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Windpower Project Development

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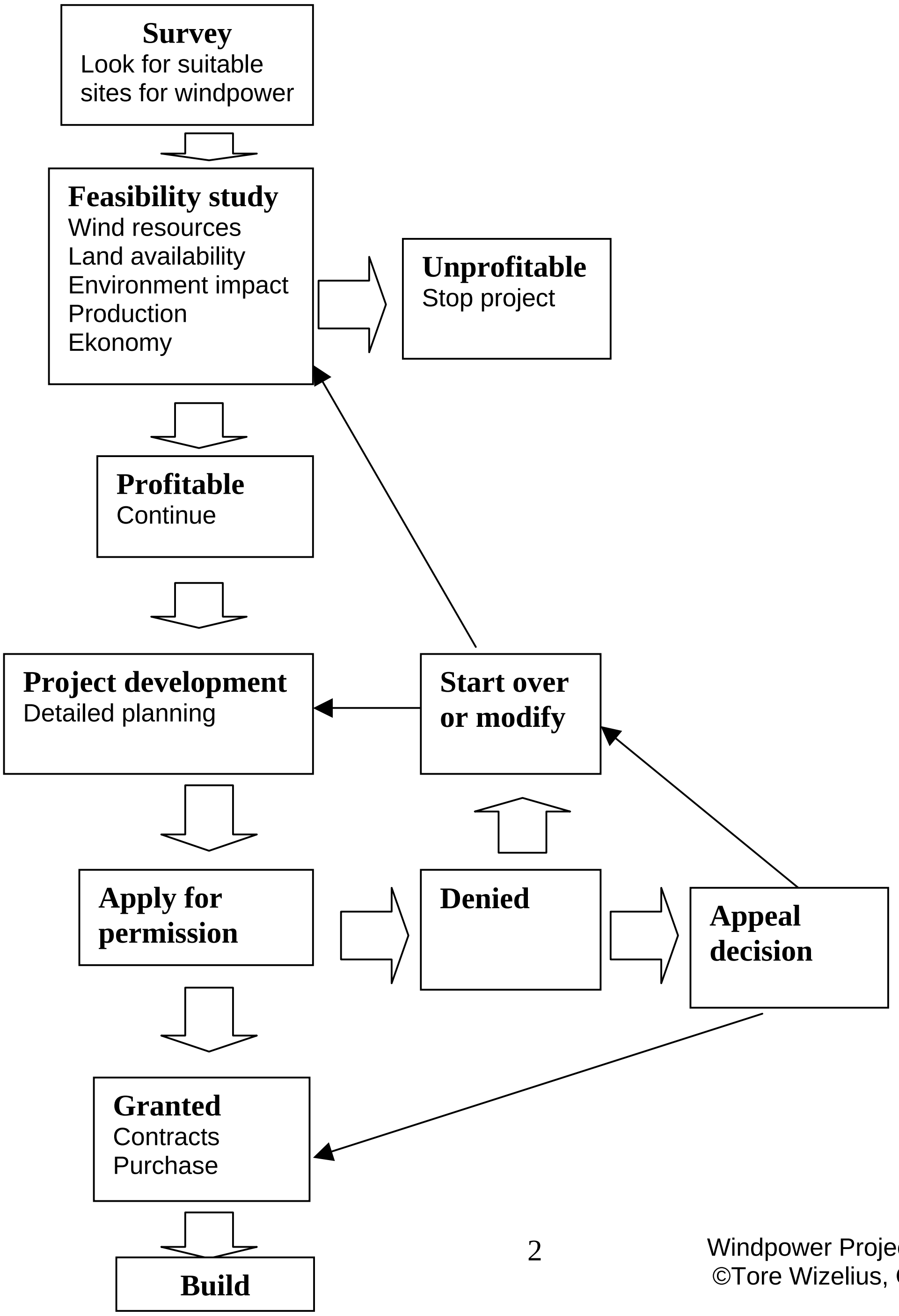
Project development

To develop a windpower project includes planning, to apply for necessary permissions, installation and finally operation of the wind turbines. This process includes many different steps that can vary depending on the preconditions. During the feasibility study, the developer will have to decide after each step if it is worth to continue, or if it is better to end the project at an early stage, this process is described in part 1. The most important basis for this decision is the result of the economic calculation, made I part 2. If the preconditions are good enough, the wind turbine has to be sited, or the wind farm designed, to optimize the output, at the same time as the demands from authorities on environment impact etc have to be fulfilled, so that necessary permission will be given. This process is described in part 3 (see figure 1).

Figure 1 Project development process



1 Feasability study

When you look for a good site for wind turbines many different factors have to be considered. The most important one is of course the wind resources. Local conditions like hills, orography, buildings and vegetation influence the wind and have to be considered in a more detailed calculation of how much wind turbines will be able to produce at the site.

The wind turbine has to be transported to the site, installed and connected to the grid, or for stand alone systems, to the consumers. The distance to existing roads and/or habours, the costs for building access roads, ground conditions that influence the design and cost of the foundation, and the distance to the grid are thus important factors that have to be included in the calculations.

When the wind turbine has been installed it should not disturb people who live close by. In Sweden and most other european countries there are rules about the maximum noise level (in dBA) that is acceptable and this defines the minimum distance to buildnings close to the site. Rotating shadows from the rotor must also be considered, so that they will not be too annoying.

Usually it is also necessary to get permission from authorities to build a wind turbine, at least if it large. These rules and regulations are specific for every country. But as a common rule the authorities will check that a wind turbine will not interfere or create conflicts with other kinds of enterprises or interests. So it is both wise and necessary for a developer to check what kind of opposing interest there may be at a potential site. It can be an airport, air traffic in general (turbines are quite high), military installations (radar, radio links, etc) nature protection areas, archeological sites, etc.

Finding sites with good wind resources

If the task is to develop one or several wind turbines or windfarms within a specified geographical area – a country, region or community – the first step is to make a survey of the area to find suitable places followed by an evaluation to find sites for more detailed feasibility studies.

The absolutely most important precondition for a good windpower project is that there are good wind conditions at the site. You start by studying wind resource maps for the area, if there are any available. If not, by collecting information about wind conditions whatever way that is possible, for example by analysing data from meteorological stations.

Feasability study

After a few areas with good wind conditions have been identified, the preconditions for windpower in the areas have to be studied. The following matters have to be clarified:

- **Neighbours.** Noise and flickering shadows should not disturb neighbours. Can the turbine(s) be sited so that such disturbances can be avoided?
- **Grid connection.** Is there a power grid with capacity to connect the wind turbine(s) within a reasonable distance?

- **Land.** Who owns the land in the area? Is the landowner willing to sell or lease his land for wind turbines?
- **Permission.** Is the chans to get necessary permissions reasonably good?
- **Opposing interest.** Are there any military installations, airports, nature conservation areas or other factors that could stop the project?
- **Local acceptance.** Wha opinion do local inhabitants have about windpower in their neighbourhood?

Impact on neighbours

To avoid that neigbours will be disturbed; a minimum distance of 500 meters to the closest dwellings will eliminate this problem. For a large windfarm this distance may have to be increased. Smaller stand alone turbines should be installed much closer to the dwellings or other building that will use the power, since shorter power lines are an obvious advantage, both from an economical and technical point of view.

Grid connection

Power lines are usually indicated on maps, so it is usually quite simple to estimate the distance from the turbine(s) to the grid. However, it is also necessary to know the voltage level, since that set a limit to the amount of wind power that can be connected. The distance to the closest interlocking plant (transformer station) is also a decisive factor. To get these details it is usually necessary and wise to consult the local grid operator.

For large scale windpower projects these rules of thumb can be applied:

Connection point	*Maximum capacity MW*
10 kV-line	1–2
10 kV-transformer	8–10
20 kV-line	5–8
20 kV-transformer	15–18
40 kV-line	13–18
40 kV-transformer	30–38
130 kV-line	30–60

Larger capacity can be connected to the transformer in an interlocking station than far out on a line. Source: Wind Energy Handbook *(Wiley 2001).*

Land for turbines

What kind of land owners there are in an area is usually quite easy to guess. In an agricultural district the land is usually owned by local farmers. In that case it’s quite probable that it is possible to find a landowner who is rpared to lease some land for wind turbines. The land can be tilled like before, but there will be an extra income. Making money of air is good business. In other cases the land can be owned by other private landowners, companies, local communities or the state. Information on land ownership you will find at the authority that keeps the land registry. During the feasibility study it’s not necessary to make an agreement with land owners, that can wait until a decision is taken on try to realize the project.

Permission

It’s no use to spend time and money on projects that can’t be built. To evaluate the prospect for getting the necessary permissions from authorities is one of the most important parts of the feasibility study. The developer has to be familiar with all the rules and regulataions that can be applied to a windpower project, and how these are interpreted by the authorities. If there are any community or regional plans, these can give a good idea of the prospects for the project in an area.

Opposing interests

The possibility to realize a project can be stopped by so called *opposing interest*. The first thing to check is if there are any military installations that can be disturbed by wind turbines close to the site. Militdary installations for radar or signal surveillance, radio communication links etc. are secret, so you can’t find them on the map. The developer should take contact with the appropriate military command to find out if the will oppose wind turbines at the site. If this is the case, you can ask them to suggest a place that will not interfere with their interests.

Wind turbines are high structures and can pose a risk to air traffic, especially if there is an airport close by. There are strict rules on how high structures close to the flight routes to and from an airport may be.

In most countries there are areas that are classified as international or national interests, to protect natural or cultural heritage, etc., like national parks, nature reservations, bird protection areas. Avoid such areas, since it likely will be difficult to get the permissions necessary for wind turbine installations. Such areas are usually indicated on public maps.

Local acceptance

The attitude of the local inhabitants to a proposed windpower project in their vicinity is largely depent on how the developer acts. In Europe, according to opinion polls and experience, most people have a very positive opinion about windpower. On the local level however, there always seems to be some people who strongly oppose wind turbines in their neighbourhood.

How local inhabitants react, largely depends on how they learn about the project. If they get good information at an early stage they will be positive. When the developer has decided to realize the project, it’s wise to create a dialoge with local authorities as well as the public, and also to listen to their opinions about the project and if possible to adapt it according to at least some of the wishes they express. When the turbines are on line it is valuable to have local support for it and local people will keep an eye on the turbines and report when some problems occur.

To calculate expected production

If the feasibility study shows that there is a good site for windpower, that does not create problems for neighbours, that it is possible to connect to the grid at a reasonable distance, there are landowners willing to lease or sell land to intall the turbines on, and that the prospexts to get the necessary permission are good, it is time to make a calculation of how much the wind turbines at this site will produce. The result of this calculation will be the most important input to the economic calculations, on which the final decision to go through with the project or not should be based.

The Wind atlas method

The most accurate way to calculate expected production at a site is to use the Wind atlas method, that makes it possible to transform wind data from existing meteorological masts to describe the winds properties at specific sites within a radius of up to 100 km. These data can then be used to make accurate calculations on the expected production at these sites.

Wind data are collected by meteorological measurement masts in many different places. These data about the wind speed and wind direction over time at a given height (10 m above ground level if no height is specified) are representative only for the place where the mast stands. Since wind at this site is influenced by the terrain, slopes, obstacles and the orography in general, these data can not be transformed to represent other sites in the vicinity, with other kinds of terrain. To make it possible to use data from one site to calculate the energy in the wind at another site in the region, the wind data have to be transformed into so called *wind atlas data.*

To do this the area surrounding the measurement mast is analysed. The roughness of the terrain is classified, buildings and other obstacles are measured and height contour lines that describe the local orography are registred. The impact of these factors on the “undisturbed” wind is known by practical experiments and measurements that have been generalized into algoritms that are used for these calculations. Wind data from the measurement mast are then recalculated by this method, så that they represent wind data for the site that would have been registred if the mast was surrounded by a plain horisontal area with roughness class 1, without any hills or obstacles. Finally these data are recalculated for a number of different heights above ground.

A wind atlas data set consists of wind speeds (frequency distribution) for 12 different directions (sectors) with one set for each of the following heights: 10, 25, 50, 100 and 250 m. In Sweden the state owned meteorological institute has prepared wind atlas data for some hundred different measurement masts from different parts of the country.

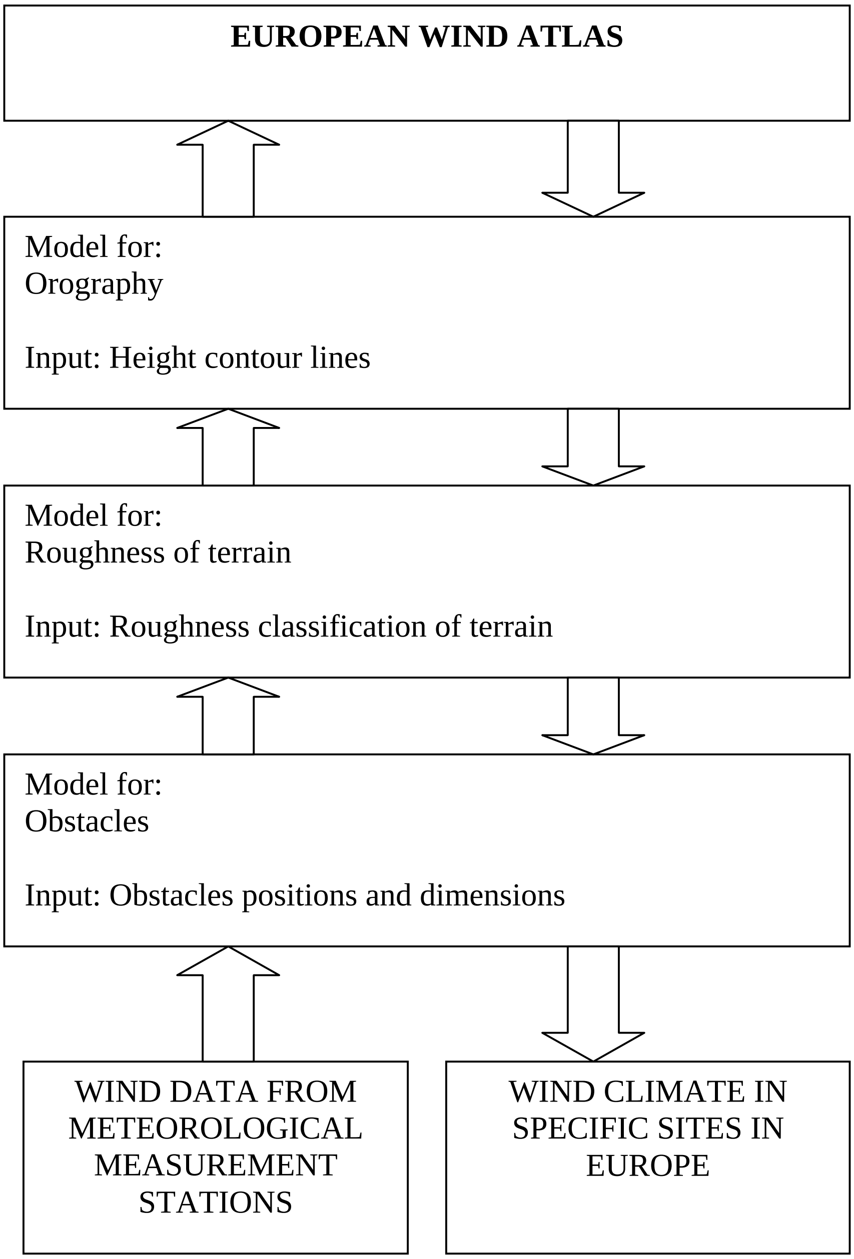


Figure 2 The Wind Atlas method. With the help of meteorological models wind data from measurement masts are transformed to data that describe the regional wind climate; Wind atlas data. These data about the regional regional wind climate can then be used to calculate the actual wind climate at a specific site within the region, using the same meteorological models.

How much a wind turbine can produce depends not only on the character of the terrain at the site, but by the terrain in an area with 20 km radius around this site. The terrain conditions close to the site have the greatest influence on the turbine's production. The roughness usually varies in different sectors and thus also with the wind direction.

When you do a production calculation with the wind atlas method, wind atlas data from one or several measurement masts within reasonable distance are used as input. An area with 20 km radius around the turbine site is divided into 12 sectors, a roughness classification is then done sector by sector. Information on obstacles (within 500 m fom the site), hills, and if the terrain is complex, also height contour lines are entered into the program (see figure 3).

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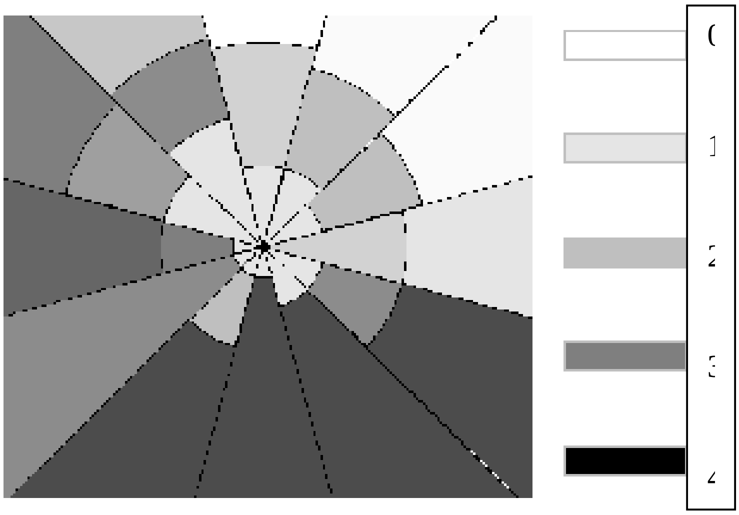
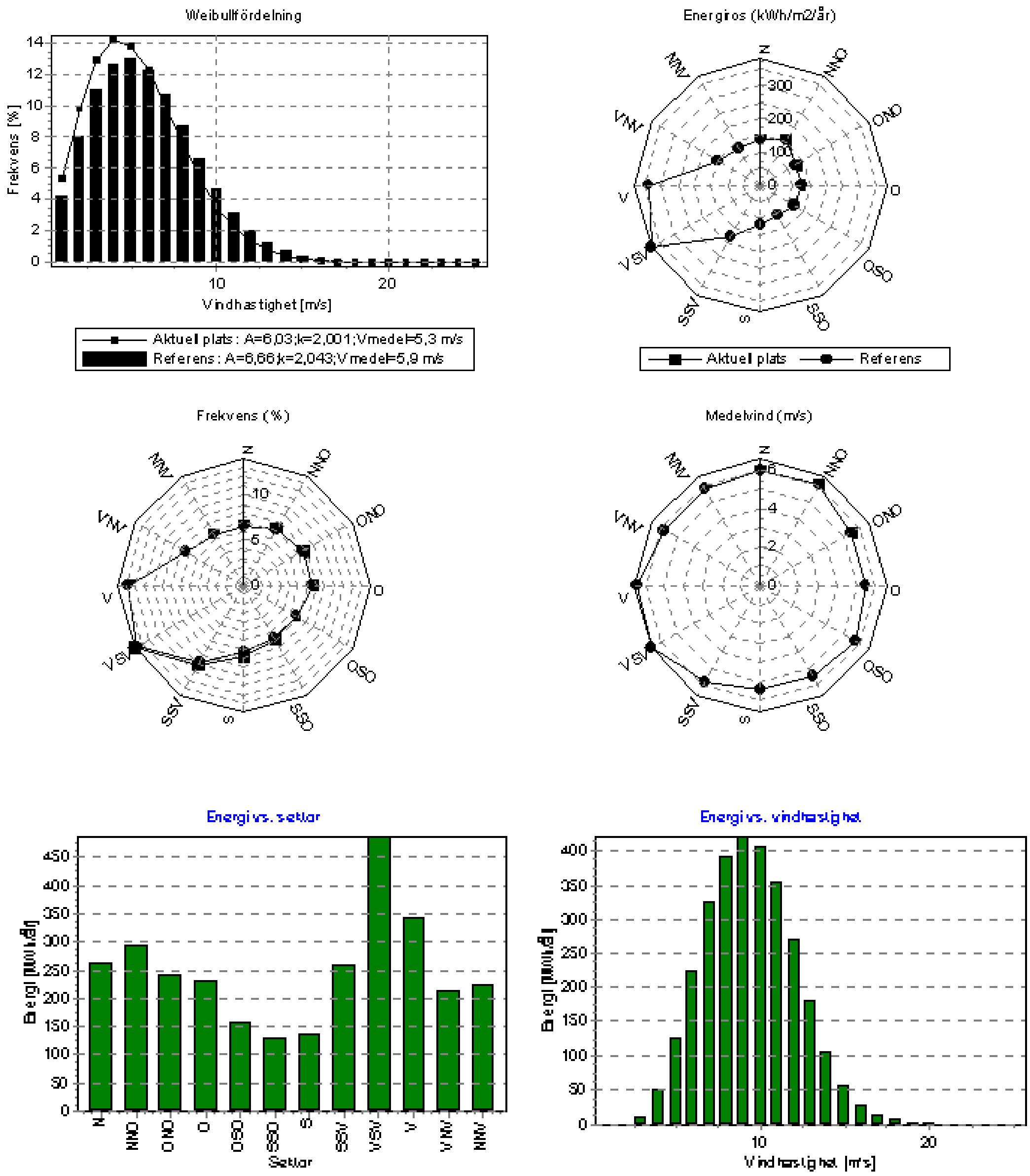


Figure 3 Roughness classification in sectors.

The wind atlas program then recalculates wind atlas data to wind data at hub height for each sector (se figure 4).



Figur4 Wind data from a wind atlas program (WindPro2). The program analyses wind data from the site and calculates how much a wind turbine of a specified model, hub height and rotor diameter is expected to produce at the site. The frequency distribution on hub height is indicated by a so called Weibull distribution (top left) and is compared with the distribution for roughness class 1 at the same site. The wind's distribution between different wind directions (sectors) is presented in three different wind roses; the frequency for different directions in % (second row left), mean wind speed for each sector (second row right) and finally the wind's energy content in the different sectors (top right). The power that the turbine is expected to produce is also divided on sectors and is shown in a diagram (bottom left). The last diagram shows how much power that is produced at different wind speeds (bottom right).

Hills and obstacles

If a turbine is sited on the top of a hill or on a slope this could increase its production. If there are large obstacles close to the turbine, the production could decrease. For large turbines the impact from obstacles are comparatively small, since the impact depends on the differense between the turbine's hub height and the height of the obstacle. The turbulence from an obstacle will spread to twice the obstacles height. The rotor of a turbine wind 60 m hub height and a 55 meter rotor diameter has its lowest point 35 m above ground level, which means that an obstacle has to be almost 20 meters high. Low obstacles should be included in the roughness classification and not entered as obstacles in the program.

The speed up effect from hills also has most impact at lower heights above the hilltop. The height of this effect increases with the size of the hill. Steep slopes however can have the opposite effect; if the inclination is larger than 40 degrees, the slope creates turbulence that will decrease production. A wind atlas program will calculate the impact of hills and obstacles on the production.

The wind atlas program first calculates the wind's frekvency distribution at hub height for each sector, and then multiplies the frequency distributions with the turbine's power curve. The results are weighted according to the frequency for each wind direction and finally summarized. If the terrain is not extremely complex this method gives very accurate results.

Errors

The accuracy of the calculation depends of course on the quality of the data that are entered into the program. This means that it is important to carefully consider and evaluate the data that are entered into the program, for example data on roughness, obstacles etc.

The wind data that the wind atlas data are based on can also contain some errors, due to technical problems with the measuring equipment, etc. The roughness classification is never absolutely correct, and the roughness can change during the season and the lifetime of the turbine.

These and other factors are considered to create an error margin of 10 percent in the calculations, an estimation that has been cofirmed by experience. This means that 10 percent should be drawn of from the result.

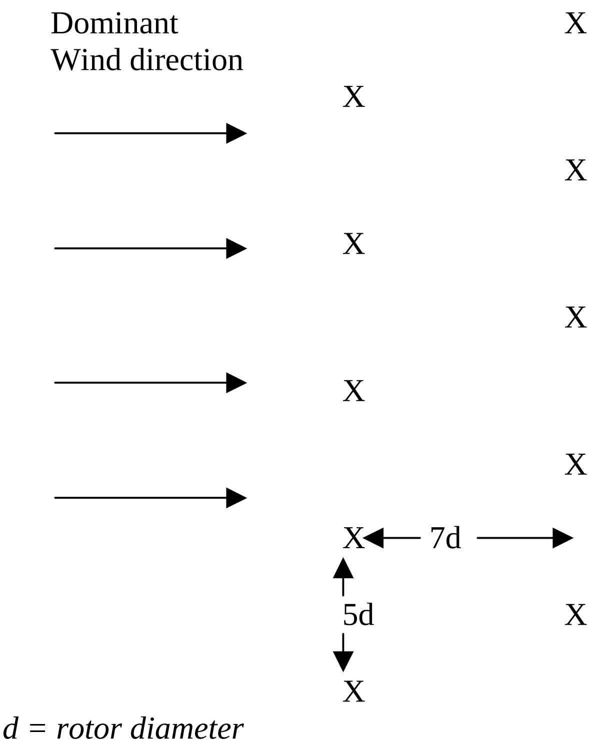
Wind atlas programs like WAsP or WindPRO are quite expensive, but are a necessity for a professional wind power developer. For single projects however, these calculations can be done by a consultant. Manfacturers also do this kind of caclculations. If the calculations are made by consultants or manufacturers, it is important to check that they have taken the error margin of 10 percent mentioned above into account.

Groups and wind farms

If more than one turbine will be installed at a site, this will have an impact on the production. How large this impact will be depends on the distance between the turbines and the wind direction. On the leeside of the rotor a wind wake is formed; the wind speed slows down and regains its undisturbed speed first some ten rotordiameters behind the turbine. This factor has to be taken into account when the layout is made for a group with several wind turbines.

A group of 2–3 turbines are usually placed on a straight line, perpendicular to the dominant wind direction. The distance between turbines is measured in rotordiameters, since the size of the wind wake depends on the size of the rotor. A common rule of thumb is to situate turbines with a distdance of five rotordiamters if they are placed in one row. Larger installations, so called wind farms, can consist of several rows and in that case the distance between rows usually is seven rotordiameters (see figure 5). In areas where one (or two opposing) wind directions are very dominant (regions with trade winds for example) the distance between the turbines in rows can be reduced to 3 rotordiameters.

Figure 5 Group configuration



The actual layout of groups with turbines is however often formed by the limits set by local conditions; distance to dwelling, roads and the power grid. If there are height differences on the site, this will also influence how the turbines should be places in relation to each other to give optimal production. It is usually not reasonable to increase the distance between turbines to eliminate the impact from wind wakes completely, it is an unefficient use of land. This so called park efficiency can be calculated with a wind atlas program. The park efficiency for groups of 5-10 turbines usually is 95 % or higher.

The final step

The purpose of a feasibility study is to find out if the preconditions for windpower in an area or on a specific site are good enough for a successful project. If the wind resources are good enough to guarantee a high production, if there are potential sites where turbines will not disturb people who live there or other values, the prospets to get the necessary permissions seem good, and it is possible to connct the turbines to the grid, it is time to continue with last and most important step in the feasibility study; the economic analysis. The final decision about the project, i.e. to stop or to realize it, depends on the result of this analysis.

2 Project development

If the economic analysis shows that the planned project will be a sound investment, it is time to take the steps necessary to realize the plans.

The area where the turbines will be installed has been cleared out in the feasibility study, now the exact location of the turbine(s) within this area has to be decided. Usually there are several other factors to consider, how much power that can be connected to the grid, specification about minimum yearaly production, maximum investment and return from the customer (utility, Power Company, etc). The developer’s task is to plan an optimized wind power plant within the limits of these restrictions.

The Project development consists of the following steps:

- Early dialogue. Inform local authorities and neighbours, etc.
- Land acquisition. Negotiate a contract with landowner(s)
- Detailed planning. Decide number, size and sites for turbine(s)
- Second dialogue. Present the detailed plan to authorities and public
- EIA. Work out an Environmental Impact Assessment for the project.
- Permission. Apply for building permission etc.
- Purchase. Ask for tenders and choose the best offer.
- Contracts. Sign agreements with grid operator and power company/utility.
- Installation. Install turbines and connect them to the grid.
- Transfer. Transfer the wind power installation to buyer/owner.

The windpower project should give the best possible return on the investment, but has also to be compatible with the demands of authorities so that necessary permission will be granted. The project development process as well as the purchase has to be financed. This is another task for the project developer to work out.

Early dialogue

The developer can start by making a few different rough outlines for a wind power installation, and invite people in the surrounding area (1-2 km from the site) to an information meeting; an early dialogue. Local and regional authorities, the grid operator and the local media should also be invited. Give information on windpower in general, the environmental benefits, local wind resources and the impact from noise, shadows, etc. Show some outlines and ask the participants about their opinions. Representatives from the local and/or regional authorities can inform about their opinion about the proposed project, and describe how a decision will be taken.

The developer should also have an early dialogue with the local community, the grid operator and other relevant authorities in separate meetings. The project should be a rough outline, the point of an early dialogue is to adapt and modify the project to avoid unnecessary conflicts.

Land acquisition

Access to land is necessary to be able to install and operate wind turbines, so an agreement with the land owner(s) should be made at an early stage. If more than one land owner will be involved, a common agreement should be made, althought the land lease contracts will be individual. In Sweden the lease usually is set at 1-3 percent of the gross yeary income from the turbine each year, or a coresponing calculated sum paid when the turbine is installed.

Detailed planning

The developer's task is to optimize the wind turbine(s) within the limits set by the local preconditions. To find the best solution, wind turbines of different size (height & rotordiameter) and power should be tested (theoretically), at different sites within the area (micrositing). For these different options the production should be calculated and the economics analysed. The impact on neighbours and environment has to be checked. Finally the developer has to choose the best option.

In a wind farm with several turbines, the layout (number, size and configuration) should be adapted to the local wind conditions, so that the wind resources are used in an efficient way.

With the aid of know how, good judgement, and some computer programs, the delveloper will find the best solution for the project; a detailed plan that should be realized.

Second dialogue

In Sweden, a developer has to have a second dialogue with local and regional authorities and with the public (according o the Environment law, for wind power installations > 1 MW), before an application is submitted. In this second dialogue the terems for the EIA (Envionmental Impact Assessment) is discussed. When the detailed plan for the project and the EIA is ready, the developer submits the application to get permission to build the turbines.

Building permission

In Sweden an application for building permission is submitted to the local municipality. For project > 1 MW an application has to be submitted also to the regional authority and for projects > 10 MW also to the government.

Purchase

When all necessary permissions are granted, time is due to purchase the tubine(s), and other goods and services necessary o realize the installation. Always ask for tenders from several different suppliers. Use local companies and entrepreneurs to build access road, foundations etc. Evaluate the different tenders and sign a contract with the one that is most favourable.

Contract

Now contacts have to be signed with land owners, grid operator, and with a power company or utility that will buy the power. Contracts for credits from banks and other financial institutions should also be signed.

Installation

The developer has to prepare the site och build the foundations. Gravity foundations have to harden for a month. The turbines are usually mounted and installed by the company that supplies them. To mount a large turbine does not take more than one day. To install the transformer (if it is not integrated in the turbine) and build a power line to the grid usually is the task of the developer.

Transfer

When the wind turbines have been mounted, connected to the grid, thoroughly tested by the supplier and ready to put on line for regular production, it is time to transfer the turbine(s) to the client, unless the developer intends to own and operate the wind turbine himself. For smaller turbines and stand alone turbines the project development can be less complicated.