Power Quality & Utilisation Guide
Section 8: Distributed Generation
www.leonardo-energy.org
January 2007

Wind farm Development and Operation: A Case Study

Ton van de Wekken, KEMA Consulting

1 Introductory notes

Nowadays most of the European countries are well acquainted with the phenomemon wind energy. In the eighties and nineties of last century mainly in Denmark and Germany the knowledge on wind energy was concentrated including the manufacturing and siting of a large number of wind turbines. The last decade Germany is still at the top in yearly installed wind power, however, Spain is following at close distance. The last 5 to 10 years a large number of European governments developed policies on promoting renewable energy sources including wind energy. Prominent examples are United Kingdom, France, Italy, the Netherlands and Eastern European countries where wind energy is already present or incentives are defined to boost the increase of renewables.

During the last 20 to 25 years the implementation of wind energy has changed dramatically. In the eighties and early nineties of last century was stand alone application of wind turbines with installed power between 100 and 500 kW quite common while the development of wind farms was rare. Due to several developments, ranging from local policies to economical considerations, currently most initiatives concern wind farm developments. The number of wind turbines in a wind farm varies from a few to more than 25.

From 2000, the installed power per wind turbine varies between approximately 750 kW and more than 3 MW. Wind farms with an installed capacity over 50 MW are not uncommon. Wind turbines in the range of 4.5 to 6 MW are available as prototypes and test specimen but not yet commercially explored.

Besides the development of onshore wind farms a tendency is noticeable to offshore siting of wind farms. Characteristic of offshore wind energy is the high installed power per wind turbine and initial investment costs which are almost doubled with respect to onshore siting. The additional expenses are caused by the high costs for offshore foundations, sea cable and special sea vessels for transport and erection of the wind turbines. Also the operational costs are at least the double compared to onshore siting. A main advantage of offshore is the low nuissance to the environment and the excellent wind resources leading to a high degree of utilisation.

The costs of onshore wind energy ranges from 55 to 100 EUR/MWh mainly depending on the wind resource. For most locations wind energy is not cost effective and incentives are a prerequiste to make a wind farm profitable.

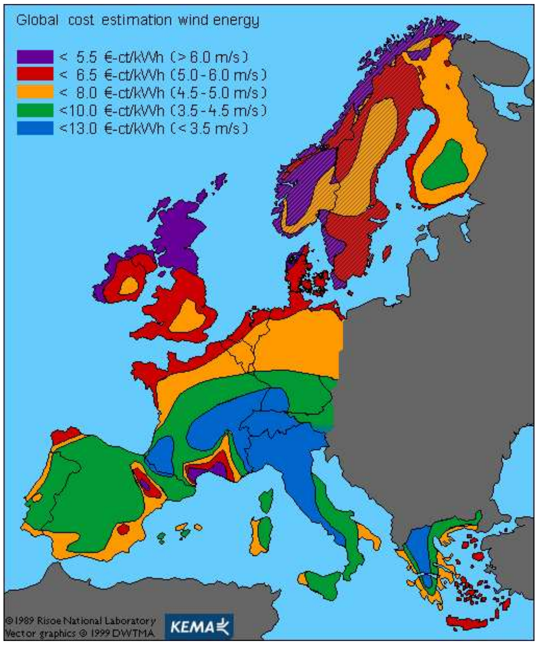


Figure 1a – Overview European Wind Atlas, no data of the Balkans and Eastern Europe is available

Figure 1b - Photograph 10 MW wind farm on flat land near the Atlantic coastline

The European Wind Atlas demonstrates that Skandinavia, UK, Ireland and the Atlantic coastline of the European continent have the best wind conditions for the developing of wind energy.

The time span from first initiative to final commissioning of a wind farm is subdivided into a development period and a building period. The duration of the building period is well known, for a small to medium size wind farm (< 15 MW) ¾ to 1 year and for a large wind farm 1 to 2 year. The technical life span of a wind turbine is 20 years.

The duration of the development period is less predictable. Mainly the time required for an irrevocable building permit is hard to predict. Depending on the mandatory procedure and the number and kind of objections put forward by concerned parties the required time span may vary from approximately ½ year to more than 5 years.

The financing of a wind farm is a matter of a special concern. In the past a stand alone wind turbine was part of the capital properties of a company. In such a case the wind turbine financing is comparable with the finance of other capital expenses.

Nowadays, for most wind farms a separate legal entity is established with limited equity capital and for the greater part founded on loans. It is clear that under such conditions the financer(s) will demand for extra financial guarantees.

Generally the development and operation of a wind farm can be subdivided into the following four phases:

- Initiation and feasibility (concluded by go/no-go)
- Prebuilding (concluded by go/no-go)
- Building
- Operation and maintenance

The following case has been selected for this note:

- Wind farm with 10 MW installed power
- Built up from five wind turbines of 2 MW
- Hub height 80 meter
- Rotor diameter 80 meter, 3 bladed rotor
- Octangular foundation, gross dimensions 18x18 meter
- Nacelle weight 100 ton, tower weight almost 200 ton
- Life span 20 years

The four phases of development will be discussed separately in the next paragraphs of this note.

2 Wind farm initiation and feasibility phase

Main subject during this phase is that one or more appropriate sites are selected for possible siting of a wind farm. Main characteristics are investigated like number of turbines, installed power and hub height. The feasibility study comprises an inventory and assessment of the main project risks like the presence of sufficient wind resources, sufficient grid capacity and verification with the municipality zoning plan.

The phase is concluded with a go/no-go decision for the next process step.

2.1 Site selection and wind assessment

In order to develop and construct an economical feasible wind farm an inevitable first step is to obtain one or more appropriate areas of satisfactory dimensions. Already for a medium size wind farm, e.g. 5 wind turbines of 2 MW, a substantial area is required. Depending on the rotor diameter the required mutual distance between the wind turbines is 300 to 500 meter and further to limit the nuisance or for safety reasons the distance to the nearest dwellings and company buildings is also at least 300 to 500 meter.

Next step, immediately following pre-selection of the area, is to assess the corresponding local long term wind climate. Generally speaking, potential wind farm sites are preferably vacant areas at the flat land or on top of hilly areas. In all cases the sites should be characterized with high and recurrent wind resources.

Purpose of the initial screening study is to identify and evaluate factors that may lead to a definitive cross out of a pre-selected area.

In case the site screening does not identify any prohibitive limitations the feasibility study may proceed.

The financial feasibility is a prerequisite for the development of a wind energy project. The wind resource assessment is of outstanding importance for the estimation of the yearly energy yield and determines for the greater part the financial feasibility. The energy available in the wind is proportional with the wind speed to the third power. Based on local wind speed data of meteo stations can be determined a local wind atlas of the planned wind farm. It is necessary to use minimal one year of wind data to avoid fluctuations in wind speed during the seasons. The wind atlas is related to a roughness map of the area which is needed to determine the wind speed at a specific site and height. The estimated wind distribution results in a yearly energy yield representing the gross income of the wind farm.

The yearly energy yield is calculated by multiplying the wind turbine power curve with the wind distribution function at site:

$$E_{\text{yearly yield}}\,(\text{kWh}) = \Sigma\, f(w_i)\,.\,P(w_i) \qquad i = 1, n$$

With

- f: wind distribution function (yearly hours per wind speed interval)
- P: windturbine power curve (power output as function of wind speed)
- w_i: wind speed at interval or “bin”i, common interval size is 0.5 to 1 m/s
- i: number of wind intervals ”bins” between cut-in and cut-out wind speed; generally from 3 to 25 m/s

Figure 2a shows a power curve (PV) of a 2 MW wind turbine with optimal efficiency, i.e. without noise reduction measures that usually lead to less energy generation. Figure 2b shows the most commonly used wind speed distribution based on the statistical Weibull function with shape factor 2 and average wind speed of 7 m/s.

Based on the PV curve from figure 2a and Weibull wind speed distribution with shape factor 2.0 the gross energy yield corresponding to 7 to 8.5 m/s is presented in table 1.

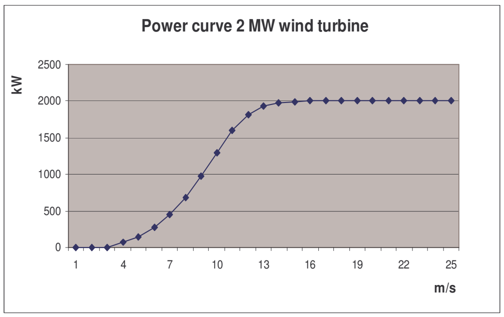


Figure 2a – Power curve of a 2 MW wind turbine (without noise reduction measures)

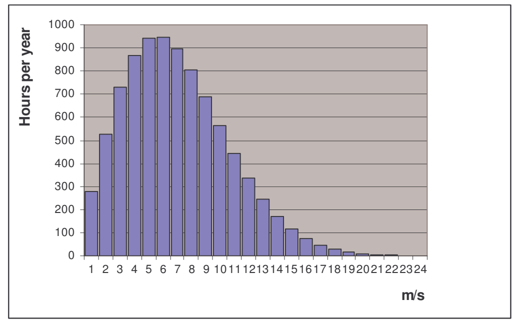


Figure 2b – Wind speed distribution, average wind speed 7.0 m/s and Weibull shape factor k= 2.0.

Table 1 – Gross yearly energy yield of 10 MW wind farm as function of average wind speed.

Average wind speed	*7.0 m/s*	*7.5 m/s*	*8.0 m/s*	*8.5 m/s*
	Weibull shape factor k=2			
Wind Farm Power (MW)	10	10	10	10
Gross Annual Energy Yield (MWh)	**27,000**	**31,000**	**34,000**	**37,000**
Equivalent full load hours	2,700	3,100	3,400	3,700

Yearly gross energy yield of the 10 MW wind farm:

- 7.0 m/s average wind speed at hub height
- Wind speed according Weibull distribution function, shape factor 2.0
- No noise reduction measures required
- Gross energy yield 27,000 MWh
- Equivalent with 2,700 full load hours (utilization 0.31)

2.2 Technical feasibility

Modern wind turbines are available in the power range from 0.75 to more than 3 MW having rotor diameters varying from 55 to more than 100 meter. Although in the past also two bladed rotors were used, nowadays only three blade rotors are commercially available. Generally, the hub height varies from 0.9 to 1.25 times the rotor diameter. Most manufacturers offer wind turbines with two or three different rotor diameters corresponding to low (large rotor), medium (standard rotor) and high or offshore (small rotor) wind climate.

At a first screening the outer dimensions of the available terrain are of importance. Wind turbines require a mutual spacing of at least four to five rotor diameters, corresponding with approximately 300 to 400 meter. A flat and undisturbed area is requested for buildings, trees and other obstacles lead to a lowering of the wind speed.

Next to the terrain orography it is well-advised to examine the local grid properties at an early phase. Main question is the distance to the nearest medium or high voltage substation with sufficient feed in capacity. It is advised to make already during the feasibility phase an appointment with the local grid operator to discuss grid connection including corresponding cost and planning.

2.3 Main risk assessment

In most countries it is prohibited that wind turbine rotors rotate above roads, railway tracks and water ways. A minimum distance has to be observed from wind turbines to public infrastructure. In northern countries and countries with continental climate specific attention has to be paid to probable icing problems. Ice developed on rotating rotor blades can be thrown far from the turbine and harm persons or result in material damage.

Local authorities and concerned parties may demand for an aditional risk analyses in case in the vincinity of the planned wind farm at least one of the following items count:

- Transport, storage or processing of hazardous goods
- Pipelines for transport of hazardous goods (also underground)
- Dwellings, company or public buildings
- Roads, railway tracks and water ways
- Medium and high voltage conductor
- Danger of icing

2.4 Permitting requirements of local authorities

The wind farm site has to meet national, regional and local requirements. In most countries special legislation is formulated for the environmental planning and the building aspects.

During the wind farm planning phase it is necessary to meet special zoning plan requirements. For instance it may be decided that a specific zoning plan prohibit wind turbines or have laid down maximum heights for buildings. Under such conditions it has to be discussed with the local authorities possible ways and procedures to adopt the zoning plan to make the installation of a wind farm feasible.

In most European countries wind turbines have to be certified according to national or international safety standards especially developed for wind turbines. Manufacturers have to demonstrate approved cerification by a valid “type-certificate”.

Planned area for the 10 MW wind farm:

- Check municipality zoning plan on competing activities and maximum building height;
- Mutual distance windturbines 400 meter
- Wind turbines in line, required length 1.600 meter
- Preferable within 300 to 500 meter from the wind turbines no dwellings and other buildings and further as less opstacles as possible
- Authorities or parties concerned may request a risc analyses if within 400 to 500 meter from the wind turbines other activities take place

2.5 Project financing

As example is shown in the tables x and y the investment and operational cost of a wind farm of 10 MW. Wind turbines investment and operational costs are fully proportional with the installed capacity. Investment costs per MW installed are about 1.25 M€ and yearly operating cost somewhat more than 40 k€ per MW.

For a 10 MW wind farm, five wind turbines of 2 MW, the investment and refurbishment costs are estimated as follows:

Non recurring investment costs - price level 2006 -	Costs per wind turbine [K€]	Wind farm costs [K€]
Preparatory costs	100	500
5 wind turbines of 2 MW each	2.000	10.000
Wind farm civil and electrical infrastructure	200	1.000
Grid connection	200	1.000
TOTAL INVESTMENT (year 1)	2.500	**12.500**
Refurbishment (at year 10) - price level 2006 -	250	1.250
TOTAL	2.750	**13.750**

Yearly recurring operating and maintenance costs:

Yearly recurring operating costs - price level 2006 -	Costs per wind turbine [K€]	Wind farm costs [K€]
Wind turbine service, maintenance and insurance	50	250
Local taxes and contribution grid connection	10	50
Land lease	15	75
Daily management	5	25
Own electrity consumption	5	25
TOTAL	85	**425**

Investment and operational costs 10 MW wind farm:

- Initial investment costs M€ 12.5 or 1.25 M€/MW
- Yearly operational costs M€ 0.425 or 42.5 k€/MW
- Estimated refurbishment costs halfway the life span M€ 1.25; i.e. 10% of the initial investment

In most cases the wind farm is financed by a mix of own capital (equity) and bank loan. The amount of equity is mostly limited to 20 to 40% of total investment. It may be interesting for companies, investment groups and private person to invest in wind energy for possible tax reduction benefits. A number of national governments in Europe have incentives to promote electricity production by renewable sources. A wellknown incentive is tax reduction for investments in “green” energy sources.

3 Pre-building phase

During this phase all preparatory work is done needed to start the building phase. The wind farm developer has to apply for all necessary permits and a power purchase agreement (PPA) has to be settled for selling the produced wind energy. The contractors for delivery of the wind turbines and corresponding civil and electrical infrastructure have to be selected. And last but not least, the project financing has to be arranged.

3.1 Wind farm design including energy yield predictions

Based on the wind resource assessment the most promising wind farm locations are studied in more detail. The computer models WasP, Wind farmer and WindPRO are some of the most wellknown models to calculate the energy yield of planned wind farms.

Not only wind speed and wind direction distribution are taken into account but also the terrain orography; for instance a steep slope in the terrain will cause higher winds at the hill top. Such details in the modelling make that wind turbines are optimal sited by assuring optimal exposure to the wind. Generally the lay-out is optimised for exposure from the prevailing wind direction.

The mutual distance between the wind turbines has to meet the requirements of the manufacturers. When siting the wind turbines too close this may result in a lowering of the electricity production. Another, more serious, consequence may be the damaging of primary structural parts caused by the wake of upwind sited wind turbines. The minimum distance depends on the siting with regard to the prevailing wind direction. When siting perpendicular to the prevailing wind direction the distance has to be at least four and otherwise minimal five times the rotor diameter.

The gross energy yield of the wind farm is dominated by the local wind distribution and the siting of the wind turbines. To calculate the nett energy yield it is needed to determine the anticipated losses. The gross annual energy yield has to be adjusted for:

- Wake losses
- Grid losses
- Availibility

3.1.1 Wake losses

The wind speed down stream the rotor, the so-called wake, of the turbine is lower compared to the undisturbed wind speed resulting in a somewhat reduced performance of down stream sited wind turbines. The wake is characterized by extra turbulence which may lead to premature damage of main structural components.

It is common practice to estimate the wind farm wake losses in the range of 3 to 4% of the gross energy yield.

3.1.2 Grid losses

Grid losses are defined as the electrical losses between wind turbine switchgear and public grid connection, i.e. the location of the accountable metering. Depending on the lay-out the electrical losses are in the range of 2 to 3% of the gross energy yield.

3.1.3 Availibility

The availability of a wind turbine is defined as the time the wind turbine is in operation or ready for operation with external conditional, for instance too low wind or grid loss, preventing the system from energy generation.

The technical availability of the turbine is 97% or higher. This figure is based on data of modern operational wind farms.

Yearly nett energy yield of the 10 MW wind farm:

- Gross energy yield 27,000 MWh
- 3% wake losses
- 3% grid losses
- 97% availability
- Nett energy yields 24,500 MWh.

3.2 Permitting procedures

3.2.1 Environmental permit

The wind farm must comply with all regulations pertaining to environmental permitting. For the environmental permit a site plan and various environmental studies, amongst others on plant and animal life, are necessary.

3.2.2 Noise

The noise impact of the wind turbines on the environment is one of the major permitting issues. Wind turbines produce noise, mostly caused by the rotor blades and drive train. The distance to nearby located dwellings has to be sufficient to assure that the noise level at the house front is below the statutory norm.

Next to a noise assessment and visual impact study, most of the authorities demand safety and risc assessment studies and shadow casting examinations. Shadow flickering is caused by sunlight reflecting on non rotating blades or tower. Shadow casting is due to periodically – about once per second – interrupting the sunlight by the rotating blades. Both flickering and shadow casting on dwellings and offices can be very annoying for people in there. Shadow casting is not regulated by law.

3.2.3 Safety

It is not allowed for wind turbines to rotate above roads or railway-tracks. In case icing on the rotor blades and nacelle may cause danger for persons and material in the near environment protective measures have to taken. A well-known measure is rotor standstill during icing up and release for starting up after visual observation all ice has disappeared.

3.2.4 Building permit

Besides an environmental permit also a building permit is necessary for the wind farm. As part of the application most authorities require information on the visual impact of the wind farm on the environment. Visualisations of the planned wind farm in the existing environment serve as input for this assessment. Another part of the application is a detailed description of the wind turbines including foundation, exact locations of the wind turbines in the terrain, overview of the civil and electrical infrastructure and a copy of the valid type-certificate.

3.3 Grid connection

Usually not each individual wind turbine is connected to the public grid separately.

For the wind farm an internal grid is designed and installed. The voltage of the internal grid is preferred at medium voltage level, between 10 to 20 kV, in order to limit the losses. In most cases the wind turbines are electrically connected in a loop to ensure redundancy. The wind turbine generators operate mostly below 1000 V and each wind turbine is equipped with a transformer to transform the power from low to medium voltage level. The wind turbine transformer is located in the nacelle or tower base or in special housing next to the tower.

It depends on the public grid voltage if a central wind farm transformer is required to transform the medium voltage to grid voltage or only a switchgear installation including accountable metering provisions.

In some occasions no public grid to the wind farm is available or the existing grid has insufficient capacity. If the grid has to be extended or reinforced for the wind farm only the costs have to be born fully by the wind farm developer.

3.4 Feed-in contract

In all cases a power purchase agreement (PPA) or feed in contract is necessary. The feed in tariff is composed from a contribution for producing and delivery of electricity and in most cases increased with an extra allowance for generating renewable energy or corresponding carbon credits. Depending at one hand on the wind resources and on the other hand on the investment and operational cost a feed in tariff of at least 60 EUR/MWh is required and for an economical viable project a tariff of 80 to 90 EUR/MWh is needed.

3.5 Selection of suppliers

Based on the scope of supply and own working procedures the wind farm developer has to decide for a public tendering procedure or to decide to send only a pre-selected number of wind turbine suppliers a request for tendering. All necessarily information for the tendering has to be included in the “tendering enquiry documentation” also abbreviated to TED.

The TED has to include at least the following bid information:

- Sufficient information on the project including permitting status and project time planning
- Requested information from bidders, e.g. financial, technical and operational information
- Time schedule, a.o. tender closure date and assigned period for additional information, questions to ask and site visit;
- Contractual issues
- Scope of supply
- Technical specifications
- Maintenance and repair conditions
- Insurance and warrantee agreements.

With regard to the scope of supply it may be decided that the contracter delivers a turnkey wind farm including wind turbines, foundations, access roads, wind farm grid and connection to the public grid. Another option is to subdivide the delivery in a number of subdeliveries with different contractors, for instance to separate wind turbine delivery and installation from the civil and electrical works. The latter may have cost advantages, however the project developer shall act as main contractor and is responsibe for the wind farm entirely. Turnkey delivery by one main contractor is mostly the well-advised option.

It shall be noted that the offered wind turbine is certified by a recognized body and possesses a type-certificate valid for the local wind climate and wind farm lay-out. In order to avoid any problems on warrantees the contractor has to state formally that the delivered wind turbines are “fit for purpose” for the site.

3.6 Project financing

As said before, for most sites in Europe wind energy is not yet cost effective. To promote wind energy incentives are essential, the most applied promotion measures are:

- Subsidies (governmental or local) on investments in renewable energy sources
- Tax benefits for investing in renewable energy sources
- Reduced interest tariffs on loans for renewables
- Subsidies on the production of renewable energy (increased feed in tariff)

In case the financing is based for the greater part on loans the financers may ask for additional securities to guarantee that the loan can be repaid. The following securities can be asked for:

- Power purchase agreement with settled minimum feed in tariff for the loan period
- Guarantee that in years with moderate wind supply the income is sufficient for interest and reapyment
- Warrantees on supplied components and wind farm performance (availability and power curve) for the loan period
- Machine breakdown and business interrupt insurrance.
- Service and maintenance contract

In annex A cashflow calculations with two different feed in tariffs are carried out for the 10 MW. In the calculations the financing costs are not taken into account. All expenses and incomes are based on price level 2006 so the influence of inflation is implicitly included in case expenses and income increases yearly with equal ratio.

Cashflow calculations for the 10 MW wind farm based on 20 year life span and price level 2006:

Feed in tariff	**60 €/MWh**	**85 €/MWh**
Gross income	1.47 M€/yr	2.08 M€/yr
Recovery period	> 15 year	> 9 year
Nett present value over 20 year (NPV)	6.1 M€	17.7 M€
Internal rate of return (IRR)	4%	11%

The calculations show that a feed in tariff of 60 €/MWh is needed to pay all costs without generating profit. Presuming the project is fully financed by a bank loan the project generates just sufficient cash to pay yearly interest (4%) and repay the laon and yearly operating costs. At a tariff of 85 €/MWh the project generates value for the owner (7%) in case the yearly financing costs ask again 4%.

4 Building phase

The building phase includes all activities from commencement of the works up to take over of the operational wind farm.

4.1 Overview of building process

Following selection of the contractors and financial close of the project the manufacturing and building process commences.

For the required exceptional transport the contractor has to verify the accessibility of supply routes towards site. Also adjacent to each wind turbine location sufficient space has to available for storage of the main components, assembly of the rotor and placing of the building crane. An area of approximately 50x80 square meter suits most applications. A 2 MW wind turbine requires at least a 600 tons caterpillar crane for hoisting of the tower parts, nacelle and rotor.

Manufacturing and assembly of the main components takes fully place in the factories of the wind turbine supplier.

The following assembled main components are shipped to site:

- Foundation anchor or tube
- Three or four tubular tower parts
- Ground controller and switchgear
- Wind farm SCADA system
- Transformer (in case of ground based)
- Fully assembled nacelle (including gearbox, generator, yaw mechanism, mechanical break, converter and if applicable the transformer))
- Hub and rotor blades

For a small and medium size wind farm the time between purchase order and transport ready is 6 to 9 months. Meanwhile the wind farm civil, including access roads, wind turbine foundations and substation, and electrical infrastructure is built. The time required for rotor assembly and constructing of the main structure takes two to three working days per wind turbine. Subsequently it takes 7 to 10 working days to finish the installation works and connecting to the grid.

From the time all material is at site the building time of a small and medium size wind farm takes only 2 to 3 month.

4.2 Quality control during production and construction

It is common use that the contractor assigns a number of so-called “hold and witness” points for the client. These hold and witness moments are meant for the wind farm owner to audit the progress and quality of work including the verification that the components are in conformity with the specifications. Hold and witness moments are mostly planned immediately following a project milestone, for instance a main component ready for transport to site. Mostly hold and witness moments are link with instalments.

The following hold and witness points are commonly used:

- Start of component production including audit of contractors quality system
- Factory acceptance test (FAT) of components ready for shipment
- Site acceptance test (SAT) of components delivered at site
- Several inspections during building at site, connected to milestones

4.3 Commissioning and take-over

Following completion of the building and installation period and before take-over of the wind farm an overall inspection and commissioning of the works is carried out. Commissioning inspections are performed by representatives of contracter and coming owner. The commissioning may comprehend an elaborate testing and measuring plan but is mainly meant to verify proper installation and functioning of the installations. Also is verified that the delivery is complete without the omission of more or less important details. Normally in cooperation between the parties involved a check-list is formulated for the commissioning procedure.

It is quite common that the first commissioning inspection results in a “punch list” with residual items. It depends on the gravity of the questions and further items on the “punch-list” if formal take-over may take place immediately after the first commissioning inspection or has to be delayed to approved second commissioning.

Approved commissioning and take-over is related to last project payments.

5 Operation and maintenance

Starting from date of take-over the owner is responsible for daily operation of the wind farm. Also from that date warrantee and maintenance contracts become valid. The technical and economical life span of a wind farm is anticipated as 20 years.

5.1 Daily operation

Wind turbines are designed to operate unmanned. For normal operation no operator has to be available at site. It is common practice that medium and large size wind farms are equipped with a wind farm control and monitoring system (SCADA). By means of modem or internet remote access to the SCADA system is available. The SCADA system provides reports on energy yield, availability and failure statistics.

Main function of the daily operator is to verify regurarly that the wind farm is in optimal condition and performing according expectation. Also the operator is responsible that maintenance and repairs are carried out accordance to contract and within reasonable time.

5.2 Warrantees and insurance

The following warrantees are common for the first five years following take-over:

- On delivered goods, including repairs and modifications
- Availability of individual wind turbines and wind farm, values of 95% or higher are not uncommon
- Warrantee on performance, for the exact wind supply is not to be predicted for a given year the warrantee is given on the power curve. Warrantees of 95% of the certified PV-curve of the wind turbine are common.

In case the availability or performance is below the warranteed value the difference between actual and warrantee values has to be settled by the supplier.

Some suppliers offer warrantees up to 8 to 12 years or at least for a period comparable to the financing period.

Insurances are required for:

- Third party liability
- Machine breakdown (e.g. material flaws, lightning strokes, fire, vandalism, fault by maintenance engineer and/or operator, etc.)
- Business interrupt (compensation for non production days following a machine breakdown event)

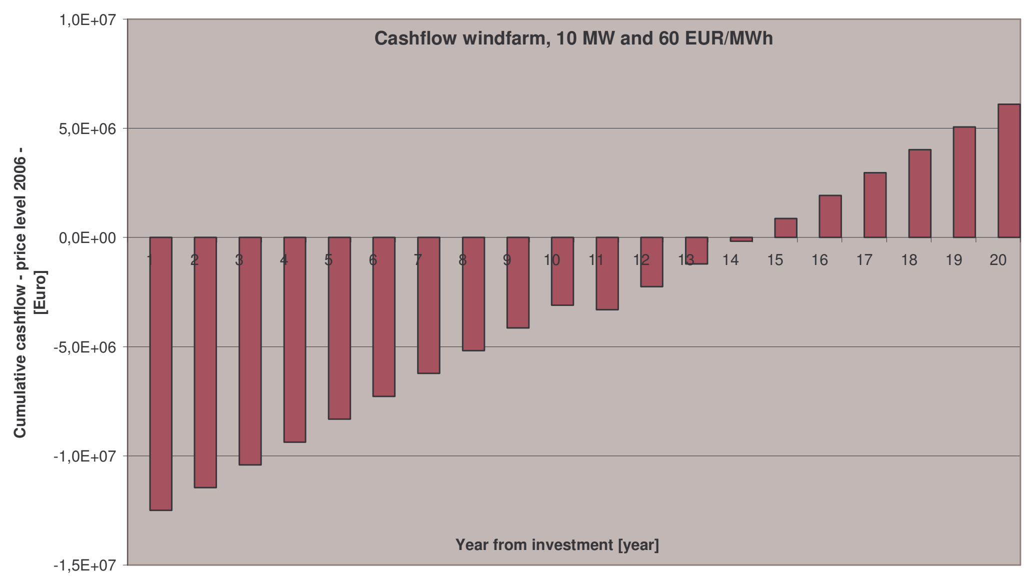
5.3 Maintenance and repairs

Modern wind turbines require twice a year a preventive maintenance service. For a wind turbine in the MW-segment a planned preventive maintenance overhaul requires 2 tot 3 working days for two engineers. The work comprehends amongst others inspection and testing of the control and safety devices, repair of small defects, replacement or filling up of consumables like bearing grease and gearbox lubrication. The gearbox is the most vulnerable component and therefore subject of special interest during maintenance. At regular intervals oil samples are taken and investigated on pollution, filters are replaced and gearings are inspected on damages.

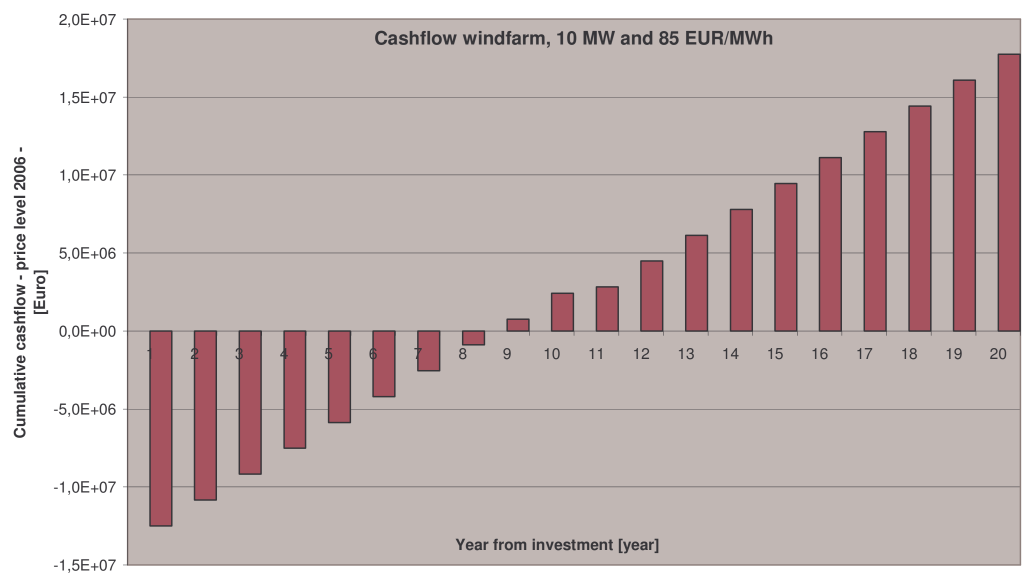
The number of repairs differ largly between individual wind turbines and wind farms. The average yearly number of corrective actions per wind turbine is 3 to 4. Only those corrective actions are counted that need a visit on site of a service engineer. The mean down time per failure is 2 to 4 days. The cause of failure is equally divided between mechanical and electrical problems.

Although not formally admitted by the manufacturers it is common practice that after 10 to 12 years of operation wind turbines need a major overhaul. The overhaul comprehends cleaning and repair work of the rotor blades and refurbishment of the drive train, i.e. replacement of bearings and if necessary replacement of gearbox parts.

6 Annex A – Examples of two cash flow calculations for a 10 MW wind farm



Summary of data scenario 1: wind farm of 10 MW	Low feed in tariff
No financing costs included!	
Price level 2006	
Investment costs (year 1)	€ 12.500.000
Refurbishment costs (year 10)	€ 1.250.000
kWh feed in tariff	**€ 0,060**
Yearly wind farm production in kWh	24.500.000
Gross income from energy production	€ 1.470.000
Yearly recurring costs	€ 425.000
Recovering period	**15 year**
Net Present Value (price level 2006, 20 jaar)	€ 6.100.000
Internal Rate of Return	4 %



Summary of data scenario 1: wind farm of 10 MW	normal feed in tariff
No financing costs included!	
Price level 2006	
Investment costs (year 1)	€ 12.500.000
Refurbishment costs (year 10)	€ 1.250.000
kWh feed in tariff	**€ 0,085**
Yearly wind farm production in kWh	24.500.000
Gross income from energy production	€ 2.082.500
Yearly recurring costs	€ 425.000
Recovering period	**9 year**
Net Present Value (price level 2006, 20 jaar)	€ 17.750.000
Internal Rate of Return	11 %