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Technical and commercial Aspects for the Development of Wind Power Projects

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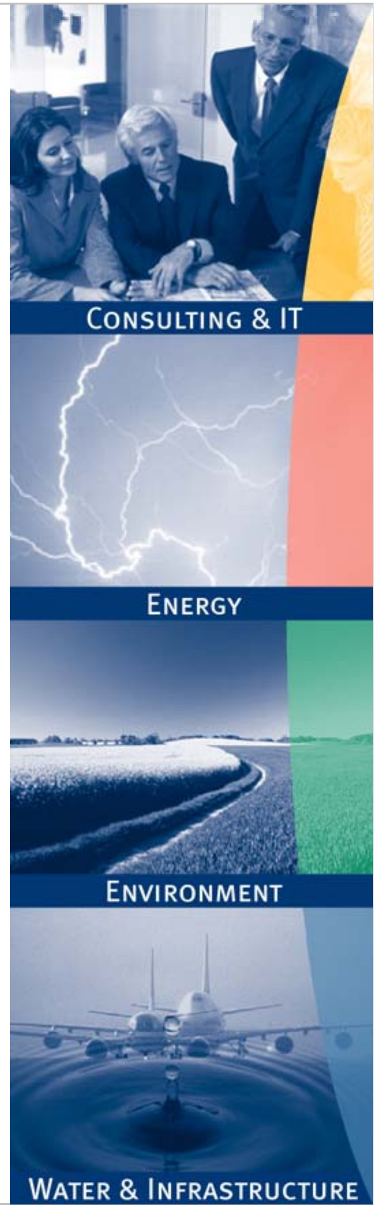

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Contents of the presentation

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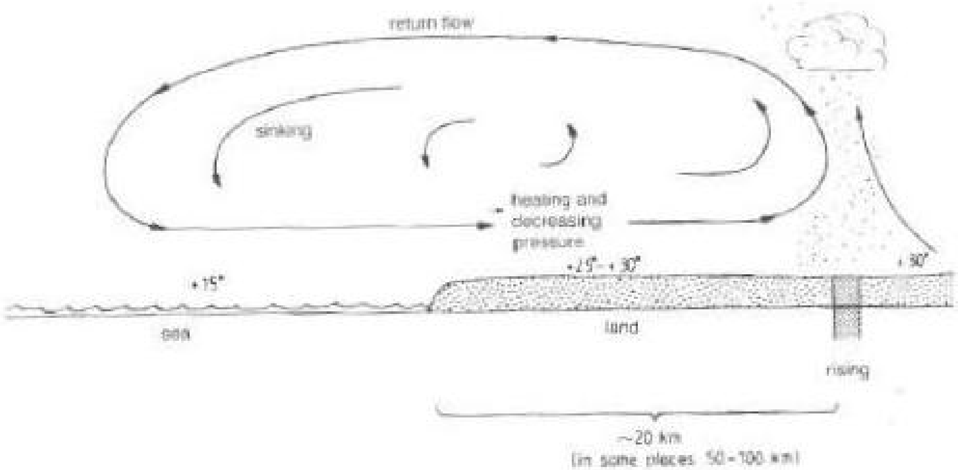
1. **About Wind Energy**
   - Introduction to wind energy
   - Wind turbine technology
2. **Project Development**
   - Location
   - Wind resource assessment
   - Wind turbine selection
   - Wind farm layout
   - Civil, electrical and construction
3. **Project Management**
   - Procurement concept
   - Project organization
   - Contracts
   - Market conditions
4. **Project Screening and Due Diligence**

Where does the wind come from?

Global winds

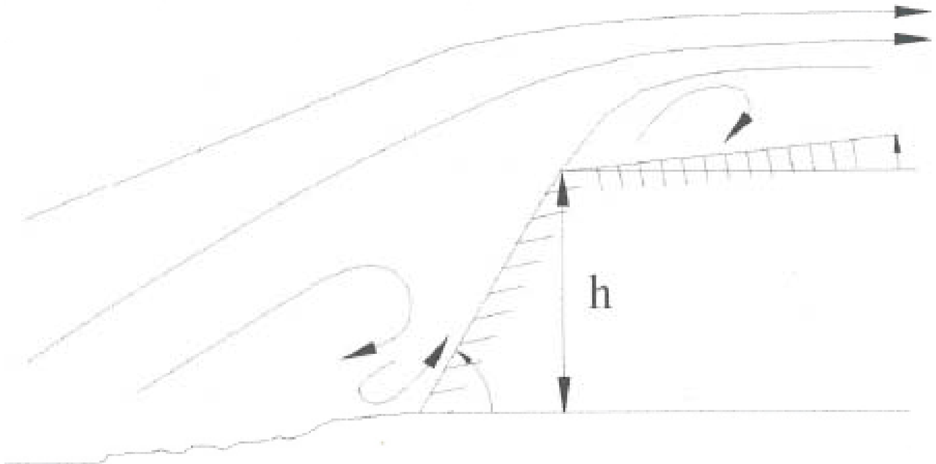
- Energy comes from the sun heating the earth unevenly
- Earth rotation and seasonal variation also has an effect



Local winds

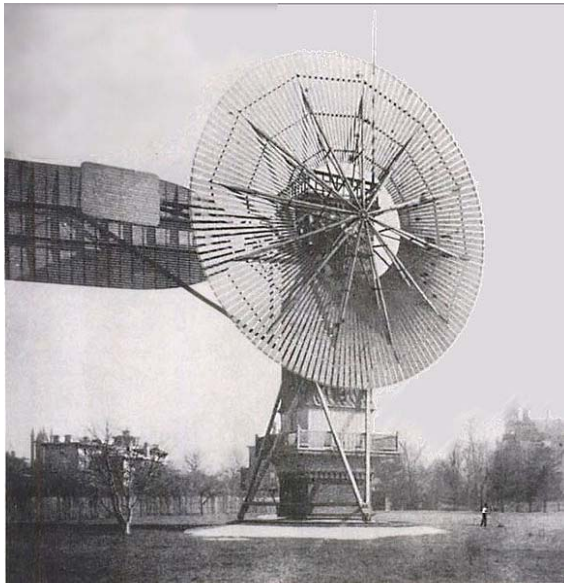
- Global winds and
- Earth topography and surface cover
- Water masses

Local winds and turbulences are within the troposphere where actually the harvesting of the wind energy takes place.

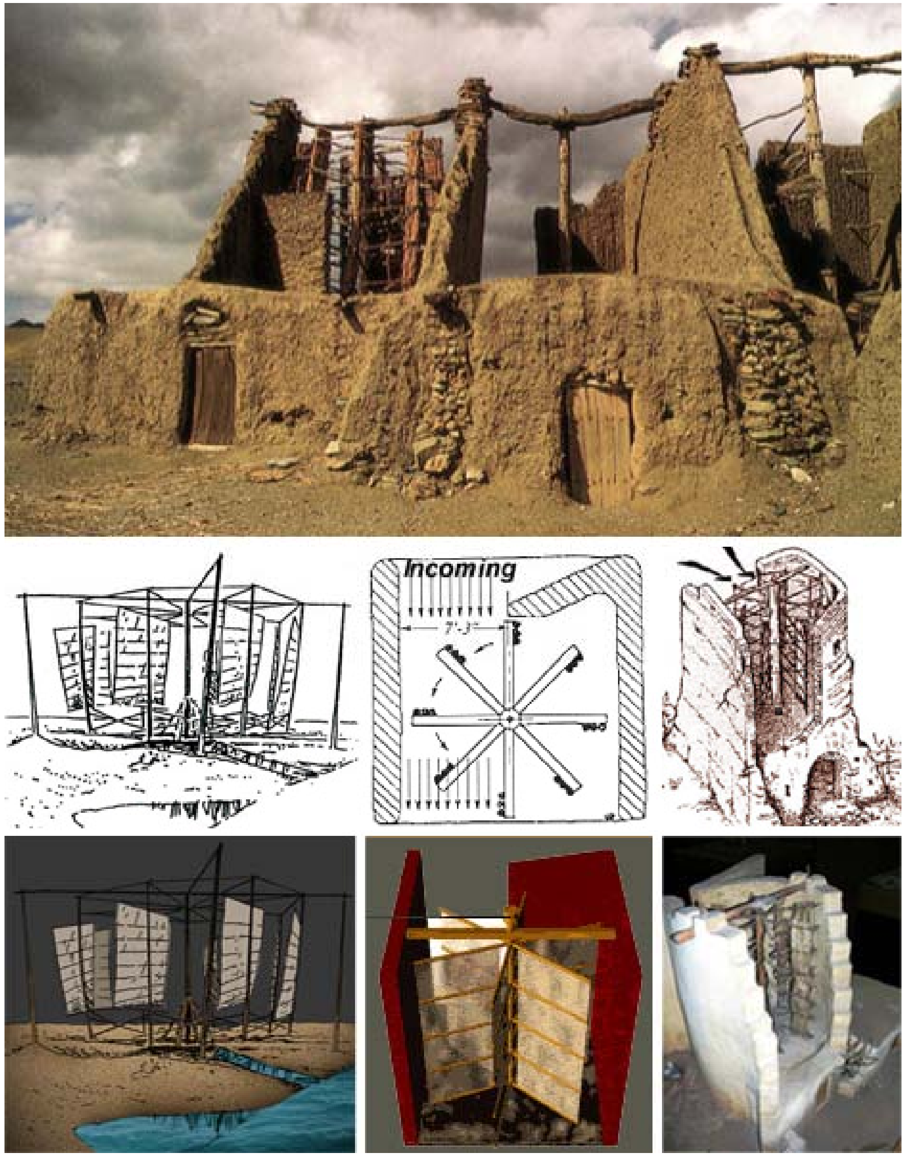


History of wind energy use

- **Wind mills were used as soon as 1700 BC. They were used for grinding grains and pumping water**
- **Ancient wind mills had mostly vertical axis**
- **They were drag machines, asymmetry was created by screening half of the rotor with a wall.**



Horizontal axis wind mill

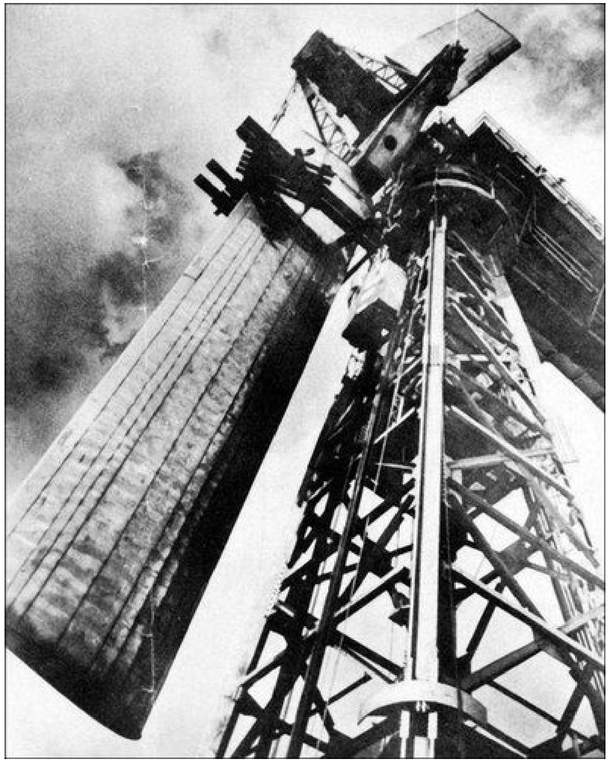


Images: Deutsches Museum, World of Energy, Blue Planet, Ullesthorpe

History of wind energy use

In the 20th century, the road to modern electricity generating started and picked up fast in the end of the century. Worldwide developments and pilot turbines were installed and shaped the modern wind turbine.

Wind turbine in Nogent-le-Roi 1955, Photo by Jean-Luc Cavey



Old wind turbine on Grandpa's knob in Vermont; circa early 1940's (DOE/NREL, Rutland Herald)

Lessons from the past (DOE/NREL, Dossett, Michele)

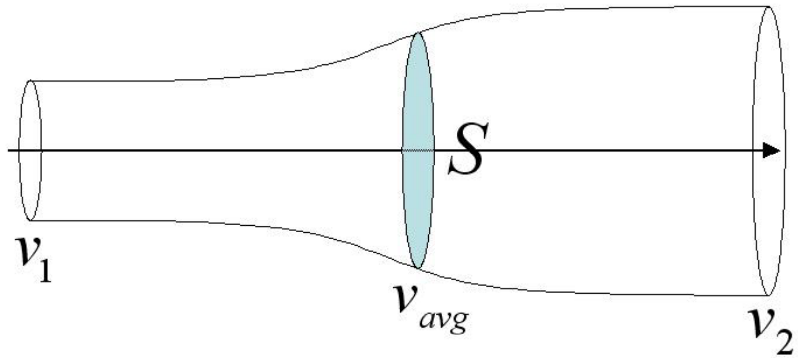
Wind energy physics

- The amount of available Kinetic energy in the wind depends on the speed of movement and the total mass.
- The mass per unit of time depends on the density of the matter, the area in question and again the speed of movement through this area.
- Available wind power is therefore the kinetic power of the wind going through the area of the rotor of the wind turbine:

$$\dot{m} = \rho \times A \times v$$

$$\text{Kinetic energy} = \frac{1}{2} \times m \times v^2$$

$$\text{Kinetic power (Wind Power)} = \frac{1}{2} \times \dot{m} \times v^2$$



$$\text{Wind energy} = \frac{1}{2} \times \rho \times A \times v^3$$

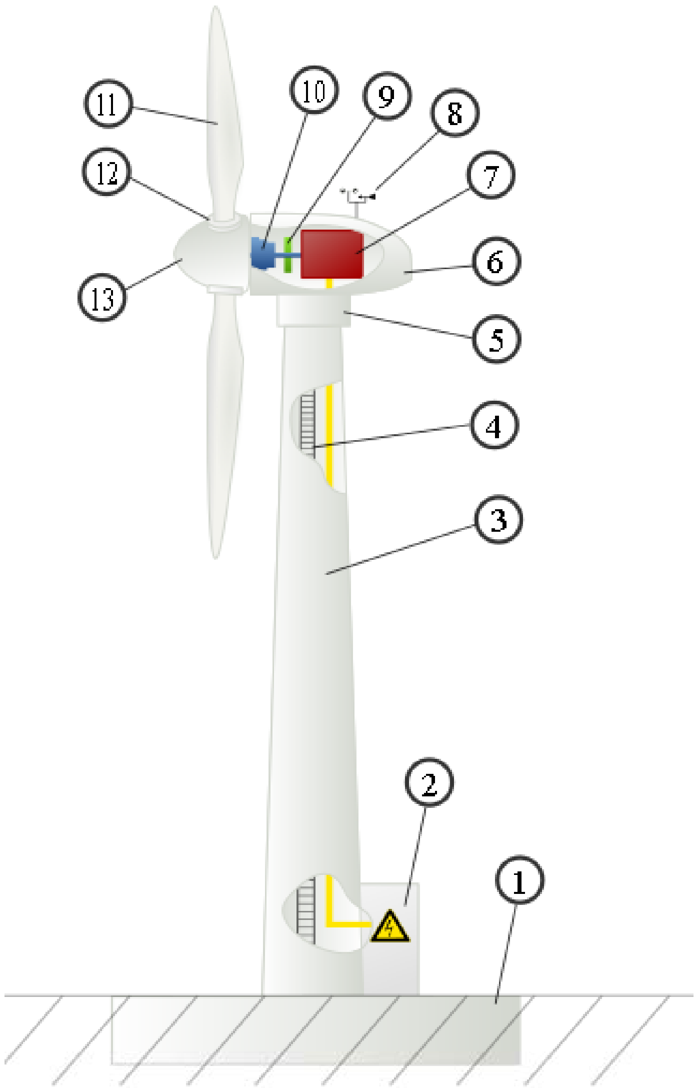
- m is the mass in [Kg]
- v is the wind speed in [m/s]
- A is the area of the rotor in [m2]
- ρ is the density of air in [Kg/m3]

Wind speed	5 m/s	6 m/s	7 m/s
Wind energy	100%	173%	274%

Wind turbine technology

The wind turbine converts the kinetic energy of the wind to mechanical energy and then to electrical energy.

1. **Foundation**
2. **Connection to electric grid**
3. **Tower**
4. **Access ladder**
5. **Wind orientation control**
6. **Nacelle**
7. **Generator**
8. **Anemometer**
9. **Brake**
10. **Gearbox**
11. **Rotor blade**
12. **Blade pitch control**
13. **Rotor hub**



Graphic: A. Nordmann

Wind turbine technology - Rotor

The rotor consists of

- **Rotor blades**
- **Hub**
- **Pitch mechanism**

The hub connects the three blades together and to the drive train of the turbine transmitting and withstanding therefore all the involved forces from all the blades. Most hubs are made from either cast or welded steel.

DOE/NREL, Gretz, Warren - NREL Staff Photographer

Researcher entering the hub of a GE Wind (formerly Enron Wind 1.5 MW wind turbine (DOE/NREL, Sandia National Laboratories)

Wind turbine technology – Rotor blades

Modern wind turbines blades are

- **manufactured with lengths that exceed 60m.**
- **connected to the hub on their root as the only support point, and turned around their axis with the pitch mechanism**

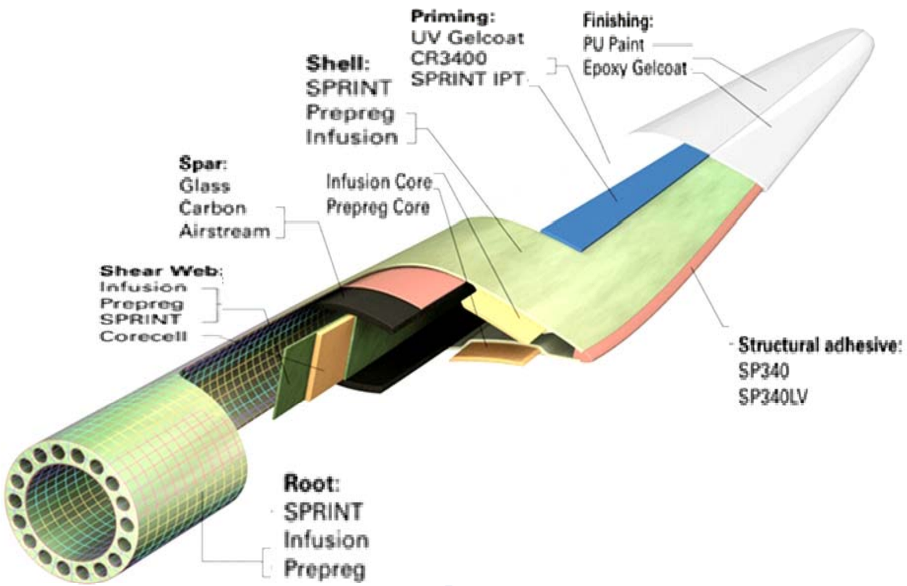


Photo: Paul Anderson

Wind turbine technology – Rotor blades

Requirements

- Aerodynamic efficiency to maximize energy and minimize noise
- Light weight to minimize loads on blades and rest of turbine
- Structural strength to stand high flap and edge wise loads and the connection on the root of the blade
- Recyclable to reduce effort and cost of decommissioning

Manufacturing

- The shape of the blade is defined by airfoils used and the corresponding chord and twist.
- Different materials were historically used for manufacturing blades, from cloth covered wooden structures to full wooden blades, steel, and aluminum blades.
- Most modern blades are though built from composite materials and mostly fiberglass in polyester resin and others.
- Recently carbon fiber is being used along with fiberglass as a combination and not necessarily as a replacement.
- infusion process, including carbon and wood with fiberglass in an epoxy matrix. Options also include fiberglass and vacuum-assisted resin transfer molding.

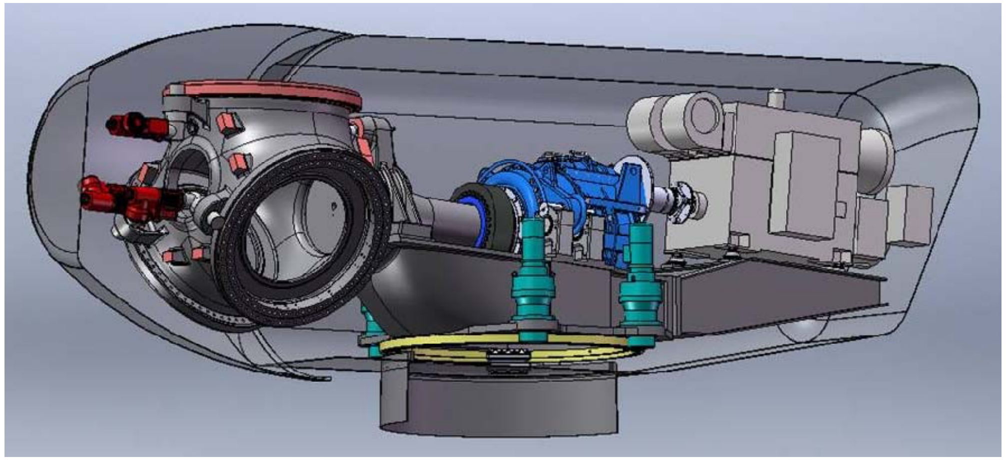
Wind turbine technology – Pitch

- **Rotating speed and torque of the wind turbine rotor are mainly controlled by the blade.**
- **Changing the pitch angle of the blade or the angle at which it receives the wind (angle of attack) results in a change of the aerodynamic characteristic of the blade and therefore the generated energy.**
- **This control is used to limit the maximum power production of the wind turbine to keep all the components within their maximum design values.**
- **Pitch control is also used for an easier start of the turbine in low wind speeds.**
- **Modern wind turbine might have hydraulic or electric pitch drives. Hydraulic pipes or electric cables have to cross to the hub through the rotating main shaft of the wind turbine.**

Wind turbine technology – Drive Train

The drive train of a wind turbine consists of:

- **Rotor shaft, couplings**
- **Gearbox**
- **Generator**
- **Brakes**



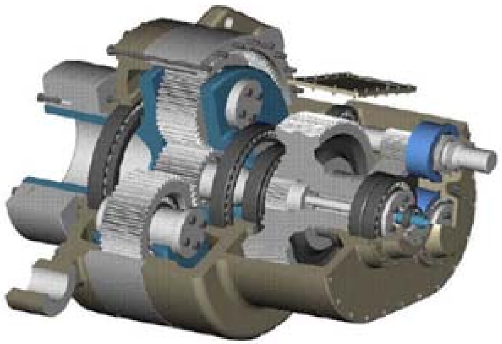
The variety in the design of drive trains come from the variety of concepts (with or without gearbox, type of generator) but also from the way the main components are arranged, number of bearings, placement of the brake and so on.

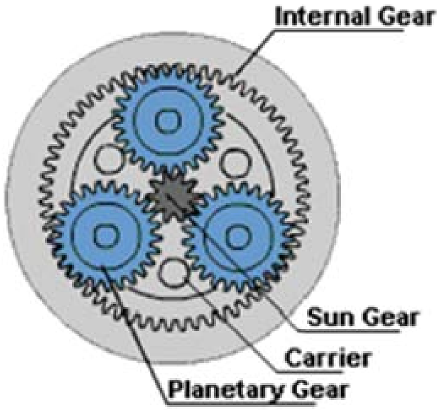
Wind turbine technology – Gearbox

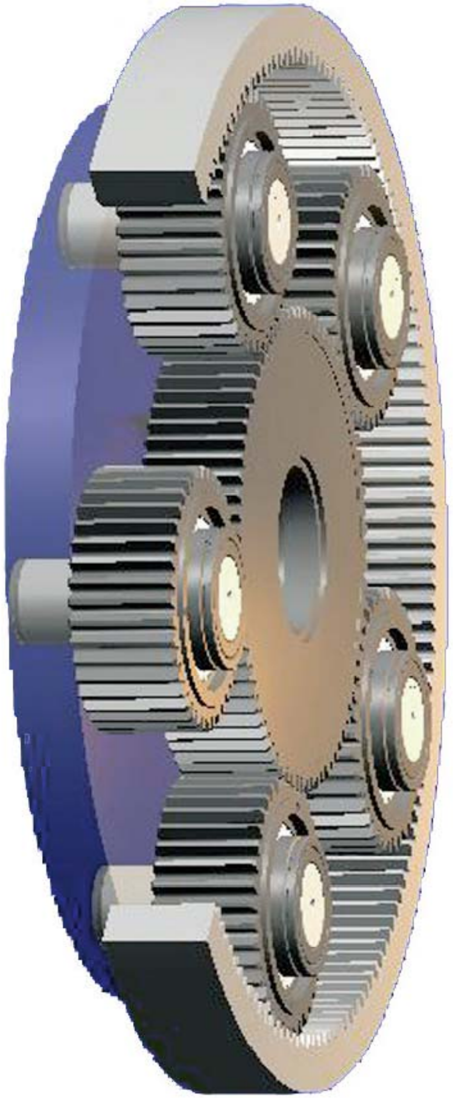
Modern wind turbines come with or without gearbox.

The gearbox steps up rotor speed to generator speed.

Planetary gearboxes are the usually preferred concept (opposite to parallel shaft gearboxes).







Wind turbine technology – Nacelle

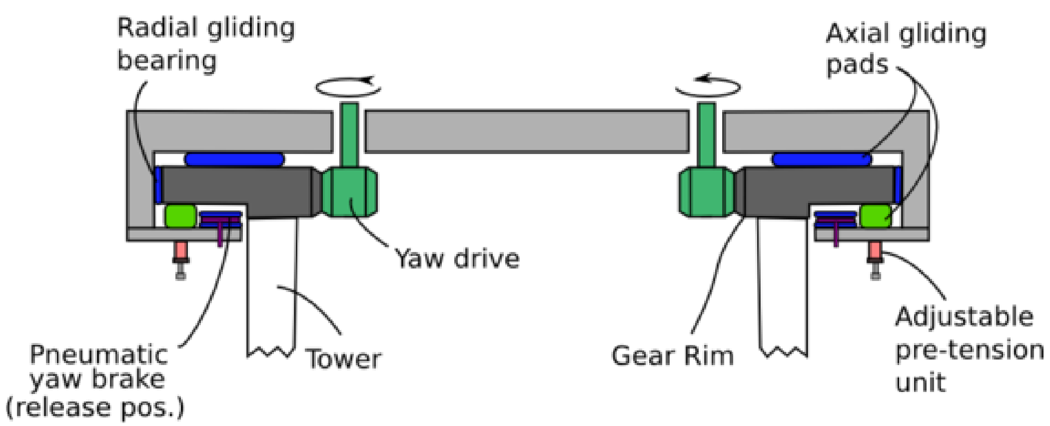
- nacelle houses the main components of the drive train and protects them against external conditions
- generally made of light weight materials such as fiberglass and has no structural role
- nacelle contains the drive train, the yaw mechanism, control and automation hardware, cooling systems and so on
- nacelle plays an important role during the maintenance of the wind turbine
- maintenance team can do their work while protected from external conditions and from there they can access the top of turbine and the hub and blades
- nacelle is usually tightly closed and cooled to protect all components from external conditions and keep the environmental parameters within range

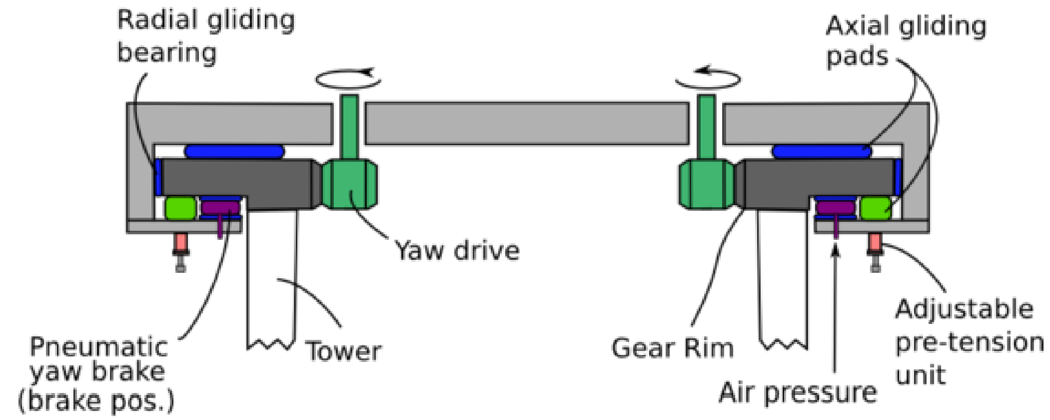
Photo by Paul Anderson

DOE/NREL, Siemens AG 2011

Wind turbine technology – Yaw system

- The yaw system directs the rotor of the turbine in the direction of the wind for maximum energy capture and equalized loads.
- Wind direction is measured by a wind vane placed on the top of the nacelle. The yaw follows an averaged direction over a certain period of time
- The yaw turns the complete nacelle and the rotor in relation to the top of the tower.
- The yaw system consists of electric drive and brakes to keep the nacelle in the desired position.





Graphic by Turbinela

Wind turbine technology – Tower

Wind turbine towers

- Assure the stability of the wind turbine and transfer all loads to foundation
- Make up to 25% of the WTG cost
- The height of the tower plays an essential role in determining the energy yield

Tubular steel and concrete tower

- Easier maintenance in cold climates
- Easier to assemble
- Require less maintenance

Lattice tower

- Easier logistics and transport
- Cost benefits
- Aesthetics may oppose permitting restrictions


DOE/NREL, Summerville, Brent


DOE/NREL, Spink, Todd

Wind turbine technology – Tower

Concrete tower concepts

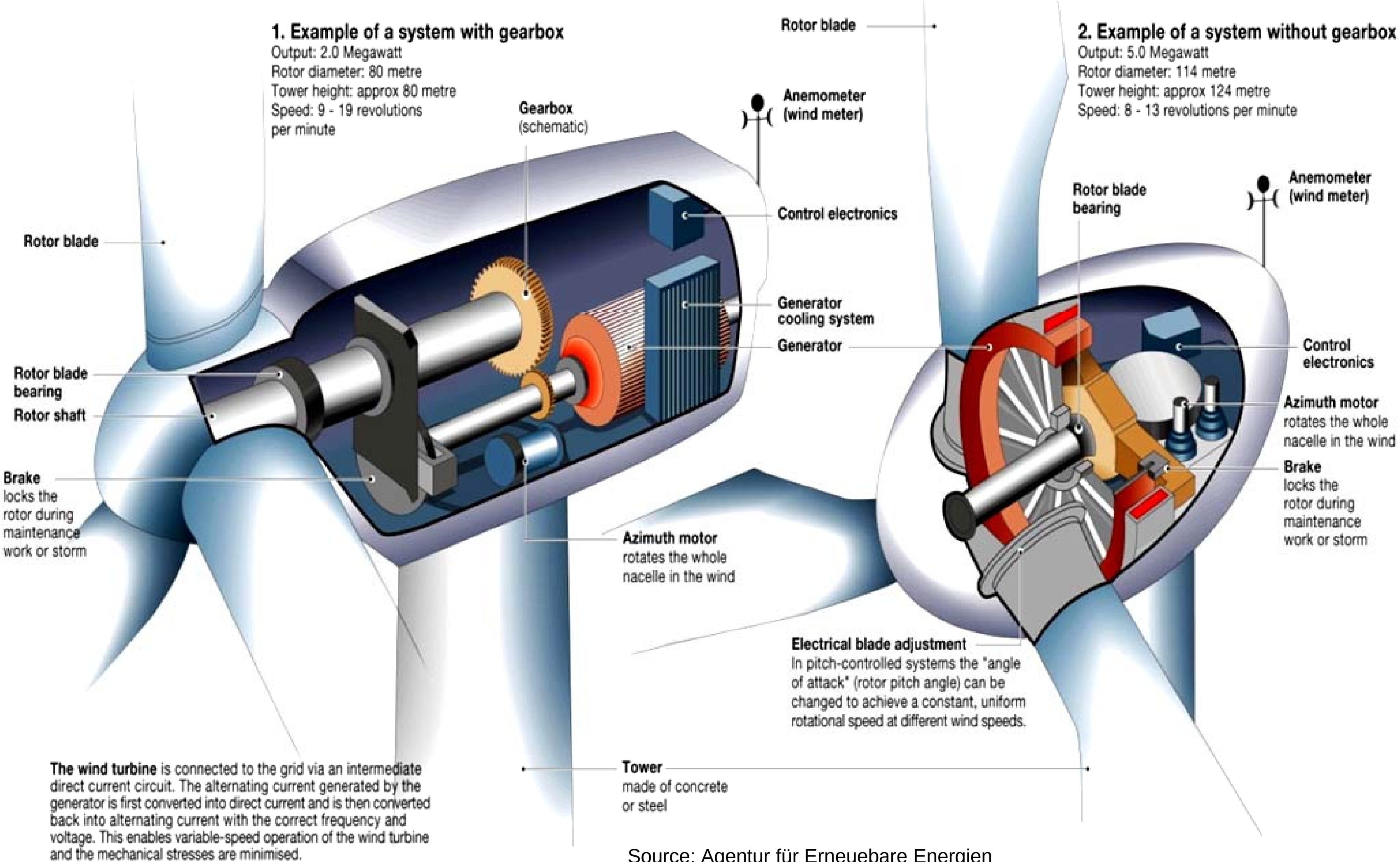
- **Slip form**
- **Prefabricated concrete unit**
- **Spun concrete**

Wind turbine technology – Foundation

- **Slab foundation**
- **Pile foundation**
- **Rock anchor foundation**

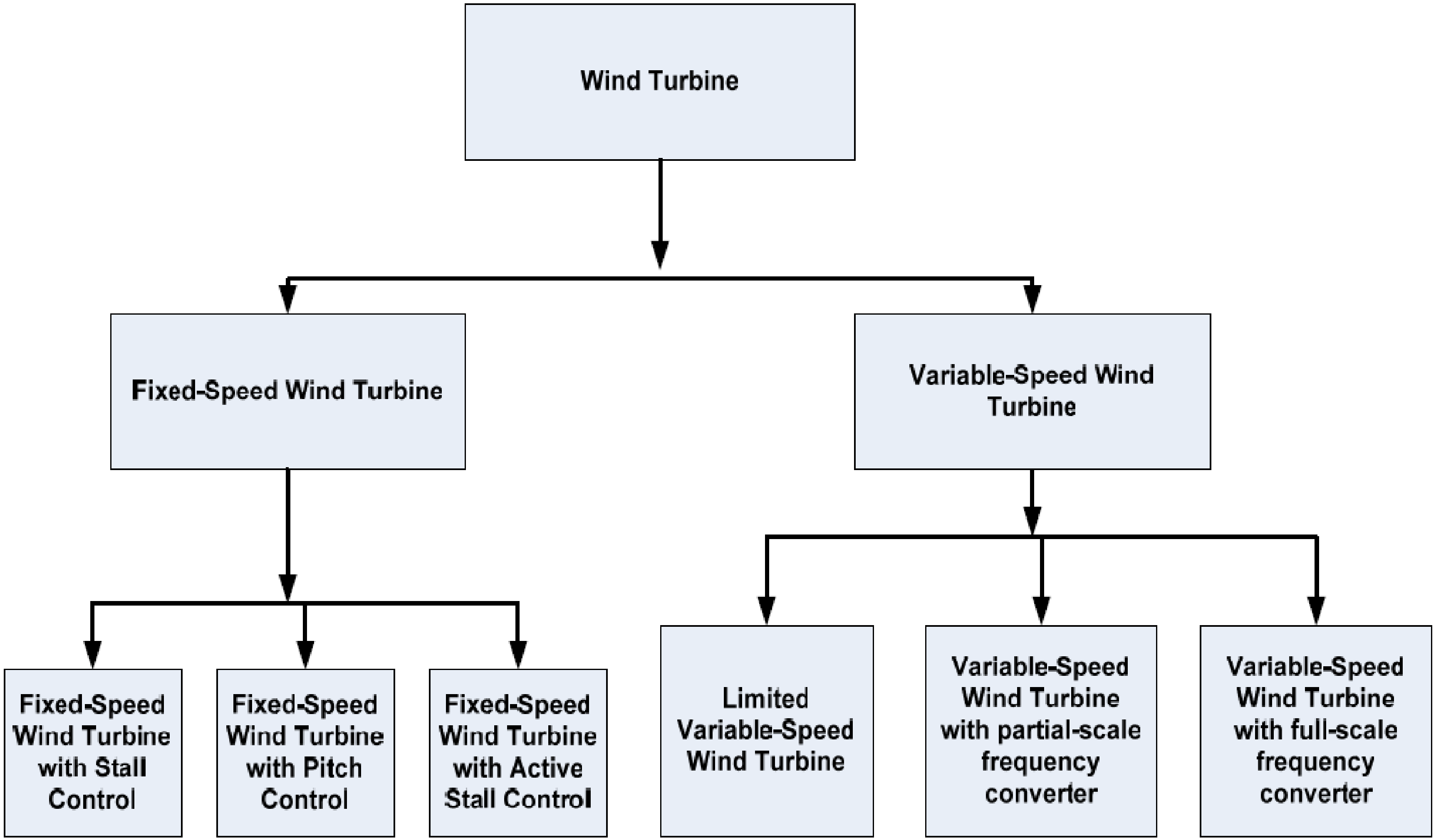
Wind turbine technology – Electrical concept

With or without gearbox / variable speed



Source: Agentur für Erneuebare Energien

Wind turbine technology – Electrical concept

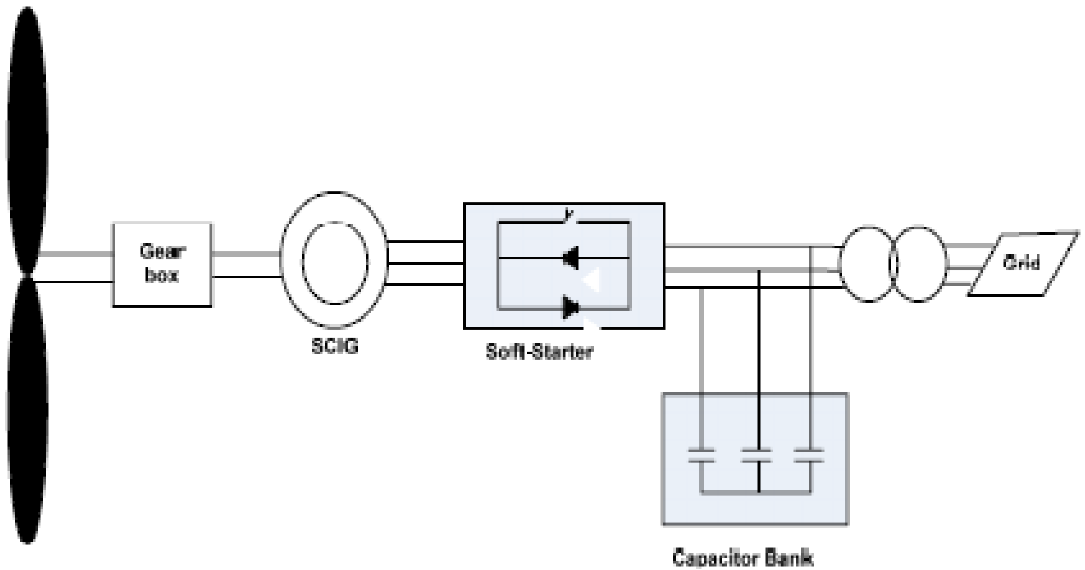


Source: Chalmers University

Wind turbine technology – Electrical concept

Fixed speed wind turbine

- **Are those using a squirrel cage induction generator (SCIG) directly connected to the grid**
- **Known as the Danish concept since it was used first from Danish developers and farmers to produce a simple and robust wind turbine**
- **This turbine draws reactive power from the grid and therefore is usually coupled with a capacitor bank to compensate for that**
- **A gearbox steps up the speed of the rotor for the generator**

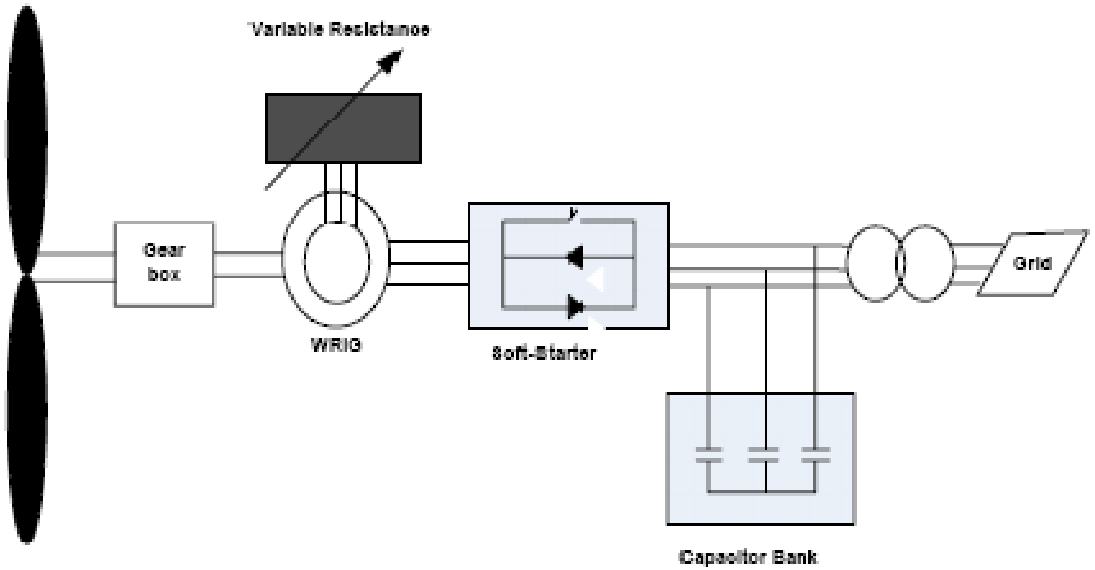


Source: Chalmers University

Wind turbine technology – Electrical concept

Limited variable speed wind turbine

- Variation of the fixed speed developed by the company Vestas where the resistance of the rotor of a wound rotor induction generator is changed allowing the change in the generator slip and allowing around a 10% range of speed variation
- A capacitor bank and soft starter can be used with this concept for reactive power control and a softer start
- A gearbox steps up the speed of the rotor for the generator

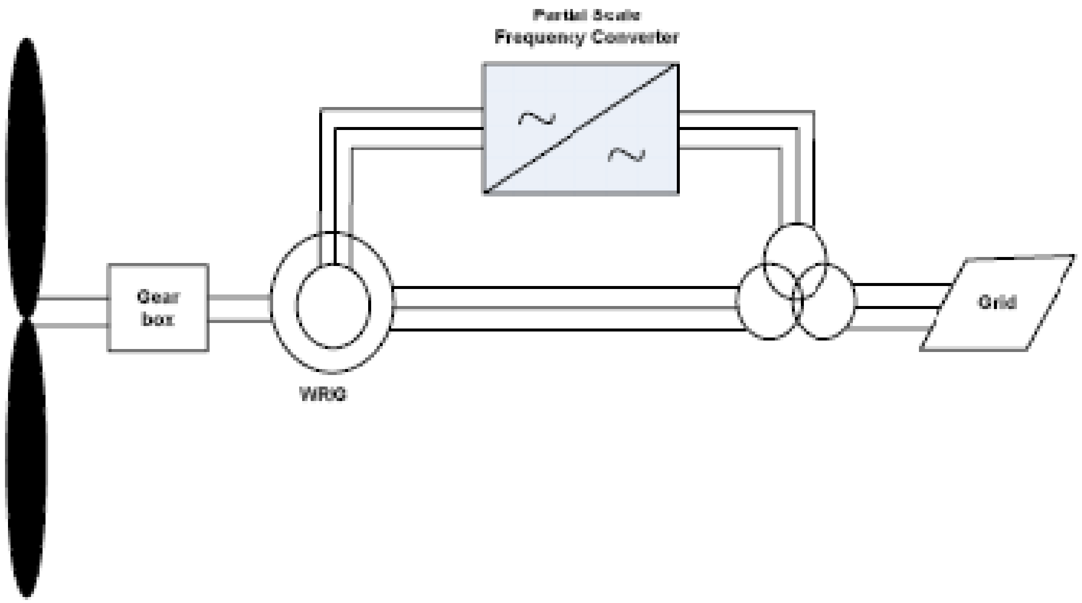


Source: Chalmers University

Wind turbine technology – Electrical concept

Doubly fed induction generator (DFIG)

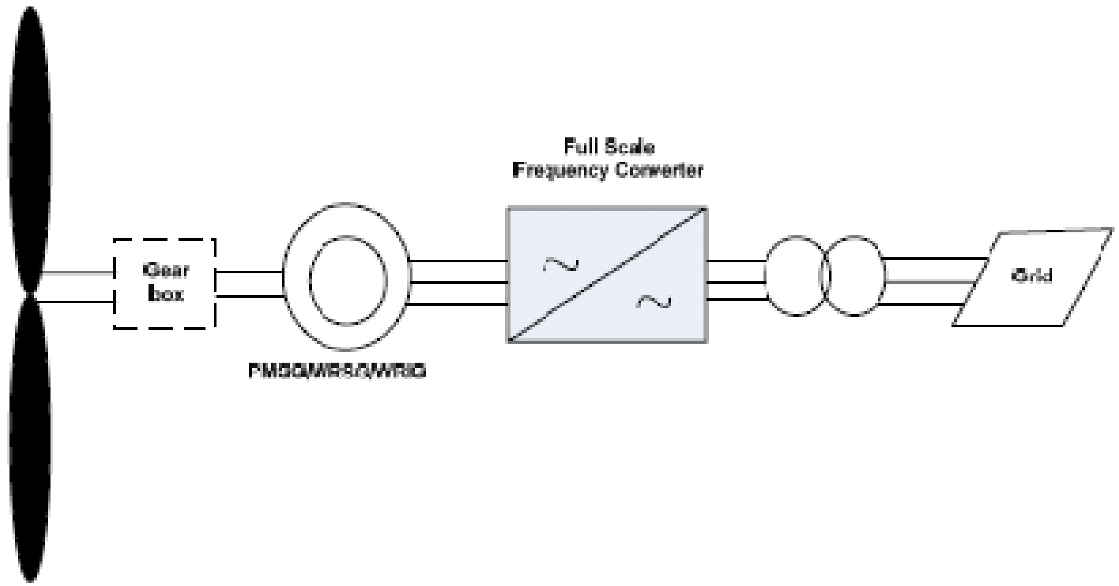
- **DFIG or variable speed with partial scale frequency (usually around 30% of rated power) converter was a successful development of above concepts allowing bigger ranges of rotational speed**
- **Frequency converter performs the reactive power control (possible therefore up to its rated power) and the soft start of the system**
- **It ensures a wider range of dynamic speed control and change by controlling the rotating field of the generator rotor**
- **A gearbox steps up the speed of the rotor for the generator**



Source: Chalmers University

Wind turbine technology – Electrical concept

Concept of a variable speed wind turbine with full scale converter



Source: Chalmers University

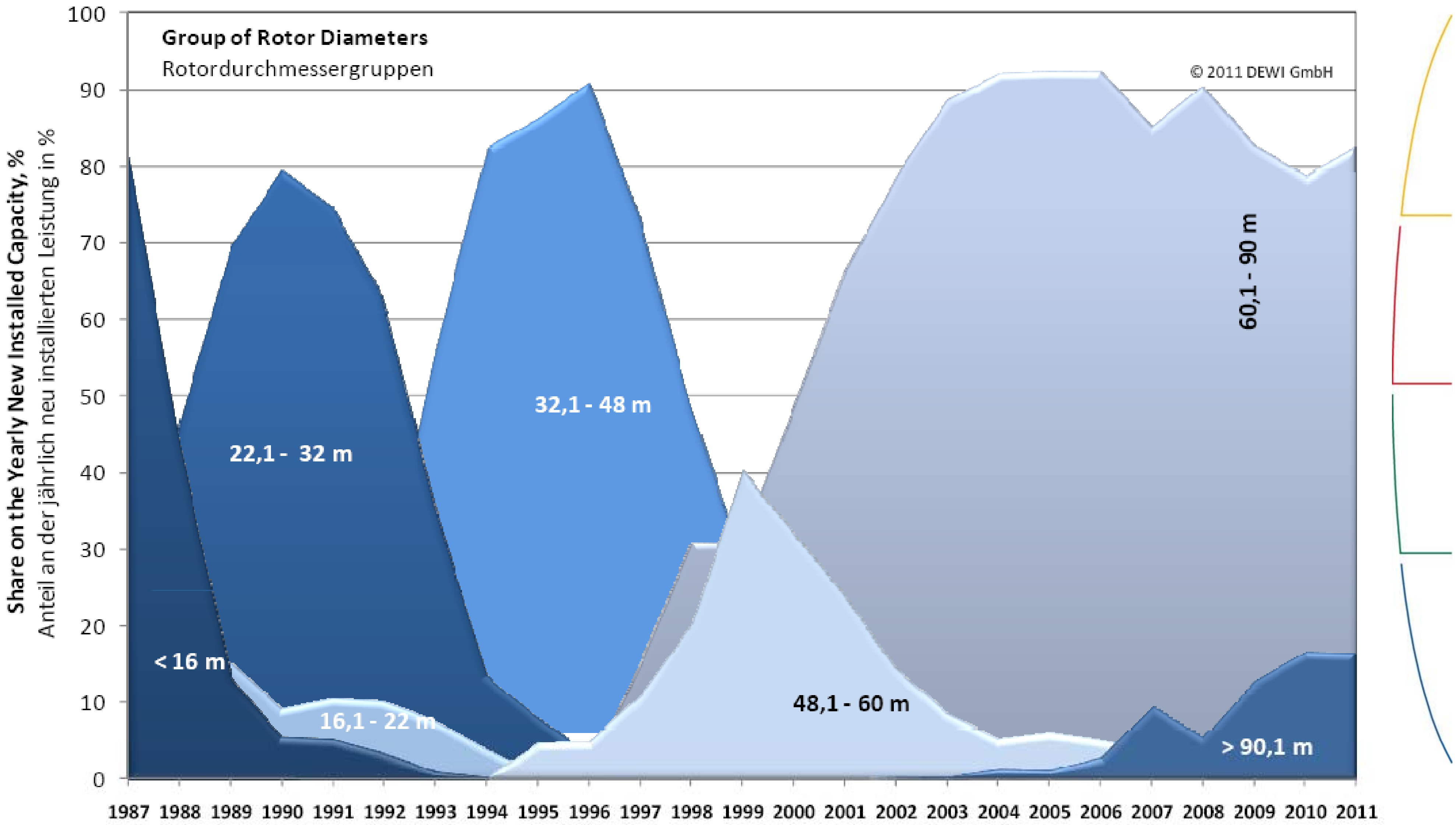
- is the most modern of the concepts where a full scale powerconverter (rated power equal to rated power of generator) stands between the generator and the grid
- Converter therefore ensures full reactive power control and allows additional functionality in active power control (gradient, maximum power) and delivers high electrical quality to the grid regardless of the speed of the generator and its behavior
- Different generator types can be used in this concept such as permanent magnet synchronous generator or wound rotor synchronous generator and sometime as a ring generator where the gearbox can be excluded giving the direct drive wind turbine

Technology and Type Groups of installed WTGS 2009

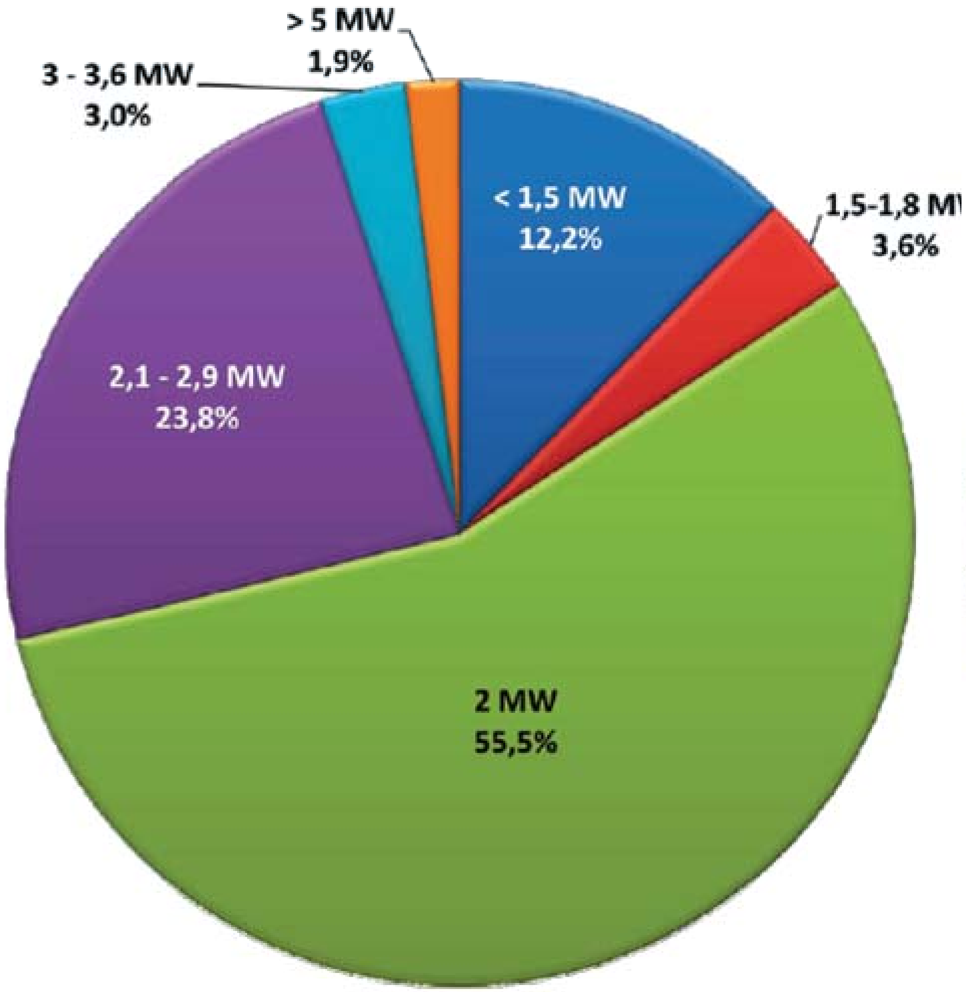
Rotordurchmesser ***rotor diameter***	**25 - 45 m**	**45,1 - 64 m**	**64,1 - 80 m**	**> 80 m**
getriebelos *gearboxless*	3	103	220	277
mit Getriebe *gearbox*	0	10	40	299
Pitch *pitch*	3	113	260	575
Stall *stall*	0	0	0	0
Aktive-Stall *active-stall*	0	0	0	1
1 feste Drehzahl *1 fixed rotor speed*	0	0	0	0
2 feste Drehzahlen *2 fixed rotor speeds*	0	0	0	1
variable Drehzahl *variable speed*	3	113	260	575
Anzahl der WEA *Number of the WT*	3	113	260	576

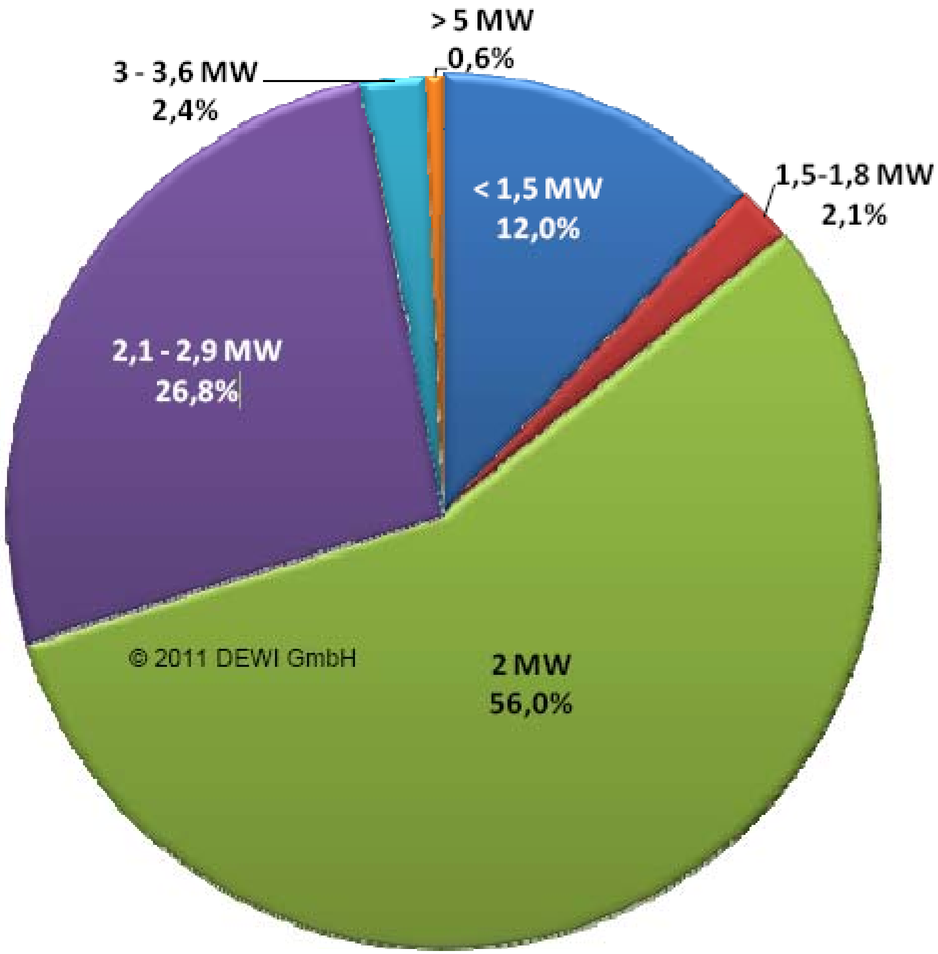
Source: DEWI 2009

Shares of different Unit Sizes in the Annually Installed Power (Germany)



Share of individual WTGS size classes newly installed WTGS





Contents of the presentation

Project development

During the development phase of a wind project concepts for the following areas / components of a wind farm will be developed and outlined:

- Location and resulting restrictions from
  - Ownership of land plots
  - Accessability
  - Environmental issues (noise, shadow, impacts during construction)
- Wind resource and prospected electricity generation
- Wind turbine selection and suitability
- Park layout, micrositing (turbine location)
- Access roads
- Grid connection and electrical design of wind park
- Wind turbine erection (availability of equipment)

The Process of Wind Power Project Development

Development Phase	Results / Deliverable	Duration
Prospecting	Site identified, land rights clarified	1-4 months
Pre-feasibility	Mesoscale wind field modelling, wind farm in principle feasible	3 months
Measurement	Wind data	12 months
Wind study	Energy yield assessment and IEC wind class	1 – 2 months
Turbine selection, optimization	Micrositing, turbine selected, optimization	1 month
Project design	Feasibility study for permit application	3-4 months
Permitting	Building Permit obtained	3-6 months
Project implementation	Procurement, contract award and construction	1-2 years

Project development – Location

Locate potentially interesting locations for wind project development on a macro level:

- **From country wind resources maps spot areas with promising average wind speeds**
- **Check the grid availability in that region and its capacity to intake additional power generation**
- **Check restriction areas such as protected areas and national parks and airports and their surroundings, residential and touristic areas etc.**
- **Check land situation, owner and readiness for leasing**
- **Check road availability**
- **Move the planning to the micro level**

Project development – Wind resource assessment

Standard wind resource assessment for wind energy:

1. **Nearby measurement or mesoscale simulation data for prefeasibility study**
2. **On-site wind speed measurement for at least 12 months at different heights, temperature measurement**
3. **Long term correlation with nearby weather stations**
4. **Extreme wind conditions calculations**
5. **Turbulence assessment**

Measurement and wind regime study

A study following industry standards has to be made by a renowned consultant in the field encompassing all of the above.

Standards: - IEC 61400-12
- MEASNET recommendations

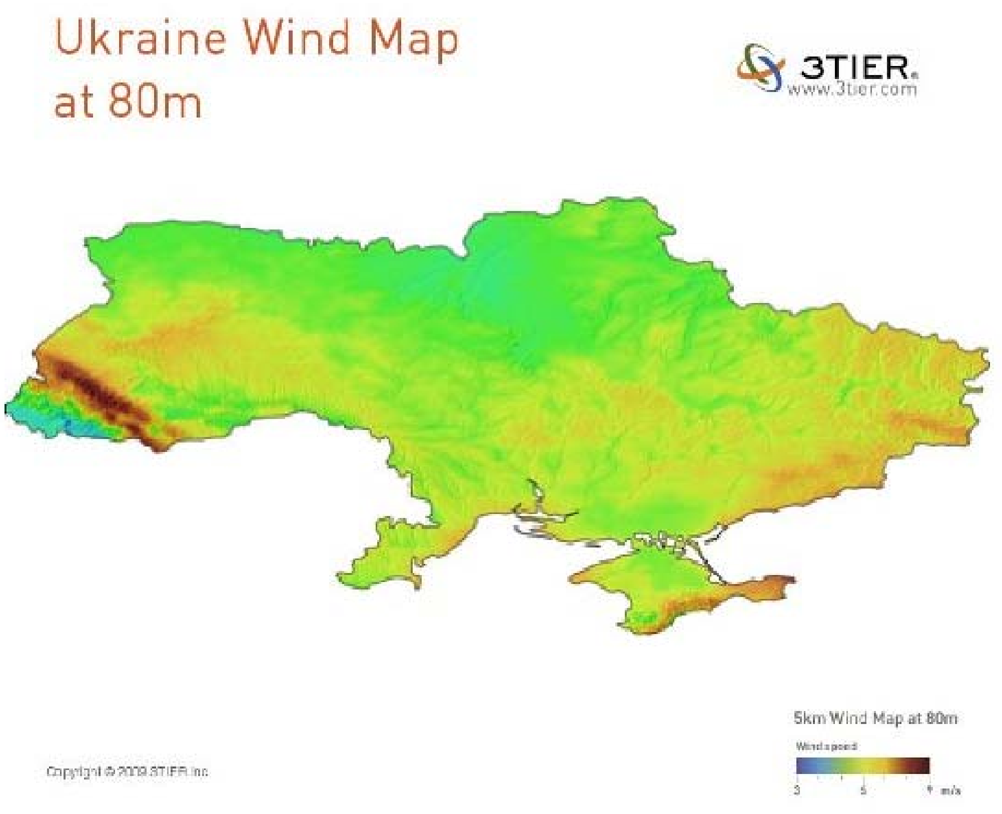
Project development – Mesoscale modeling

Mesoscale modeling uses satellite data describing the geostrophic wind (upper wind) and simulates wind conditions near the earth‘s surface for wind energy application for example.

The model takes into account the cover of the earth’s surface and using equation of conversation of mass and energy and fluid dynamic equations.

Specialized companies produced wind resources map for most of the countries and can reproduce detailed wind conditions for specific locations.

Mesoscale data do not replace wind measurement but forms a good basis for pre-feasibility studies.

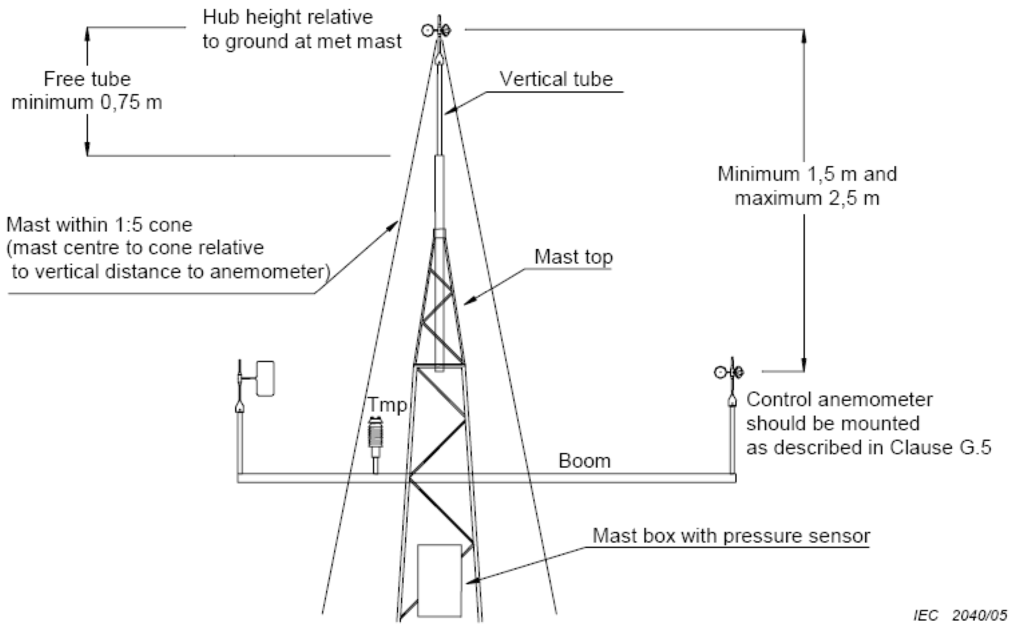


Source: 3 Tier / EBRD

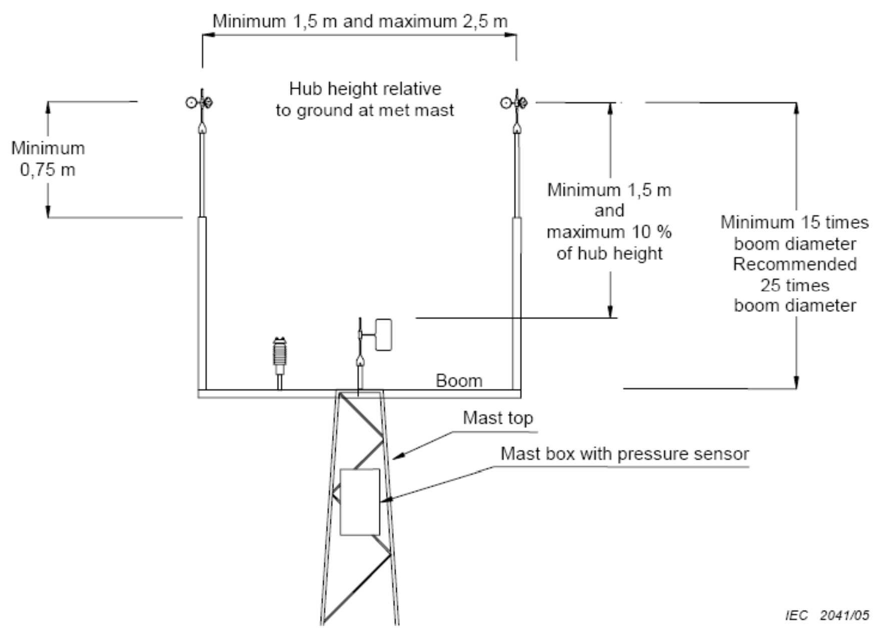
Project development – Wind measurement

On-site wind measurement is necessary for at least 12 months

- **Calibrated sensors on different heights**
- **No obstruction**
- **Measurement according to IEC 61400-12**



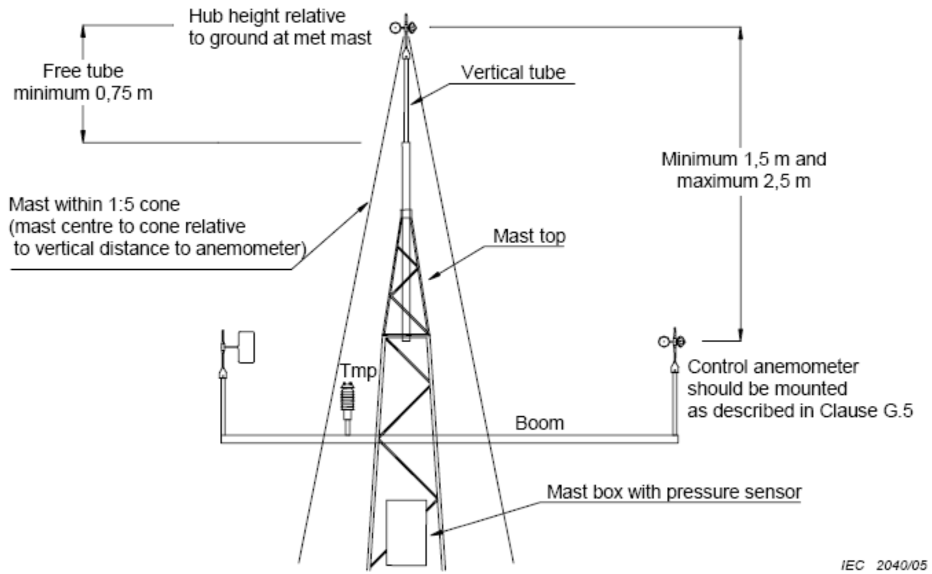
Preferred measurement constellation – IEC 61400-12



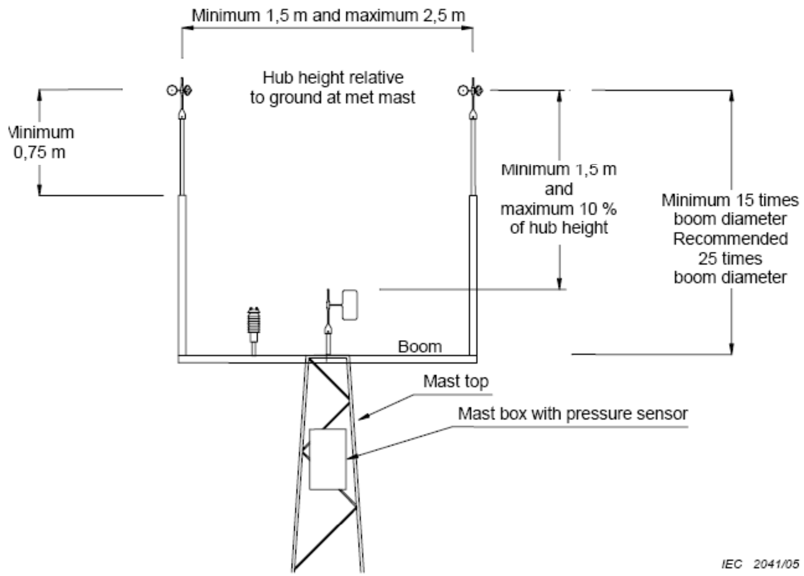
Alternative measurement constellation – IEC 61400-12

Project development – Wind measurement

Mounting of other meteorological instruments



Example of a top-mounted anemometer and mounting of control anemometer, wind vane and other sensors on a boom – IEC 61400-12



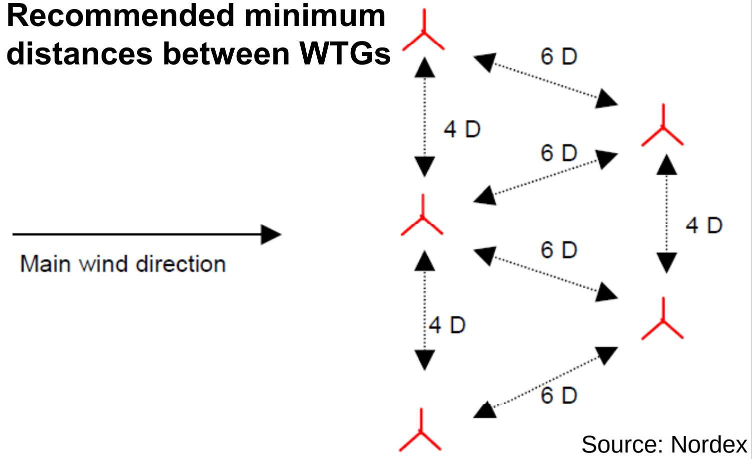
Example of top-mounted primary and control anemometers positioned side-by-side, wind vane and other instruments on the boom – IEC 61400-12

Project development – Wind farm layout

The wind farm layout is designed and optimized with following considerations:

- **Minimum distance between turbines (to and WTG induced turbulences)**
  A commonly applied rule of thumb suggests a minimum distance of 5 rotor diameter in main wind direction and 3 rotor diameter perpendicular to main wind direction.
- **Maximized energy production**
- **Roads and accessibility**
- **Consideration for electrical interconnection and to grid**
- **Minimize shadow and noise on sensitive areas**
- **Land availability and permits**

Recommended minimum distances between WTGs



Source: Nordex

Source: EWEA

Project development – Turbine selection

Wind Study

Restrictions (max. height, boundaries) determine initial layout

IEC class
- Average wind speed
- Extreme wind speed
- Turbulence

Commercial
- Market availability
- Delivery time
- Contract conditions
- Price

- Maximizing production
- Minimizing costs
- Restrictions: environmental aspects and land availability
- Shadow and noise

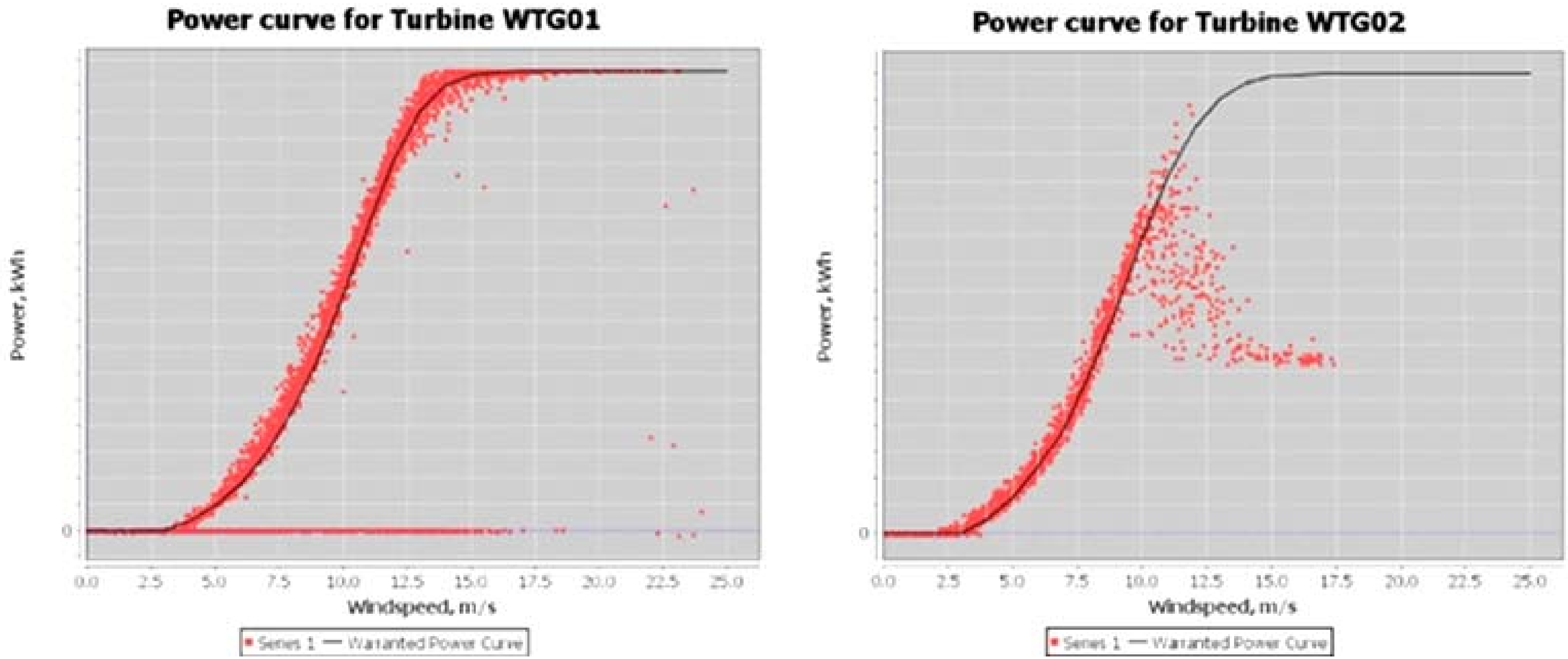
Wind turbine selection (~2-4 models)

Micrositing for selected wind turbines including
- **Layout optimization**
- **Update of energy yield calculation (complete energy yield assessment)**

Power Curve

Wind turbine power curve correlates the wind speed with the energy output of the wind turbine generator

- **Measured according to IEC 61400-1**
- **Calculated power curve for new models, prototypes**



Source: www.renewableenergyworld.com

Energy Yield Assessment - Uncertainties

A state of the art energy yield assessment should contain a complete uncertainty analysis. (ISO Guide 98, IEC 61400-12, recommendations of German FGW Fördergesellschaft Windenergie)

Examplary results of an uncertainty assessment

Issue	Uncertainty (%)
Wind measurement, anemometer calibration and data acquisition	4
Long term stability and representativity of met station data	3
Referencing to the long term - seasonal bias	0
Referencing to the long term - method, scatter, wind statistics and discretisation / binning	4
Transfer from measuring heights to hub heights	6
Transfer to the location of the planned turbines (terrain model, wind model and coordinate transformations	6-8
Power curves	3-5
Wake losses	2
Air density	1
Availability	1,5-3
Icing	0,5
Transmission losses, grid downtime and substation downtime	1,5
Total	**12,4-13,1**

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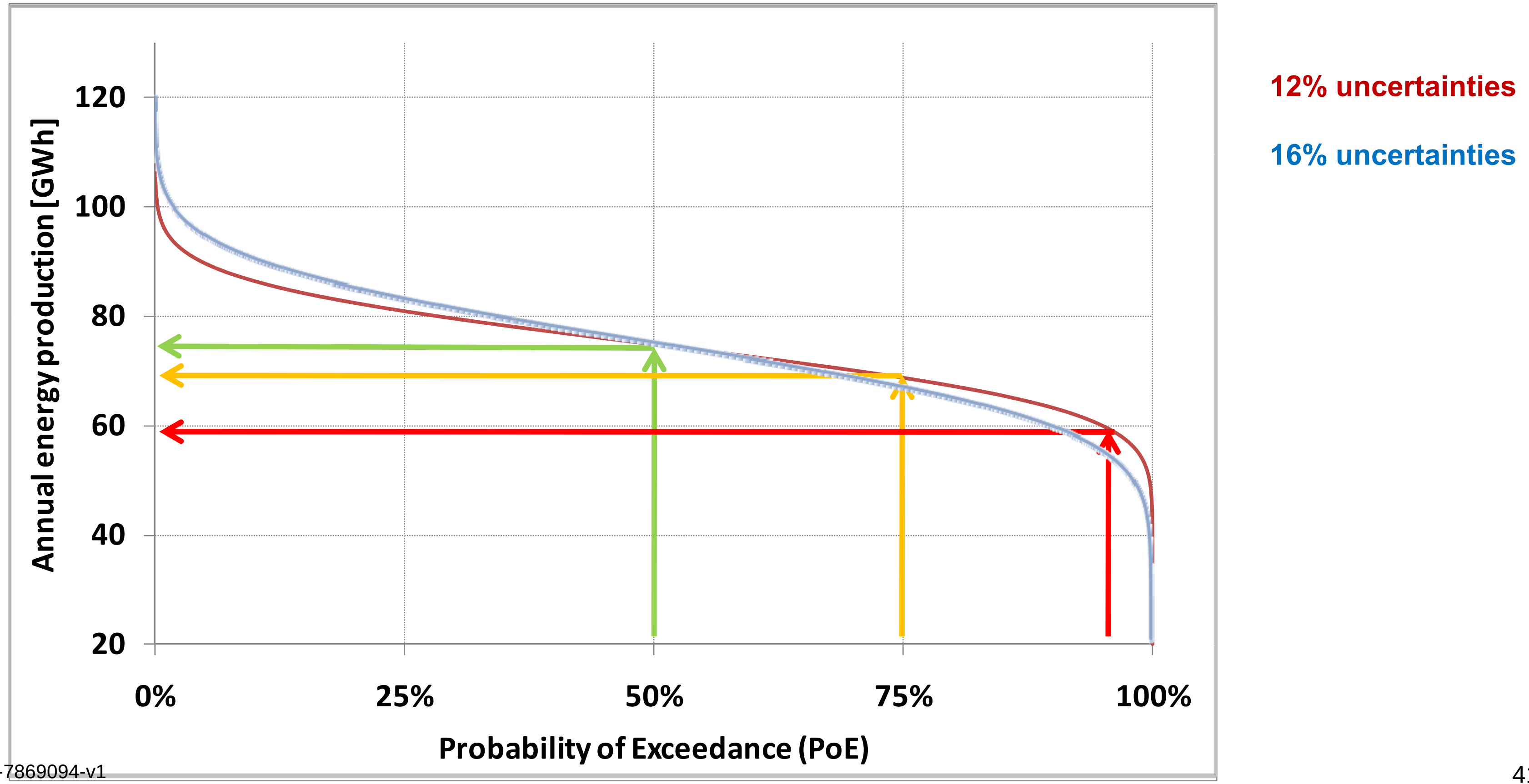
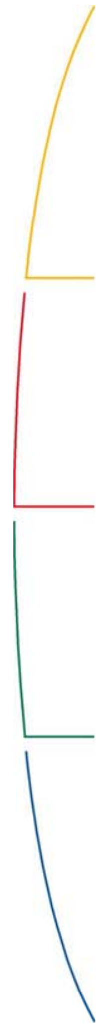
Energy Yield Assessment – Probability of Exceedance

Probability density function is used for calculation of the probability of exceedance (PoE)

- **Total uncertainties X annual energy yield = Standard Deviation**
- **Usual cases are P50 (50% probability), P75 and P90 (90% probability, downside case used by most banks)**



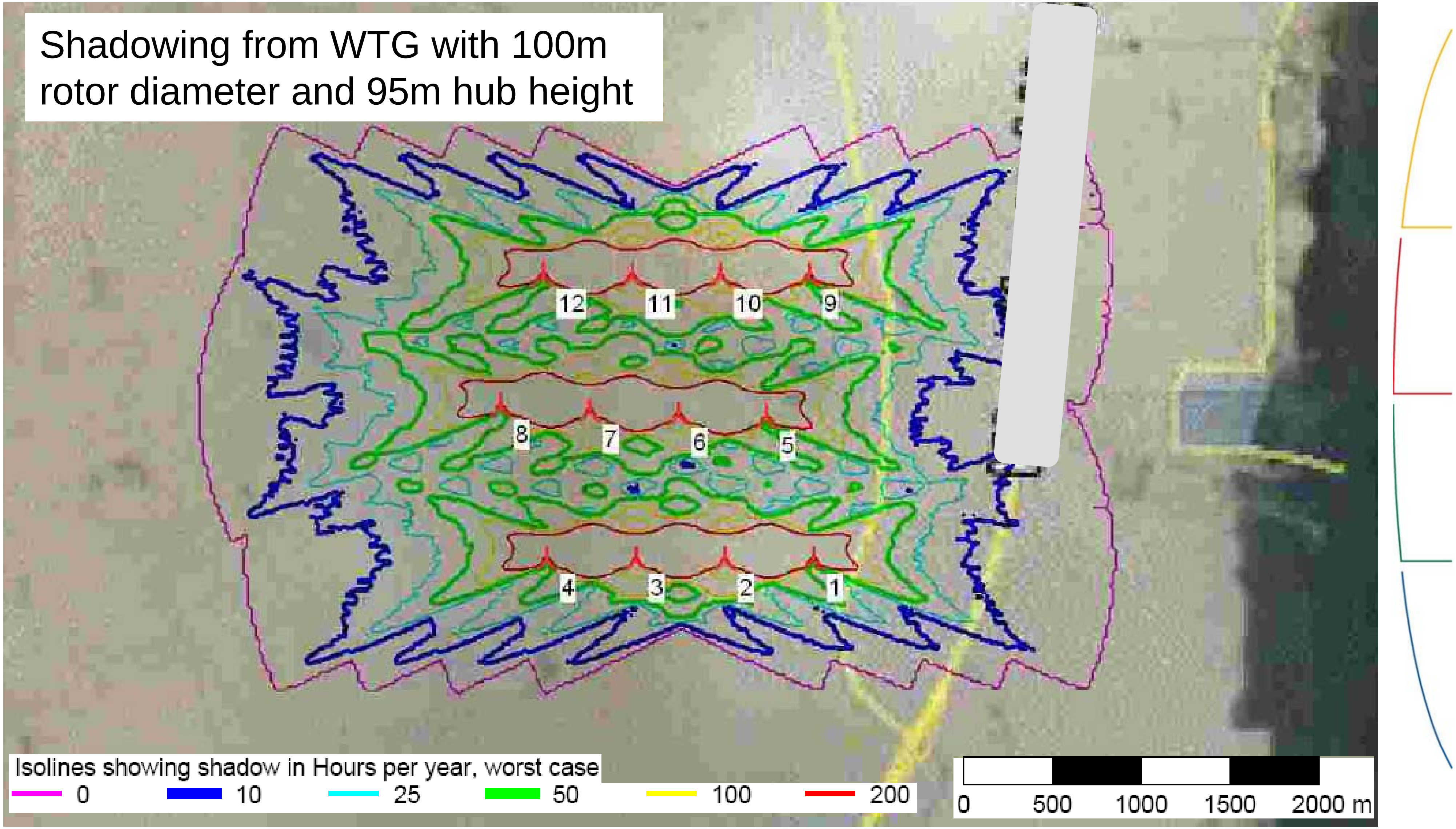


IEC class

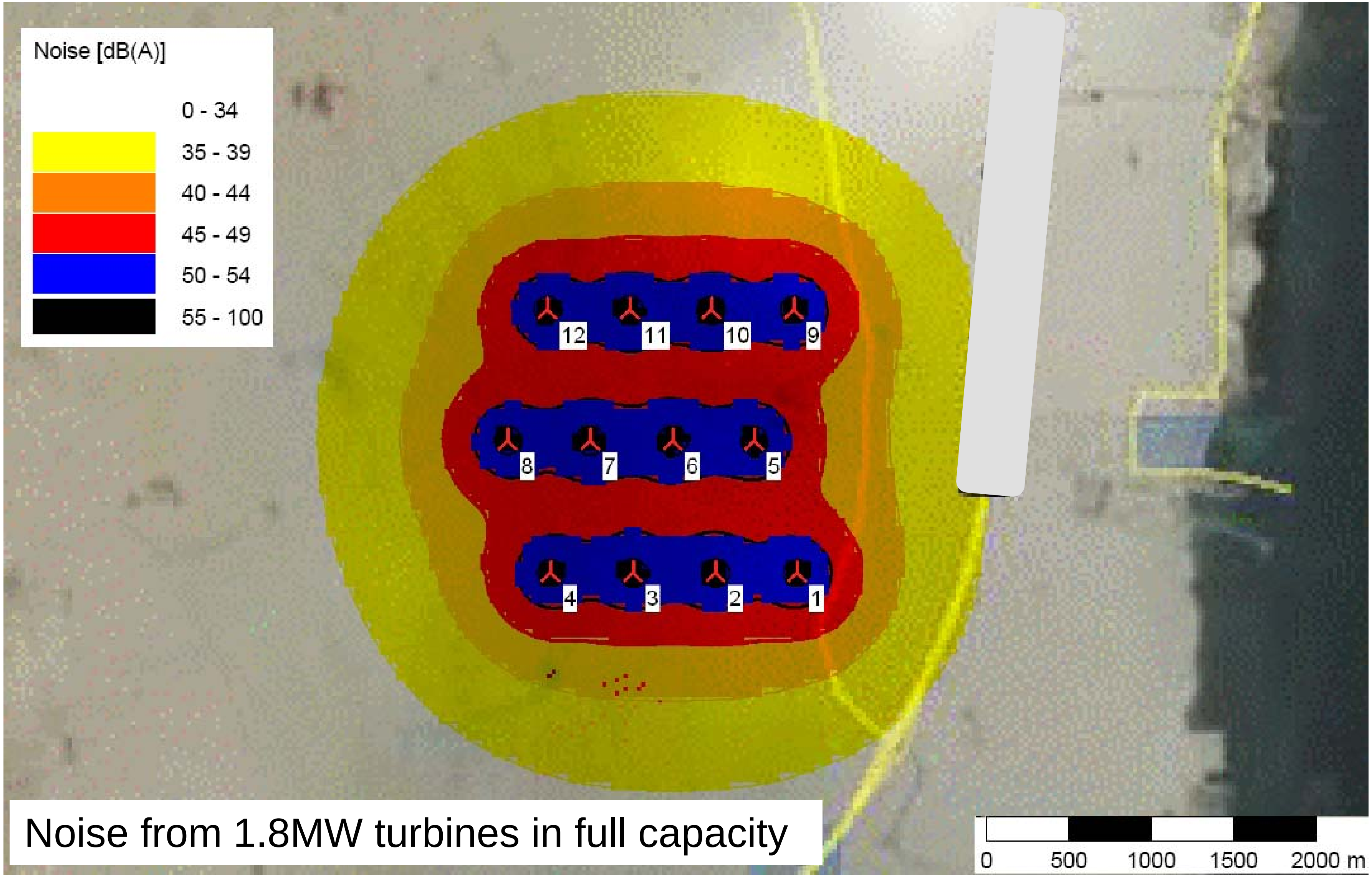
Definition of IEC wind class according to IEC 61400-12:

WTG class	**I**	**II**	**III**	**IV**
Reference wind speed v_{ref} [m/s]	50	42,5	37,5	30
Annual average wind speed v_{ave} [m/s]	10	8,5	7,5	6
50-year return gust speed	70	59,5	52,5	42
1-year return gust speed	52,5	44,6	39,4	31,5
Turbulence intensity I_{15}, class A	18%			
Turbulence intensity I_{15}, class B	16%			

Project development - Shadow

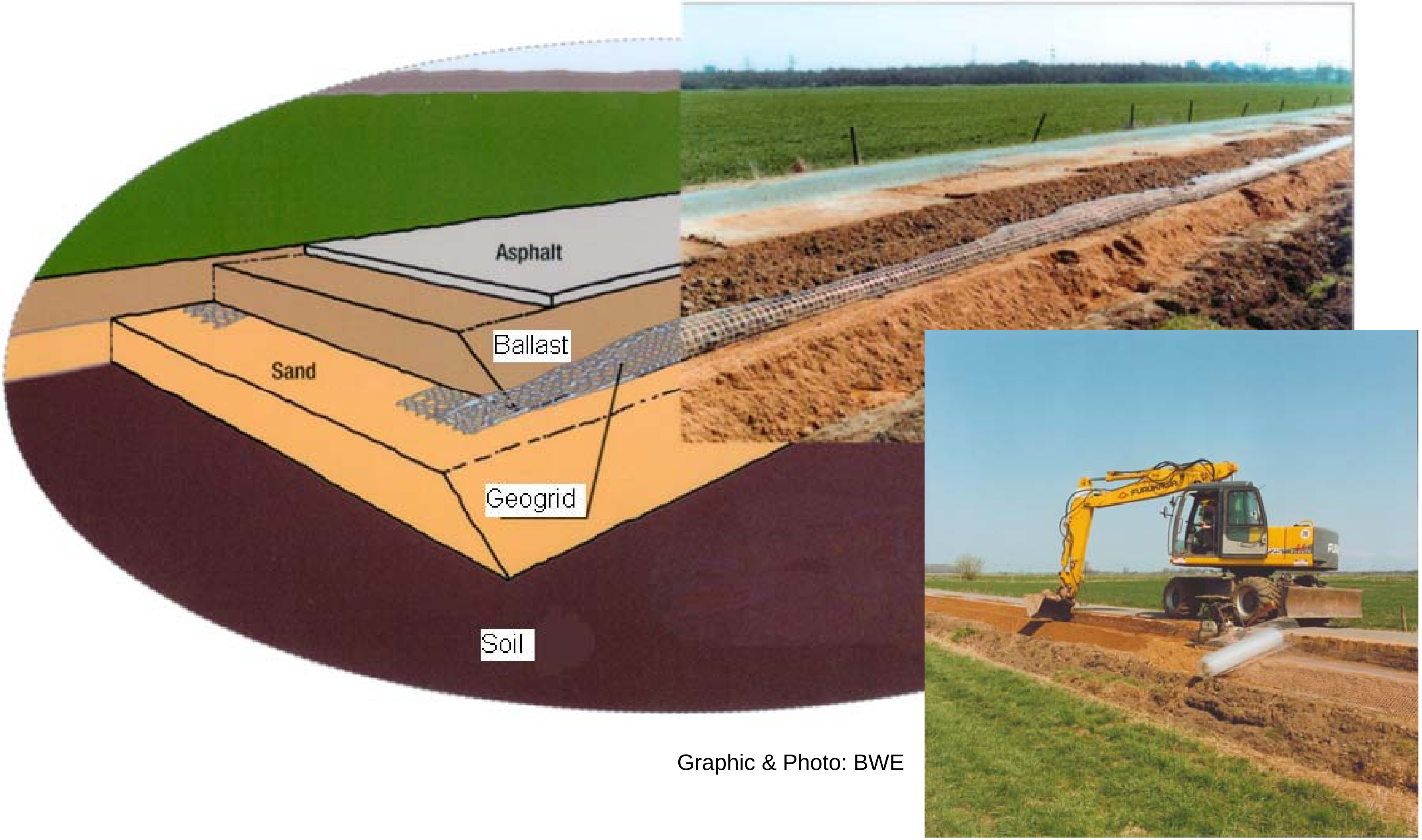


Project development - Noise



Noise from 1.8MW turbines in full capacity

Project development – Access roads



Graphic & Photo: BWE

Project development – Access roads

Photos by Paul Anderson

Minimum road requirements are usually specified by wind turbine manufacturers in what concerns:

- **Minimum width on straight roads and turns**
- **Minimum turn inner and outer radius**
- **Clearances around the road**
- **Requirements for axle load**
- **Requirements for areas for cranes and storage**

Project development – Electrical design

Wind turbines are usually interconnected on the MV level and then connected to a central wind farm substation.

Most wind turbines produce electricity with 690V and have a step-up transformer up to the medium voltage level.

The substation can then step the voltage to the high level according to the grid connection point.

Cables are to be optimized to minimize energy losses on the one hand and keep the costs down on the other.

Wind turbines are usually connected in strings with up to 6 turbines.

Turbine base and transformer (Photo: P. Anderson)

Construction Phase – Electrical Installation

Photos: BWE

Construction Phase – Foundation

Photos: BWE

Project development – Erection

Photos: BWE

Project development – Erection

Photos: DOE/NREL, Spink, Todd

Project development – Erection

Photo: Nordex

Photo by Walter Baxter

Photo: DOE/NREL, Spink, Todd

Construction Phase - Inauguration

Photo: BWE

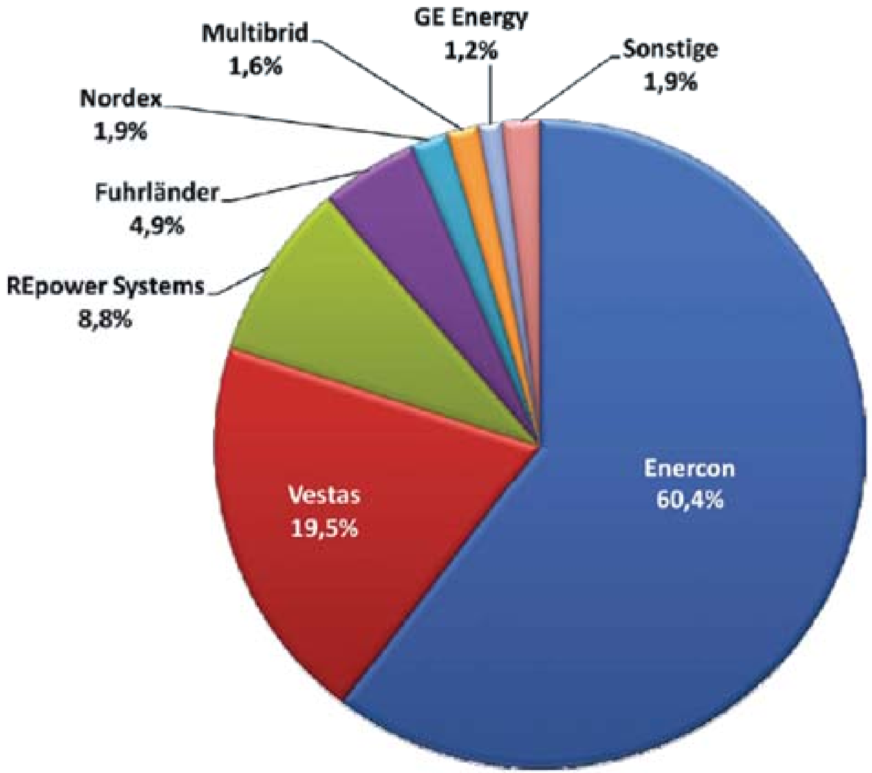
Current Market Conditions

- **Delivery and Erection Time**
  - **5-8 months for WTGs only depending on the single WTG manufacturer**
  - **4 weeks per foundation + 4 weeks concrete curing**
  - **1 week per WTG erection**

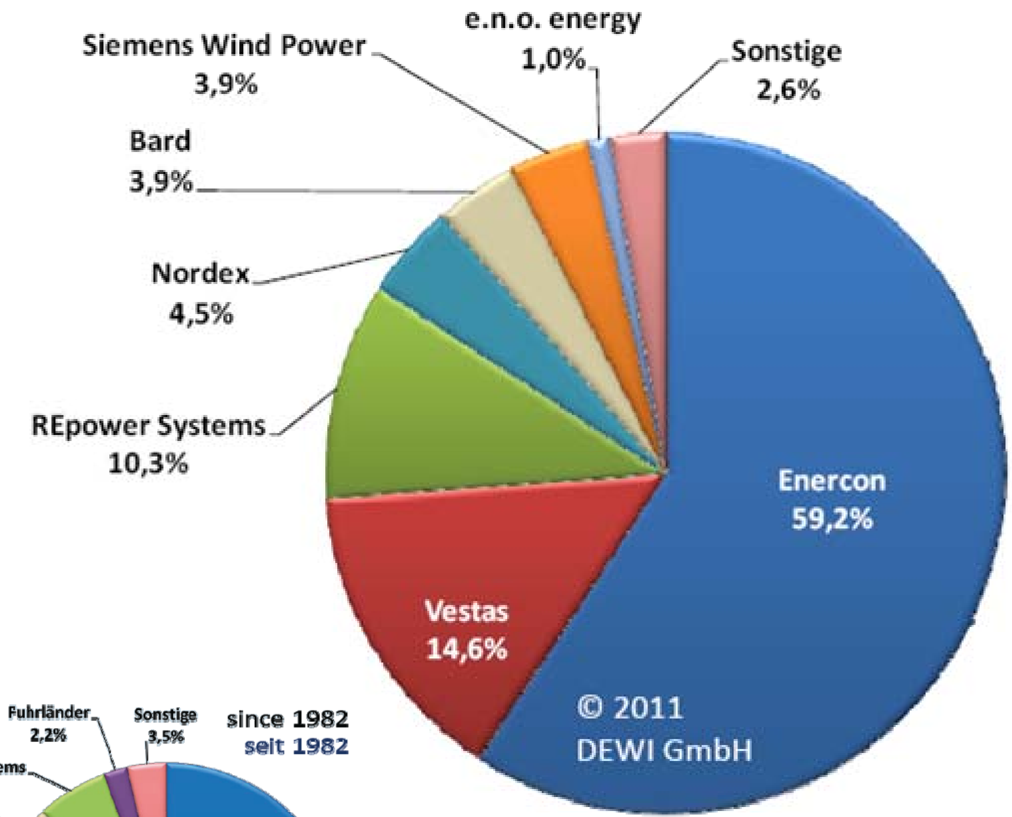
- **Commercial conditions**
  - **down payment 10-15% is usually accepted**
  - **Warranty and defects liability period for turbine 18-30 months (can be prolonged by Service Agreement)**
  - **Liability of Supply Contract 20-30% of contract value**
  - **Liability for availability under the Service Agreement max. ~5-10% of annual revenue**

- **Pricing**
  - **Recent contract prices range around 1000-1100 €/kW for the WEC- only**
  - **+10-20% for transport and erection**

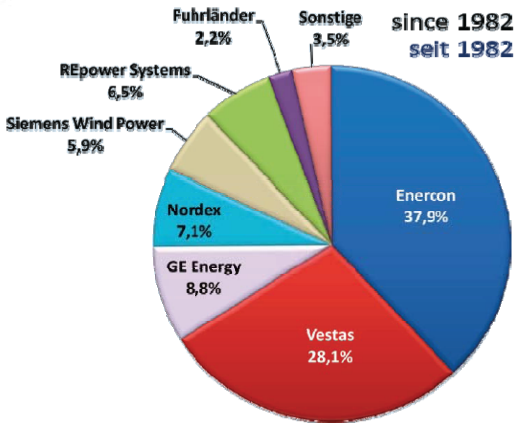
Suppliers in the German Market of Installed Rated Power



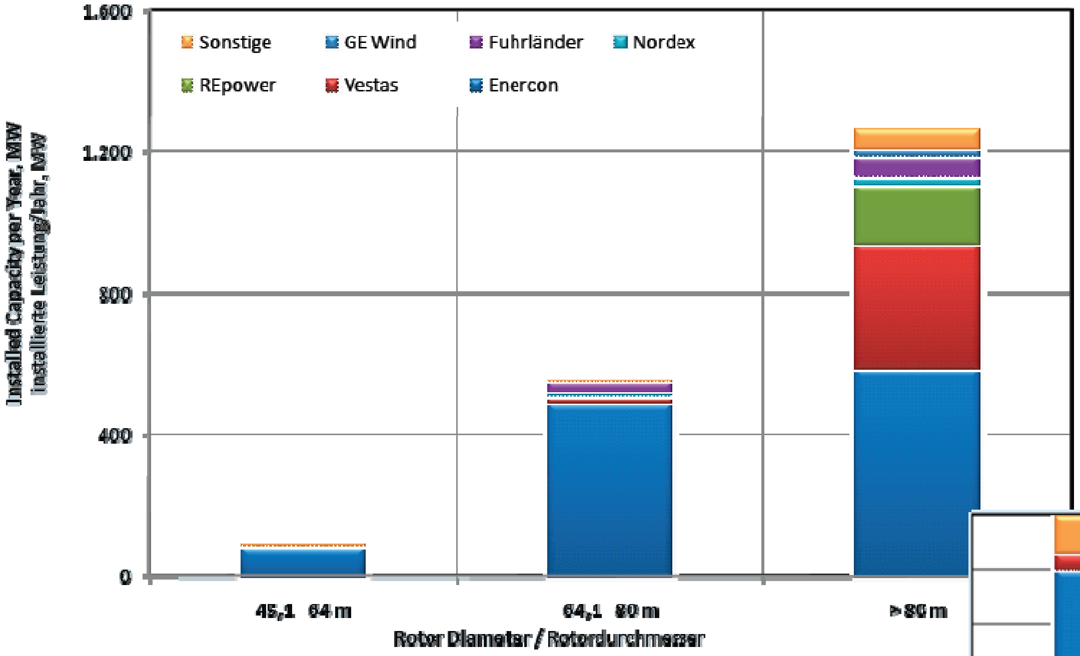
2009

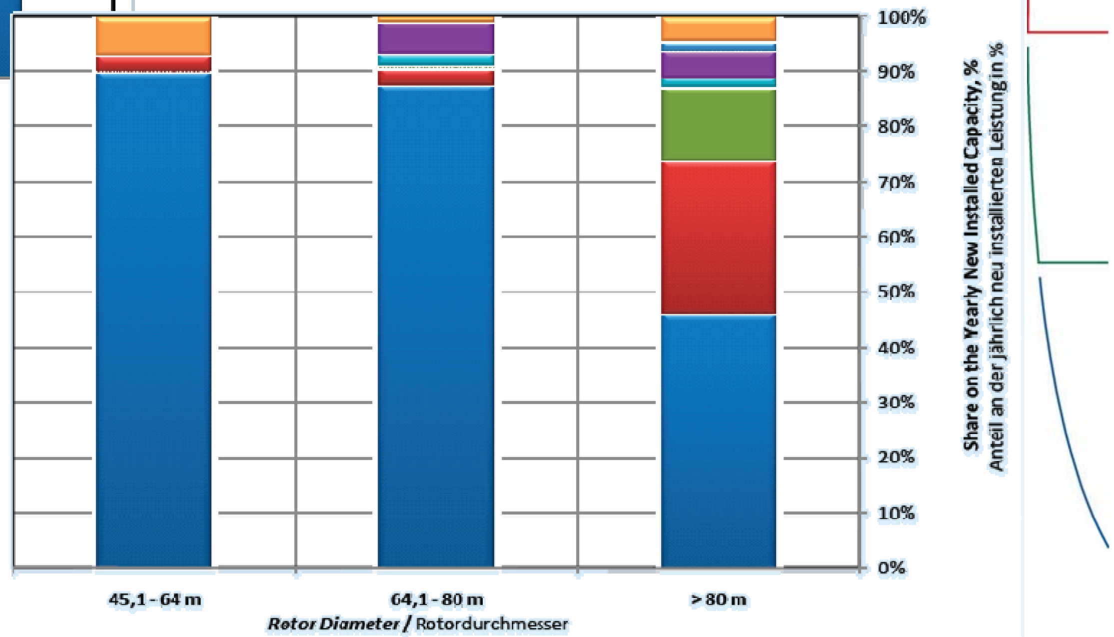


2010



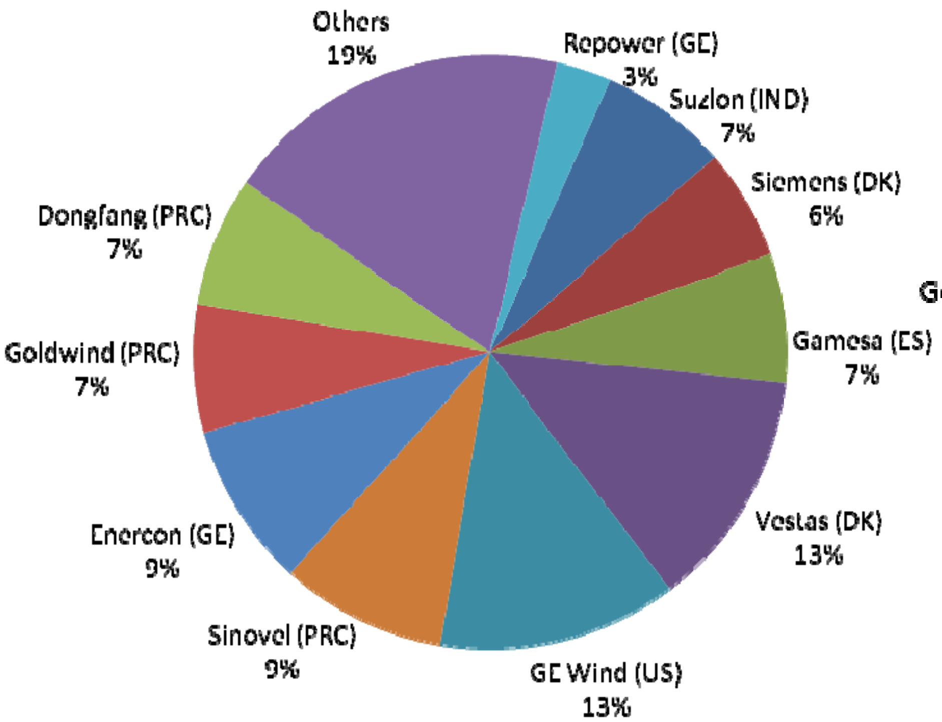
Suppliers' installed capacity in Germany in 2009 in MW



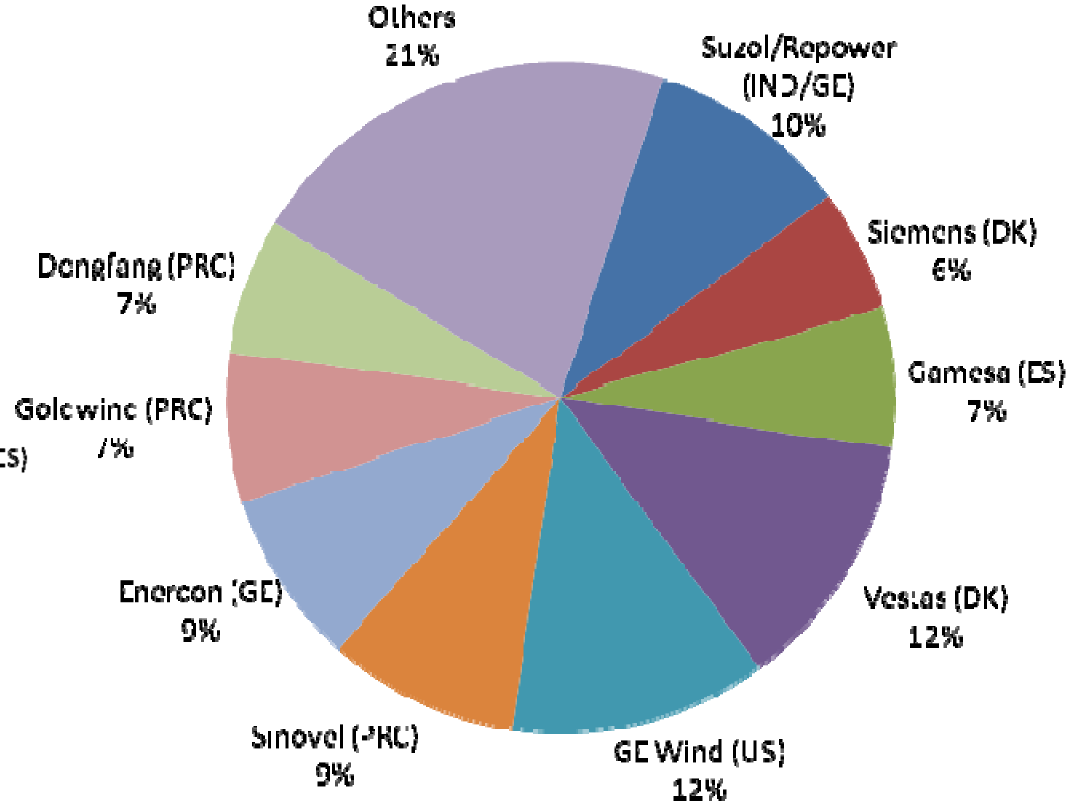


Source: BWE 2009

Shares of Suppliers of WTG in World Market 2009 and 2010



2009



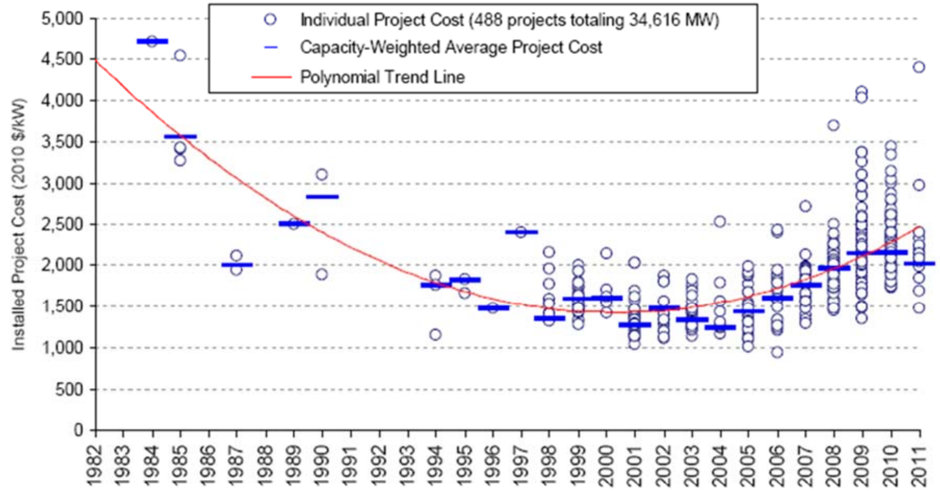
2010

eigene Darstellung, basierend auf DEWI (2011)

Wind energy costs – Project costs

The economics of owning a wind energy converter depend on many factors, including wind speeds, the size and cost of the wind energy converter, interest rates, taxes, and electricity prices.

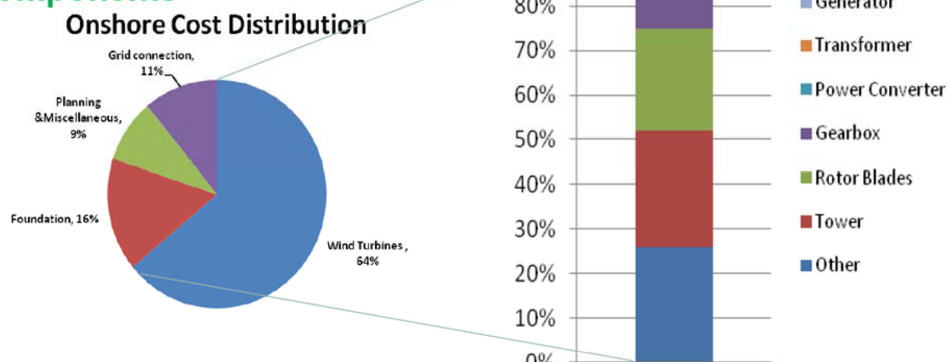
Investment costs plays a major role in defining the economics of a project and they come mostly from the wind turbine price.



Typical wind project cost structure

Turbine 65% of cost

Tower and blade are key cost components

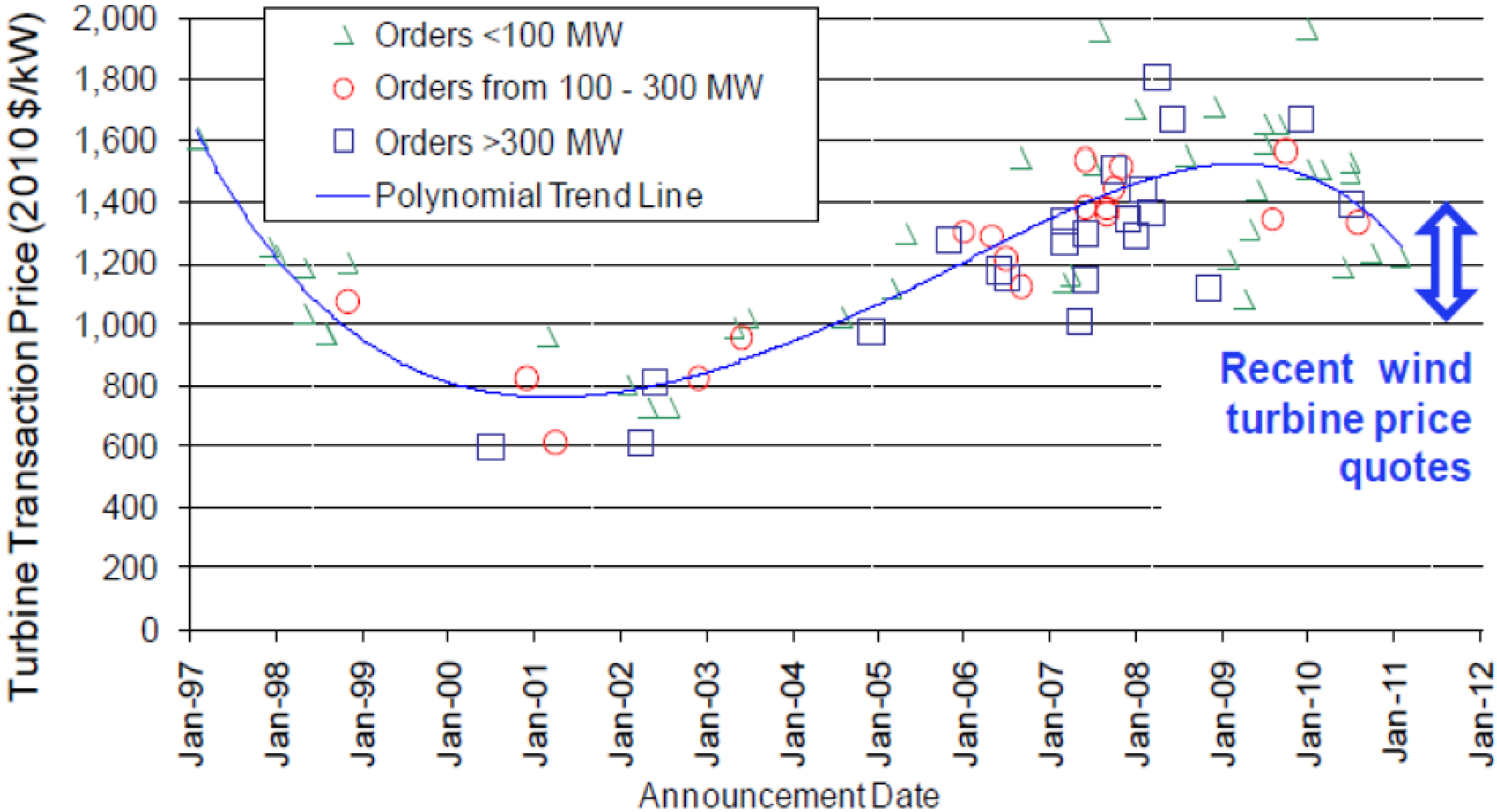


Project investment cost 2010:
Onshore USD 2 000/kW
Offshore USD 4 000/kW

Source: DOE , from Berkeley Lab

Wind energy costs – Turbine costs

Wind turbine costs in the US



Source: DOE , from Berkeley Lab

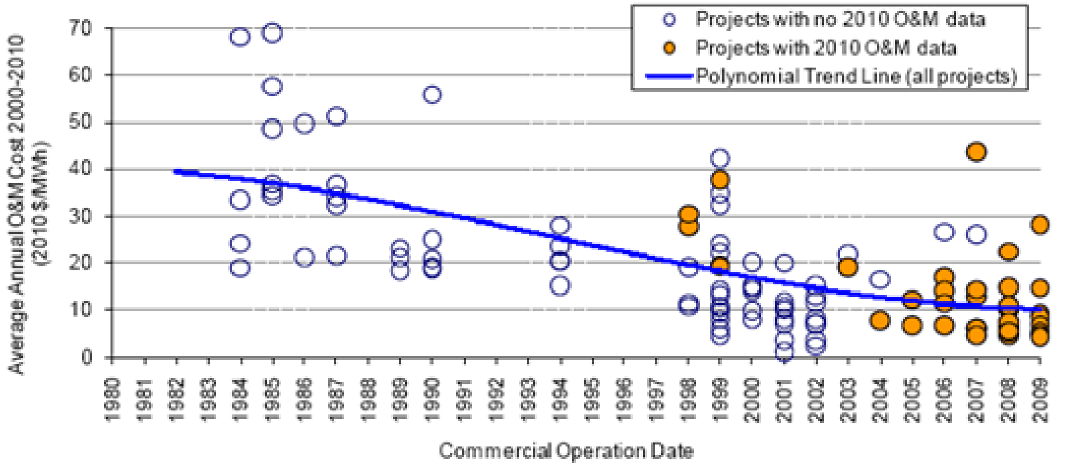
Wind energy costs – O&M

Operation and maintenance costs constitute a main share of the costs of a wind energy project next to investment cost. They can be crucial for the economical viability of a project.

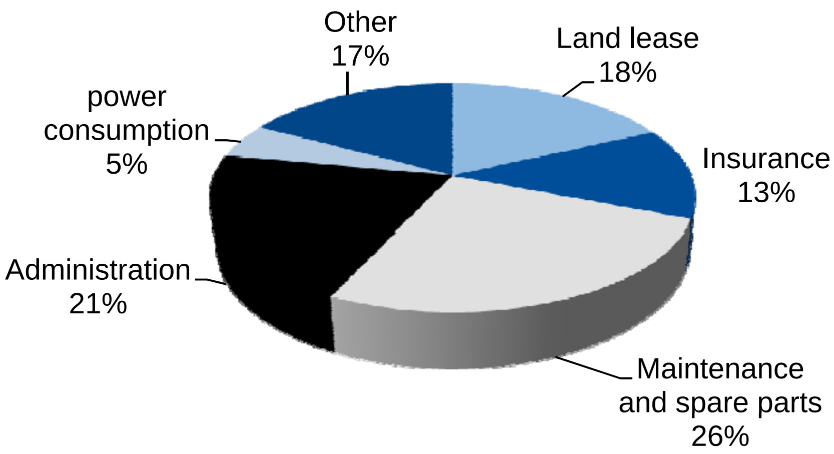
Service agreements can be signed with wind turbine manufacturers at a predefined price and for prolonged periods to minimize the risks of the project.

In addition to the standard service comes insurance, administration and land lease costs.

Repair costs can be minimized by the careful design and turbine selection of the project.



Source: DOE , from Berkeley Lab

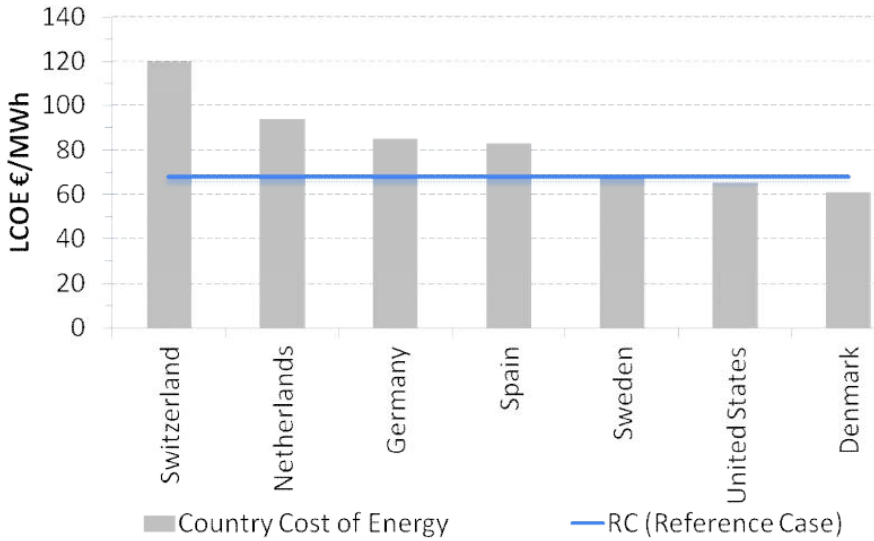


Source: DEWI

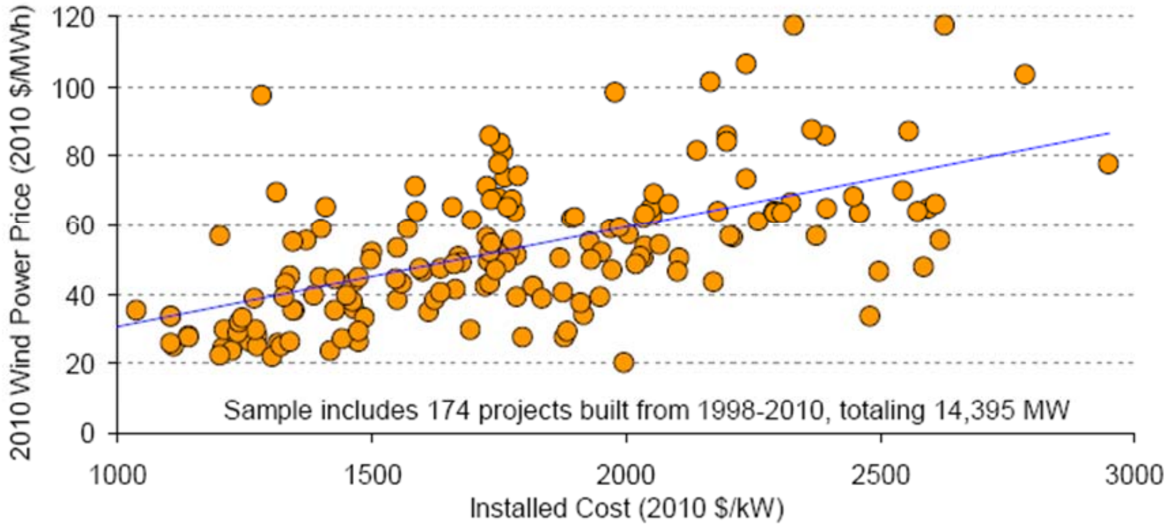
Wind energy costs – Energy cost

Levelized cost of energy is calculated taking into account investment and operation costs of the project as well as its energy production.

It can be compared to the selling price per kWh for the assessment of the viability of a project.



Source: IEA



Source: DOE , from Berkeley Lab

Contents of the presentation

EPC-turnkey Contract vs. Multi-Lot Contract

- **EPC – turnkey contract**
  - **WT manufacturer takes responsibility for civil and electrical lots**
  - **depends on the willingness of the manufacturers, however it is usually not the preferred option and decision for EPC solution will reduce selection of available suppliers**
  - **includes high overheads**
  - **preferred by banks as there are less interfaces and a clear risk allocation**

- **A multi-lot approach usually comprises 2-3 Lots an hence contracts:**
  - **WT, Civil and Electrical**
  - **alternatively WT and BOP Lots**
  - **Interfaces among the lots are suggested to be verified and discussed during meetings with Vendors**
  - **There are no significant differences between the WT models on battery limits.**
  - **Optimization of equipment quality and costs by developer is possible**

Procurement Procedure

Suitable Models → **First Contact with Manufacturers** → **Preparation of tender docs and distribution of ITT** → **Bid Evaluation and Contract Negotiations**

Suitable Models

according to general screening criteria

- results of layout optimization
- WECs complying with permit requirements
- generally suitable, recommendable WECs

First Contact with Manufacturers

1) Availability of model
2) Scope of Works
3) Delivery time
4) Time for proposal preparation

1st Shortlisting

Preparation of tender docs and distribution of ITT

Definition of

WEC S&E, Civil and Electrical Lot

[EPC Contract]

4-5 weeks

2-3 months

Receipt of tenders

Bid Evaluation and Contract Negotiations

Contract negotiated, ready for signature

→ Financial Close DD

2nd Shortlisting

Considerations for a Procurement Strategy

- **WT Model pre-selection**
  - Models shall be state of the art WT with proven technology and good track of references, best also in the region (bankable WTG model / manufacturer).
  - Type certificates as well as calculated and measured power curves shall be available.
- **Scope of Works / Contract structure**
  - WT manufacturers should be available for “supply and erection” contract.
  - WT Ex-works supply is in principle not recommended.
- **Time line**
  - For WT “supply and erection” some 4-5 weeks should be considered as reference time for the offer.
  - Time for offer preparation in case of EPC contract can be anticipated to be in the order of 2-3 months, with a typical offer validity of 4-5 weeks, a certain extension at the time of negotiations being reasonable to be envisaged.
- **Service contract**
  - WT manufacturer should be available for a long term (i.e. 5-9 years) service and maintenance concept and guaranteed availability (especially for project financed projects).

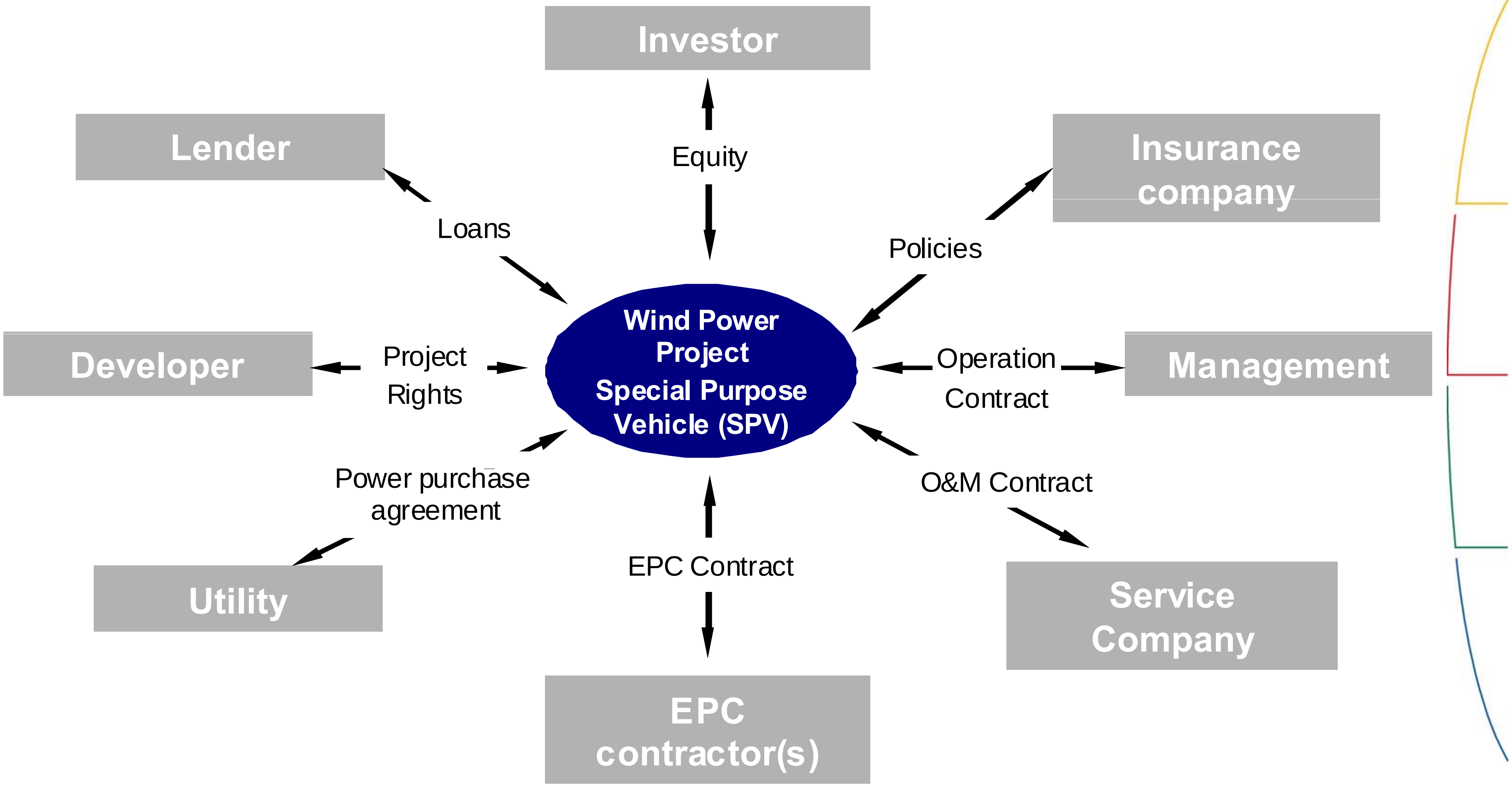
Evaluation Criteria

The following main criteria are suggested for the comparison of the WT manufacturers and its models:

- **Wind farm assessment and suitability for the site**
- **Reference list World, Europe and Ukraine**
- **Key Wind Turbine technical parameters, IEC class and certification status**
- **Current delivery time and conditions for advance booking**
- **Current Wind Turbine standard price and delivery**
- **Willingness for different contract type (EPC / supply & erect / ex-works)**
- **Standard commercial / contractual conditions**
- **Construction and commissioning standard schedule (shipping, erection etc.)**
- **Service structure in the region**
- **O&M service concept, pricing and guaranteed availability and duration**

Contents of the presentation

Project Constellation and Risks



Due Diligence - Typical Wind Project Risks from the Lender‘s Point of View

- **Average annual energy yield lower than predicted**
  - Review of wind measurements and long-term wind data assumptions
  - Review of the energy yield assessment as to the reliability of the input data, methods and results
  - Consideration of losses
  - Wake Effects, Wake Models
  - inter-annual variability, long-term correlation
- **Technical Design**
  - Evaluation of technical concept such as layout, grid connection, civil works
  - Review of the suitability of the wind turbines to the site (e.g. turbulence, max. wind speed, site complexity, soil conditions)
- **Permit approval risks**
  - Time schedule, duration of permits
  - Special conditions and their fulfillment
  - land-lease agreements, right-of-way, projects in competition
- **Environmental impacts**
  - Special conditions and their fulfillment
  - envisaged Natura 2000 areas
  - noise emissions
  - shadow flicker

Due Diligence - Typical Wind Project Risks from the Lender‘s Point of View

- **Cost overruns (construction, O&M),**
  - Review of cost estimates
  - consideration of contingencies
  - monitoring of budget and time schedule, project steering
- **Deviation from contracted technical performance**
  - Availability reduction
  - Power curve / performance
- **Time Scheduling**
- **Contracts / project agreements including mainly: EPC-Contract, grid connection agreement, PPA, O&M, technical and risk allocation to the project parties / Contracts**
  - Check of adequacy and appropriateness as well as negotiation of the technical warranties and its verification procedures (e.g. performance test, availability, technical characteristics)
  - Liquidated Damages, penalties
  - Review of Project Insurances
- **O&M / Maintenance concept**
  - Supply with spare parts, duration
  - Experience of contractor,
  - Local representation
  - Unscheduled repairs

Due Diligence - Typical Wind Project Risks from the Lender‘s Point of View

- **Project structure**
  - Assessment of project structure and obligations of project parties, transaction structure
  - administrative operation
  - Evaluation of the qualification of involved parties, QC/QA concept

- **Financial performance**
  - Review of financial model input data including
  - project costs and contingencies,
  - revenues,
  - technical input data
  - Assessment of applicability of project within the CDM / JI framework
  - Analysis of project sensitivities / risk assessment
  - Price risks, feed-in tariffs, duration of feed-in tariff

- **Risk Assessment**
  - Summary of risks
  - Monitoring of developments
  - Recommendations and mitigation measures

⟶ **Preparation of a Due Diligence Report**

Project screening and DD (USELF Programme)

1. Technical screening

- First assessment of project
- Assessment of measurement and resources
- Assessment of first stages of planning
- First economical assessment

2. Project due diligence

- Detailed assessment of wind measurement, wind resource assessment
- Assessment of turbine selection, farm layout and technical design
- Assessment of procurement strategy
- Assessment of signed contracts
  - EPC contract/ Subcontractors contracts
  - Turbine supply contract
  - Operation and maintenance contract
- Assessment of time schedule
- Detailed economical assessment

Required Technical Documents for a DD 1/5

1. Detailed **organization charts** **showing the intended project organization in the Contractor's head office and at site, including involvement of subcontractors.**

2. **Time schedule and work program** depicting mainly the design / planning, **procurement, manufacturing, shipping time incl. custom clearance, inland transport, civil works, erection works, commissioning, trial run, training, and final completion date.**

3. **Subcontractors/suppliers proposed by the Contractors**
Contractors shall include details of all major items of supply or services that he proposes purchasing or subcontracting, giving details of the proposed subcontractors/suppliers, including vendors, for each of these items.

4. **Equipment and machinery**
A list providing information about the equipment and machinery intended to be used by the Contractor for the Works. Separate lists shall be provided for the proposed subcontractors.

Required Technical Documents for a DD 2/5

5. Technical documentation and drawings:

- **Detailed description of the equipment and components, essential technical and performance characteristics**
- **Type Test Protocols / Certificates for main equipment**
  (Only relevant pages shall be added, e.g. sound summary sheets)
  Only type tested equipment shall be used. If no type test certificates are available, the relevant type tests shall be performed at the Contractor's expenses
- **For all major activities like e.g. erection and installation of wind energy converters, cabling works and substation (incl. tie-in) a method statements shall be provided by the Tenderer describing how the works are intended to be performed, safety measures to be taken, equipment to be used, etc.**
- **Wind farm concept and layout**
  - layout drawings of the wind farm, incl. (layout drawing, foundation, vehicles, roads, temporary installations, MV cabling, substation etc.)
  - general assembly drawings: these shall show to scale all necessary components of the equipment, to be identified by a legend. The exact Bill of Quantities is to be included.
  - dimensioned drawings and sectional views of the principal plant components
  - outline drawings: drawings of the equipment indicating overall dimensions with minimum required distances to neighboring equipment, weights, anchoring and connection details, and erection working space.
  - schematics of the principal plant systems
  - general descriptions of individual systems and descriptions of operation
  - all other documents necessary for comprehension of the offered plants and equipment
  - space requirement for construction site and equipment
  - electrical single-line diagrams including overall substation protection scheme
  - general arrangement of electrical equipment

Required Technical Documents for a DD 4/5

5. Technical documentation and drawings (continued):

- **Wind energy converters**
  - **Contract documents (Supply and Erection and Maintenance Contracts)**
  - Preliminary review results of Employer's wind farm layout; confirmation that the offered WEC type and model and IEC class is considered suitable for the meteorological conditions on the wind farm site and layout, in particular with respect to turbulences and survival wind speed
  - Confirmation of suitability of Lot 2 design (access roads, crane pads)
  - Preliminary noise immission prognosis based on the guaranteed noise level of their wind turbines
  - Measured power curve according to IEC 61400-12
  - Acoustic noise measurement according to IEC 61400-11
  - Power quality characteristics according to IEC 61400-21
  - Compilation of tolerable/acceptable conditions (meteorological etc.) and any other further restrictions for use/operation of the WEC
  - Description of the operational behavior of the WEC under special consideration of Bora wind conditions
  - Description of the condition monitoring system including listing of monitored components, type and positions of sensors
  - Recommended spare parts, equipment, tools and instruments
- **Instrumentation & control system**
  - description of the wind turbine control system
  - control system architecture showing all components provided for this project in their actual structural arrangement
  - description of hardware, software and design characteristics of the control system
  - description of field equipment
  - list of signals to be transmitted by the SCADA system and preliminary specification of required optical fiber cables
- **Substation and MV cabling**
  - Description of the main equipment, step down transformer switchgear, circuit breaker, auxiliary system
  - Description of protection equipment and philosophy for the substation and the OHL
  - Cable sizing calculation, operation scheme for normal operation and cable outage cases (worst case)

Thank you for your attention

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