altitude. On a hot day with low atmospheric pressure, the air's density is low at high elevations. At low elevations, when the pressure is high and the temperature is low, the air has the highest density.

As air pressure decreases, oxygen continues to account for about 21% of the gases in the air. There is less oxygen in the air, however, because all of the gases in the air are less abundant. When you reach 12,000 feet, the air pressure is about 40% lower than at sea level.
In the second case, there is less density in humid air than in dry air. If we add water vapour to the air, how does it become lighter? In his book Optics, Isaac Newton stated that humid air is less dense than dry air. In the early 1800s, Italian physicist Amadeo Avogadro discovered one of nature's laws that explained why humid air is less dense than dry air. His research shows that at the same temperature and pressure, a fixed volume of gas, say one cubic metre, always contains the same number of molecules regardless of what gas is present (Williams, nd).

It is free for molecules to move in and out of our cubic foot of air. Avogadro discovered that if we added water vapour molecules to our cubic foot of air, some of the nitrogen and oxygen molecules would leave - remember, the total number of molecules stays the same. The molecular weight of water molecules is 18, which replaces nitrogen or oxygen. (One oxygen atom with an atomic weight of 16, and two hydrogen atoms with atomic weights of 1). In comparison to nitrogen and oxygen, it is lighter. As a result, replacing nitrogen and oxygen with water vapour decreases the weight of air per cubic foot.

You might say, "I know water is heavier than air." The truth is that liquid water is heavier than air. However, the water that makes the air humid isn't liquid. Water vapour is a lighter gas than nitrogen or oxygen because it is made up of water. Compared to the differences caused by temperature and air pressure, humidity has little effect on the density of air. At the same temperature and pressure, humid air is lighter than dry air. This supports the idea that we live at the bottom of an ocean of air currents. This ocean moves masses of gas around, and this movement creates the weather we experience every day, It would seem that the difference in atmospheric pressure between low and high caused by the movement of molecules generates a pressure gradient force. This force is the only force that moves air masses from zero, forming the wind. As for the other forces, they are forces that contribute to changing the speed and direction of the wind. But it is unable to form the wind.

It can be explained that in many countries, meteorological institutes have converted wind data into wind resource maps. These maps show wind energy content, and others show wind speed at different altitudes.

4.3 EIA and legislation

Planning, approvals, and eventually the installation and operation of wind turbines are all part of the process of developing a wind power project. Depending on the prerequisites of each country, there are many steps involved in this process. It would seem that developers must decide after each step if it is worth continuing the project, or if it is better to end it early. The result of the economic calculation is the most critical factor in making this decision. This is from the developer's side. If the conditions are suitable, wind turbines or a wind farm should be built.

It would be argued that the authorities' demands regarding environmental impact and the like should be met so that a permit can be granted. In terms of environmental impact, authorities in different countries have different requirements. This is from the government agencies' side. Permissions for these projects are strictly controlled by government departments. Depending on the project's size.

Country	Local municipality	Regional authority – EIA
Sweden	1 wind turbine with any total height. 1–6 wind turbines with total height. less than 120 m	2 wind turbines with total height more than 150 m. more than 6 wind turbines .
Denmark	1–3 turbines with a total heigh of ht Less than 80 m.	4 or more turbines or more, with total height more than 80 m.
Germany	1–2 turbines	3 or more turbines or any turbines with more than 10 MW.

Table no.7: Project size and EIA requirement in Sweden, Denmark and Germany (Wizelius, 2015).

For this reason, the municipality must approve all submitted wind power projects; large projects may require regional or national approvals as well. It will be up to the authorities to determine whether the requests are in accordance with the laws and regulations. A country's government and parliament formulate and approve an energy policy. There are also a number of agreements, directives, and treaties pertaining to energy at the international level. A new directive on renewable energy was adopted by the European Union in 2001, with a number of targets recommended for its member states. Industrialised countries are also under an obligation to reduce greenhouse gas emissions under the Kyoto Protocol, which was ratified in 2005. The development of wind energy is a key component of the Kyoto Protocol. According to Wizelius, Some countries' energy policies are affected by these types of international treaties. Depending on the country, the municipality (or council) evaluates building permission applications for planned wind farms. It is generally the responsibility of the building committee or similar institutions, whose board members are usually local politicians. Building codes, in this case, must be followed when making decisions. In most countries, the county administration is the regional power of the state. Depending on the size of the project, this may be the level at which wind energy licensing decisions are made.

A legal investigation is being conducted by the county administration to determine if the project complies with applicable laws. In the case of larger projects, an Environmental Impact Assessment (EIA) is required. Depending on the country, different rules determine the size of a project that requires a comprehensive EIA. Laws and procedures vary from country to country regarding the processing of wind energy permits. An appeal against a decision made by the authorities usually takes several years in Sweden.

This supports the idea that the developer usually chooses a group of sites for his project. Then one of them is finally selected to be the desired site. It is a site that fulfils a set of conditions and requirements, the most important of which is strong wind resources, and then comes the minimising of the negative impacts of turbines on the surrounding environment and landscapes. In Sweden, Impacts on the environment can take many forms, according to Wizelius (2015):

- Impacts on the ecosystem like a chemical/physical impact – acidification, eutrophication, climate change, pollutants, etc. Where the impact will be on flora and fauna (nature).
- Impacts on health and well-being, where neighbors may be affected by noise, shadow flicker, or safety hazards
- Impacts on culture, where the visual impact on landscape and cultural heritage.

However, I think compared to other types of energy, globally and regionally, wind power is the best option from an environmental standpoint. Climate change, acidification, eutrophication, and their impacts on agriculture, forests, lakes, landscapes, and human health. Most of the material used in the turbine can be recycled, and it can be disassembled without leaving any traces behind. The environmental impact of all other methods of generating new electric power is greater. according to Table 8.

Energy source	Raw product	Emission	Other impacts
Combustion	Coal, oil, gas	CO_2 , NO_x , SO_x , VOC, ash	Oil exploitation, mines, transport
Combustion	Biomass	NO_x , SO_x , VOC, ash	Forestry, transport
Hydro power	Running water	None	Exploitation of land and watersheds
Wind power	Wind	None	Land use, noise
Solar heating, PV-cells	Solar radiation	None	Land use

Table no.8: Environmental impact from different energy sources (Wizelius, 2015).
CO_2 = carbon dioxide, NO_x = nitrogen oxides, SO_x = sulphur oxides, VOC = volatile organic compounds.

On the other hand, fossil fuels and uranium power plants use land throughout the entire production chain, from the exploitation of raw material to waste dumps, mines, oil wells, refineries, ports, and storage facilities.

4.4 Planning, land demand

An empirical study found that the demand for land for wind power is about 4.5 ha/MW, including foundations, access roads, transformers, and other equipment. According to the same study, a British nuclear plant requires 16 ha/MW (Wizelius, 2007). However, wind turbines do not occupy all this land, land demand refers to the area surrounding the outer towers in a group of turbines. The spacing between them should be about 5 diameters of the rotor (the diameter of the rotor is the diameter of the wind turbine blades). So for a wind turbine with 80 metre rotor diameter - Vestas V80 - It is about 400 metres for turbines in a row, and between the two rows, there must be no less than 7 diameters of the rotor, which is about 560 metres. Therefore, Turbines and surrounding infrastructure (including roads and transmission lines) occupy only a small portion of the wind facility's total area. See (Figure no. 35).

To clarify: A line of turbines requires very little land; three rows of four turbines each require more land. If twelve 1.5 MW turbines are sited in a 3 x 4 group, they need an area of 81 ha, but if they are sited in a 2 x 6 group, they require only 47 ha. This group has a total nominal power of 18 MW, giving a land requirement of 4.5 and 2.6 hectares per MW. At least 95 percent of the area can still be used as before. Consequently, the land requirement per MW is only 0.225 and 0.13 ha. See (Figure no. 36 & 37).

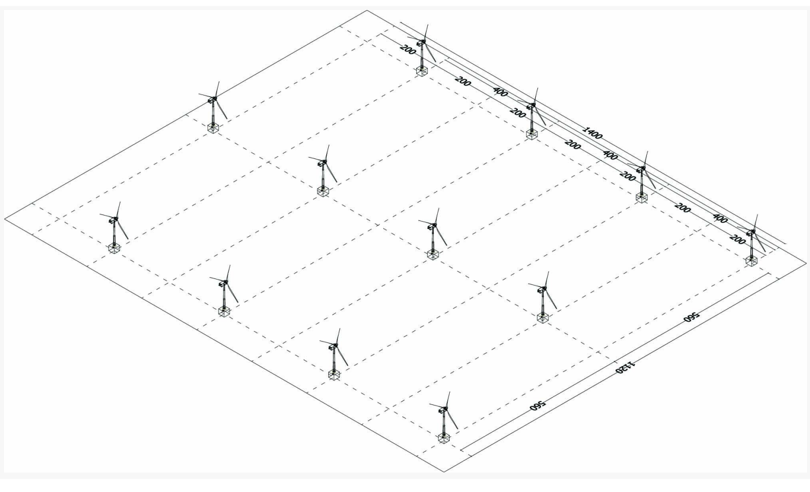


Figure no. 35: Twelve 1.5 MW turbines are sited in 3 groups x 4, they need an area of 81 ha . total nominal power of 18 MW.

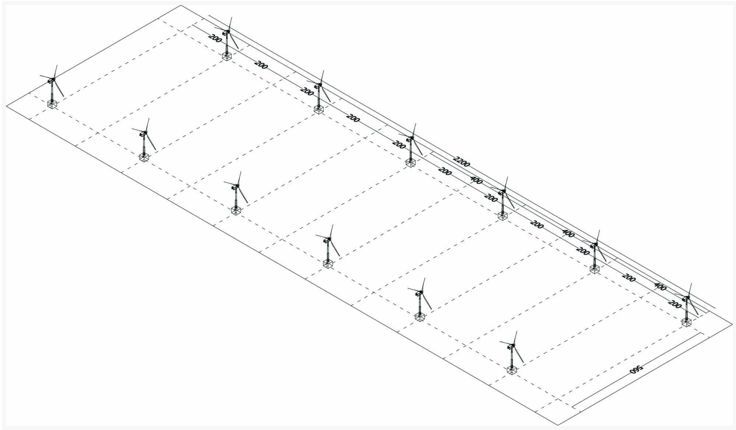


Figure no. 36: The same Twelve 1.5 MW turbines are sited in 2 groups x 6, they require only 47 ha. total nominal power of 18 MW.

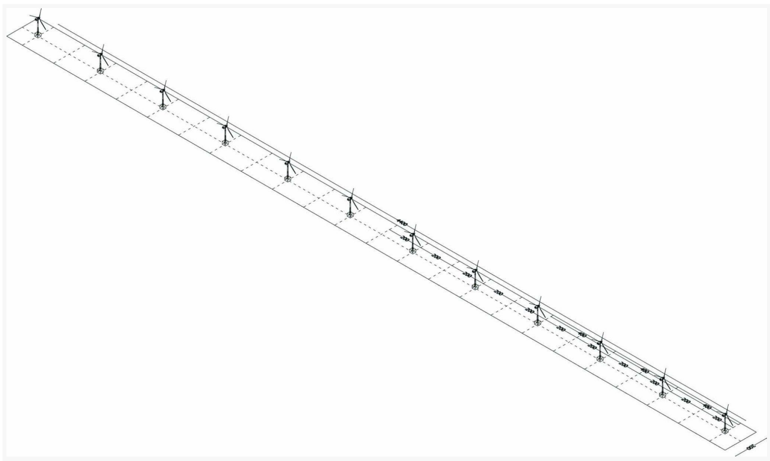


Figure no. 37: The same Twelve 1.5 MW turbines are sited in a 1 group x 12, they require only 20 ha. total nominal power of 18 MW.

If the same nominal power were installed using 3 MW wind turbines, to secure the 18 MW only six wind turbines would be necessary so 6 x 3 = 18 MW but the distance between the turbines should be greater. If the rotor diameter is 90 metres in two rows with three turbines in each row it would require an area of 56 hectares. As for the use of four wind turbines with a nominal capacity of 5 megawatts 4 x 5 = 20 MW. If the rotor diameter is 128 metres, it can be placed in a square, and it requires an area of 57 hectares. These larger turbines require about the same area per megawatt, but they have taller towers and produce more, so electricity production per area increases with the increased size of the wind turbine. So the rule is stronger winds, fewer turbines, better electricity, and therefore less damage to landscaping. As a result, we will need to place artificial structures within natural environments with a complex ecosystem. We will test changes caused by the effect of these structures. But wind energy is renewable energy and the most powerful alternative towards achieving climate goals. I believe that there is a kind of biodiversity sacrifice that we are making by acquiring land to create wind farms. Indeed, we are in the midst of a tough struggle between preserving the earth, and its biodiversity, and combating climate change. Thus, we are faced with the paradox of impacting biodiversity to combat climate change. As land use change leads to reduced biodiversity.

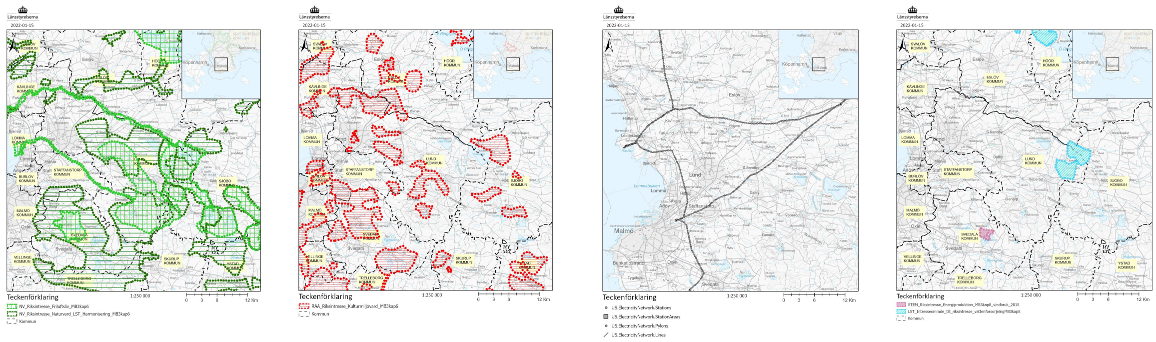
4.5 Land use and site selection

Land use change has been identified as the biggest threat to biodiversity degradation globally. We need to achieve climate goals without causing significant land use change and biodiversity loss. In other words, equal achievement of three of the seventeen sustainable development goals: 7- To secure “clean and affordable energy” and 13- Support “climate action”, 15- without undermining “life on Earth” (IPBES, 2019). As a result of removing cover vegetation, on-site construction of turbines on cement bases, and span roads (Kati et al., 2021), wind farms still have a large area of land even though they produce less energy per square metre than other renewable energy sources (UNCCD, 2017). Roads that penetrate natural ecosystems or former wilderness areas have effects beyond their direct physical impact (Kati, et al., 2021). The impact of road encroachment on nature can include further land use changes, habitat loss, fragmentation, land degradation, and intensive resource extraction (Kati, et al., 2021).

It could be argued that we have a green versus green dilemma:
Conservation measures require large areas of land, i.e. biodiversity conservation on the one hand and the achievement of climate goals on the other hand, i.e. infrastructures for renewable wind energy. In other words, an overlap in an area between ecological value and renewable resources (Kati, et al., 2021).

A site with hard rocky soil to be chosen is a very useful idea and is supported by the above, because of its positive impact on the type of foundation used, such as the spread shallow type, as there will be no need for deep excavation, backfilling and soil replacement. And thus reducing the construction works, i.e. reducing the time of human activity at the site and stimulating the number and type of machines at the site, as the rocky soil does not help the growth of a vegetation cover rich in species.

In Sweden, advance maps are provided by the county board for the areas that are excluded from the planning, design and construction of wind farms within them. Where the provinces provide preferred, documented and studied maps of the areas that are not suitable for the establishment of wind farms within or even near them, and these areas must be excluded when planning these projects, such as natural reserves, hiking areas, fishing, etc. The figure maps show the excluded areas in Lund and Lomma municipalities. See (Figure no.38).



Natural areas
Outdoor hiking areas

Cultural heritage areas

The national electricity grid

Fresh water bodies.

Figure no. 38: maps show the excluded areas in Lund and Lomma municipalities

It would seem that after excluding these areas, it is good to choose a site close to the main streets to reduce the need for more service roads, as these works negatively and permanently affect on the landscape, as they lead to their division and fragmentation.

4.6 From the factory to the site

It is now possible for some companies to transport turbines and installation equipment 1,400 nautical miles without refuelling using newly developed aircraft. No infrastructure is required to transport goods, equipment, and personnel weighing more than 40,000 pounds. During transport, the blade is attached to the airship's gondola, a two-part system that facilitates loading and unloading and provides support once the blade reaches the ground (LMC, 2017).

Furthermore, the balloon's airbag landing system allows wind turbine companies to

transport parts anywhere in the world safely and affordably. This suggests that by combining their power with technologies that conserve the environment and create efficiency, hybrid aircraft will revolutionize the transport of heavy cargo.
In my opinion, it may be also useful to choose the site closest to the electrical national network in order to connect the farm to the grid. I think proximity to the network is a very important issue, because of the cable laying operations, which require excavation and filling operations, as there will be human activity during the implementation operations, in addition to the fact that trees cannot be replanted over the cable channels if they existed before. On the other hand, the primary consideration for project managers and specifiers in this stage should be the environmental impact of cabling products used on any project. In the case of cabling, the use of poor quality products on these projects can lead to degradation and breakdown of materials, causing chemicals to leach into the soil.
It could be argued that the challenge for cable manufacturers when considering how to mitigate the impact of their products and manufacturing processes on the environment, In order to meet this requirement, fire safety performance must be balanced with this requirement. Cable manufacturers must reduce their consumption of energy and water to minimize the environmental impact of their production activities. They should also reduce waste production and disposal in landfills and other sensitive environments.

4.7 Implementation and concrete work

Construction of cable channels can also result in soil compaction, which can negatively impact biodiversity. From an environmental perspective, wetlands, swamps, and bogs should be avoided when planning underground cable systems as these habitats may be severe or even irreparably damaged (Basce, 2019).

This shows that the foundation construction can also lead to soil damage, in addition to emissions from the industrialization of cement. Choosing the type of foundation can which is depending on the site soil specification, significantly mitigates these negative impacts. Also, it was found that mixes containing 50% blast furnace slag replaced with cement gave the best mechanical properties. It is possible to use recycled concrete aggregate without significantly affecting the strength of the concrete, particularly if the concrete also contains slag (Berndt, 2004). It could be argued that a crushed concrete aggregate is one example of how concrete can be recycled, reducing landfill waste and conserving materials.

4.8 Operating stage and side effects

The turbine operating period is the main part of the turbine life cycle, which may last up to 25 years. There are different effects during this period. **Birds** moving through a wind farm can be negatively affected by the placement of turbines near prominent landscape features, particularly migrants and wetland species (Langston & Grewitt, 2006). Therefore, proper sitting is essential to reduce bird mortality and thus population impacts. An obvious assumption of previous wind farm assessment studies is that bird abundance and death from collision with wind turbines are closely related. However, this recent finding challenges this assumption, as collisions occurred more often when high wind conditions were poor, such as gentle slopes, when temperatures were weak, and when turbines were taller at higher altitudes (de Lucas, et al., 2008). In my opinion, there is no clear relationship between species mortality and species abundance, although all large bird collision victims were raptors, there is a noticeable difference in bird mortality and abundance between seasons, but the mortality rate was not higher in the season in which the abundance of birds was higher.

It is currently recommended that the lowest effective intensity white lights be used as often as possible. Red lights that blink or are solid attract birds more than white strobes that flash every 1–3 seconds. A single bright point source is less likely to disorient birds than using lights on the outer turbines only, which could result in diffuse lighting (Langston & Grewitt, 2006). There is also a relationship between bird-species collision probability, turbine height (longer = more victims) and height above sea level (higher = more victims) (de Lucas, et al., 2008). Indicating topographical and species-specific factors implicated in collision mortality. On the other hand, there is no relationship between the probability of collision and the type of turbine or the position of the row (de Lucas, et al., 2008).

I think recommendations for measures to minimise collisions with wind turbines are difficult. However, proactive prevention may be the best solution, which begins with choosing a location far from the migration lines of birds, in addition to the type of land use, reducing the number of turbines and avoiding sites on hills with gentle slopes should reduce bird mortality, but these measures will not eliminate the problem of collision.

As for **bats**, by reviewing previous assumptions about the causes of collisions with wind turbines, I think the Swedish studies have provided some insight into the topic. Since the bats focus their activity during the months of August and September when the wind speed is less than 6 m/s. However, delaying the cut in speed in August and September from 4 m/s to 6 m/s would reduce bat mortality by 90 percent (Rydell, 2012).

I think that designing wind farms in a grid could increase the wake effect, making it a minefield for bats. See (Figure no.39).

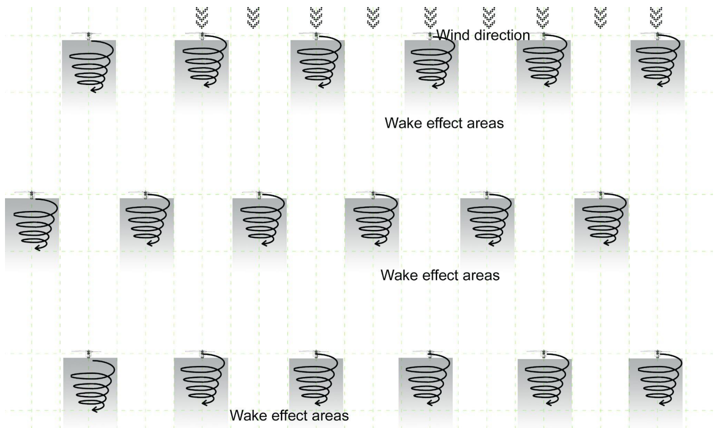
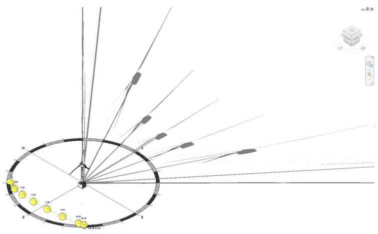


Figure no. 39:
Diagram showing the wake effect behind the turbines in a wind farm consisting of 3 rows of turbines.

Terrestrial mammals are likely to be affected by the construction and operation of wind farms, including an increase in direct deaths due to traffic collisions. Habitat destruction and modification, including road development, habitat fragmentation, barrier effect, noise effects, visual effects, vibration, and shadow flicker effects from turbines. There are few studies regarding terrestrial mammals. However, these studies found no evidence that electromagnetic fields cause deterioration in animal health, decreased productivity or fertility, or changes in animal behavior. For other pets, there appears to be a lack of scientific research on wind noise or visual disturbances.

A particular grazing area, for instance, should not be exploited because it is critical for animals (Walter et al. 2006). I think that grazing areas, in addition to agricultural lands, can also be excluded from the construction of wind farms, in addition, to cable channels that carry electricity. In addition it is also the danger of agricultural machinery on cable channels.

As for the **shade** of the turbine: the southern side of the site, at about 110 degrees from southeast to southwest, is not exposed to any shade during the year. As for the rest of the regions, they will receive shadows that differ according to the difference in the location in terms of proximity or distance from the turbine. A facade with a length of 10 meters will receive shadows during the day for a period of between 5 to 7 minutes per day. That is, a glass window two meters wide may not receive shadows for more than two minutes. I think that the effect of shadows is an effect that can be overcome by taking a safe distance from the turbines. This distance varies according to the location, as the shade of the turbines decreases as we approach the equator. Each site must be studied separately. See (Figure no.40).



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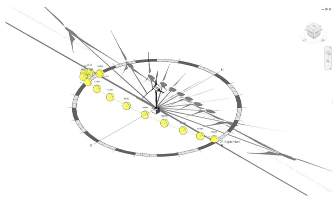

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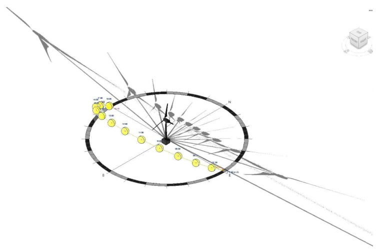

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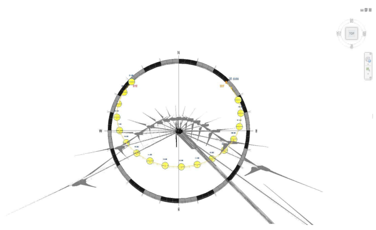

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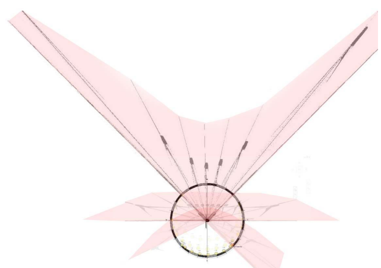

All days

Figure no. 40:
The effect of the turbine's shadows on the area around it. The shadows cover about 250 degrees. The length for an 80-meter-high turbine varies from 95 meters in June to several kilometers in December.

Wind turbines' visual impact decreases rapidly with distance. There must, however, be a threshold at which the visual impact becomes negligible. For wind turbines with a 90-metre tower, a radius of 900 meters dominates the landscape ten times the height of the turbine axis, i.e., at a distance ten times the height of the turbine axis. As a result, the noise emission limit would be exceeded by 40dB. Despite being clearly visible from greater distances, the turbine does not dominate the landscape, and after 10-16 km, it dissipates into the landscape. It is possible to see wind

turbines 400 times their height, i.e. up to 36 km for a turbine with a 90 meter shaft. Clear weather and a clear view are necessary for visibility. Visual impact is also influenced by the number and size of turbines. Experience has shown that it is very difficult for the human eye to distinguish between small and large turbines (Wizelius, 2015). Many factors affect the visual impact of a wind turbine, including the size, color, and shape of the turbine. Also, observation distance, landscape diversity, and time of day. The concept of vision itself usually includes a variety of landscapes. It is therefore of great importance to determine the extent of the visual impact area of wind turbines in order to properly assess its visual impact.
By reading maps or interpreting laws and regulations, it is not possible to determine how structures, additions, or other changes will affect the value of the landscape. Landscape values are determined by the evaluations of the people who work and live in them. The traditions, memories and feelings of these local people determine by their different opinions about the proposed sites so as to achieve an outcome in which wind energy is good energy with minimal side effects.

Finally, it is critical to understand that humans have shaped our landscapes. If I have time for another year, I will continue researching the reconfiguration of wind farm areas, where the turbines, service streets, and underground power cable ducts have subdivided it. and investigate the possibility of putting them back together. The importance of this is the possibility of integrating the turbines with the landscape to become part of the general landscape. Thus changing the negative view of some people towards it.

5 Conclusion

As addressed in the analysis of recent research, the advantages of switching to wind power greatly outweigh the disadvantages. The wind is not only an abundant and inexhaustible resource, but it also provides electricity without burning any fuel or polluting the air. Wind turbines operate in various environments, where there are high-quality wind resources, which is a prerequisite for establishing a wind farm.

Each proposed wind farm site can be considered a special case, the future effects of which are determined by many factors such as geographic location, topography, vegetation cover, sun, roughness factor, and site ecosystem. Choosing a suitable site and gaining neighborhood acceptance, in addition to other side effects of the turbines, remains a topic of research and a concern for some opponents. This may be the first essential step to mitigate the side effects of the project.

Soil physical and chemical properties may be one of the main points of preference among a group of proposed sites. The high bearing capacity of the soil will be reflected in the type of foundation used. This by saving a large amount of cement and through this reduces emissions. This also helps to choose the appropriate type of surface foundation without the need for excavation and filling operations. This in addition to the need for piles required by agricultural soils, which in turn causes damage to the soil and prolongs human activity. The closer the site is to the national electricity grid, the shorter the length of the underground energy cable channels which reduces excavation, filling and changing the ground cover, in addition to reducing human activity.

Site with slop in the land between 10 percent and 20 percent will have good effects in reducing the length of the shadow that the turbine casts on the neighbourhood, in addition to that a slight slope increases wind speed and thus increases productivity. The proximity of the site to the main streets used in transportation will contribute during the implementation, maintenance and operation phases to the reduction of service streets that the developer will have to construct, and thus reduce its impact on the fragmentation of landscapes resulting from the construction of these streets. The site should be away from the lines taken by migratory birds during their migration. This will greatly reduce the effects of fatal collisions and wall barriers. Pasture lands can be excluded from the construction of wind farms due to their impact on terrestrial mammals. Sites of heritage value, natural areas, outdoor hiking areas, water bodies, swamps, as well as granting approvals for the establishment of wind farms within them are excluded.

Proper planning also contributes to mitigating the side effects of land demand. A multi-row wind farm design requires three to four times the land area of the same project but with a single-row design. The use of curved shape design may have better advantages in terms of visual effect advantages. White lights that flash every 1-3 seconds can be used instead of strobe or flashing red lights, which attract birds more and can increase the risk of collision, especially in poor visibility. Starting the turbine cut in August and September when the wind speed is more than 6 m/s instead of 3 or 4 m/s will decrease the collision of the bats with the turbine. 325m to 525m from the turbine is a sufficient distance to reduce the aerodynamic noise to the permissible limit of 40 out of 105 dBA. 775m would lower it to 35 dBA. Mechanical noise can be reduced by properly protecting the nacelle, using sound-absorbing materials, and suppressing vibrations. Regard to shadows, it is better to study this for each project and each residential unit separately, because this effect changes with the change of terrain and latitude.

Dividing the environmental impact study on the landscape, before establishing a wind farm, into three levels (air, ground, and underground) and linking them with the project phases (planning, transportation, implementation, operation, maintenance, dismantling) based on the opinions of specialists and researchers to give a comprehensive view of the problem and make a sustainable wind power project.

Reconfiguring and reshaping the landscape to mitigate the negative impacts and then treating them during the farm operation phase. Restoring the areas that were destroyed during implementation operations, such as service streets, turbine base surfaces, and cable channels. So these structures can be integrated into the landscape, and become an accepted part of the public scene. Last word: stronger winds, fewer turbines, better electricity, and therefore less damage to landscaping.

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7- Photos and figures references

Figure	Date	*References*	*Note*
1	2007	*https://www.kavehfarrokh.com/arthurian-legends-and-iran-europe-links/the-windmill-and-the-contribution-of-persia/*	*open source*
2	1890	*http://www.ironmanwindmill.com/windmill-history.htm*	*open source*
3	2023	Chadi Kattach	
4	2023	Chadi Kattach	
5	2023	Chadi Kattach	
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7	2023	Chadi Kattach	
8	2023	Chadi Kattach	
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10	2023	Chadi Kattach	
11	2023	Chadi Kattach	
12	2018	*www.wind-turbine-models.com/fotos/l3Kt1q5T4Xl-dornier-flender-darrieus-55-55kw-vertical-axis-wind-turbine-generator-prototype-vawt-heroldstatt-germany*	*open source*
13	2007	*https://commons.wikimedia.org/wiki/File:H-Darrieus-Rotor.jpg*	*open source*
14	2021	*newvawt.yolasite.com*	*open source*
15	2021	*newvawt.yolasite.com*	*open source*
16	2003	*http://xn--drmstrre-64ad.dk/wp-content/wind/miller/windpower%20web/en/tour/wres/wake.htm*	*open source*
17	2023	Chadi Kattach	
18	2017	https://www.dailymail.co.uk/travel/travel_news/article-4861684/Footage-shows-wind-turbine-blades-transported-trucks.html#v-240182666691458451	*open source*
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31	2023	Chadi Kattach	
32	2021	https://www.spenergynetworks.co.uk/userfiles/file/SPEN_Approach_to_Routeing_Document_2nd_version.pdf	A request for permission has been sent through the site to use the image
33	2015	www.nexans.com	A request for permission has been sent through the site to use the image
34	2015	www.nexans.com	A request for permission has been sent through the site to use the image
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38	2023	https://vbk.lansstyrelsen.se/en	
39	2023	Chadi kattach	
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