General Description

WIND TO ENERGY®

W93

2.05 MW

W2E Wind to Energy GmbH

Impress

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1 Introduction

The W93 constitutes a 3-bladed, horizontal axis, upwind and variable-speed wind turbine type with approximately 93.2 m rotor diameter and a nominal power output of 2,050 kW. It is designed to meet the requirements of *IEC 61400-1*, wind class IEC 2a.

The W93 also constitutes a machine according to *European Machine Guideline 2006/42/EG*. Therefore, the *European Machine Guideline 2006/42/EG*, the *Low Voltage Guideline 2006/95/EG*, the *EMC Guideline 2004/108/EG* as well as the *Guideline of German Lloyd, Edition 2003*, including addition 2004 were applied for the development and the design process as well as for the documentation of the W93. The chapters below provide an overview of the W93 subsystems.

2 Basic data

Basic Data	
Rotor	Triple-blade rotor as the upwind assembly
Rotor axis	Tilted horizontally by 5°
Speed control	Electrical pitch system with triple-redundancy
Nominal power	2,050 kW
Cut-in wind speed	3.0 m/s
Nominal wind speed	12.0 m/s
Cut-out wind speed	25 m/s
Design life time	20 years
Nacelle and rotor certified acc. to	*IEC 61400-1,* class 2a
Operation at ambient temperature of	-20 to +40 °C
Colouring of blades, nacelle and tower	RAL 7035

3 Rotor

The rotor assembly consists of the three rotor blades, the rotor hub, three geared bearings and three-phase drives for adjusting the pitch of the rotor blades. The rotor blades are made of high-grade fiberglass-reinforced plastic (FRP). The pitch system, which is accommodated in the hub, is designed with triple-redundancy. The rotor blades are equipped with a lightning protection system.

Rotor	
Rotor diameter	93.2 m
Swept area	6,822 m²
Rated power / Rotor area	293 W/m²
Rotor speed	8.5 to 17.7 rpm
Tilt angle	5°
Coning angle	5°
Total weight	approx. 45 t

Rotor hub	
Material	Modular graphite cast EN-GJS-400-18-LT (GGG 40.3)
Weight	approx. 11.5 t (machined)

Rotor blades	
Material	Fiberglass-reinforced plastic (FRP)
Overall length	45.3 m
Weight per blade	approx. 8.2 t

Pitch system	
Motor	Three-phase induction motors, 4-pole
Max. pitch speed	12°/s
Rotor speed control	IGBT-inverter
Backup	Lithium-Ion Battery Option: Capacitors

4 Drive train

The drive train includes a rigid moment bearing for absorbing the forces and bending moments acting on the rotor. The moment bearing is directly attached to the front of the machine frame. Hence, the rotor bending moments and forces are transferred directly into the tower structure without compromising the drive train. Thus, only the rotor torque is transmitted to the gearbox via a hollow shaft. The main shaft is connected to the gearbox by means of an annular set of elastomeric elements (silent blocks). The gearbox is connected to the machine frame via an annular torque support that arranges silent blocks around the entire circumference of the gearbox. The complete structural-borne noise decoupling of the drive train contributes considerably to the minimization of noise emission. The connection between the gearbox and the generator is established via a coupling with overload protection.

The gearbox is designed as a two-step planetary gear with one helical gear step. The gearbox is cooled by an oil-water cycle and a water-air cycle with stepped cooling capacity. The gearbox bearings and gear meshing are continuously supplied with splash oil by a mechanical oil pump via reduction gear. The pump operates independently of the sense of rotation of the rotor. An additional electrically powered oil pump is turned on for peak loads.

Rotor bearing	
Type	Double-row tapered roller bearing
Dimensions	2,330 mm x 285 mm
Lubrication system	Grease lubrication
Weight	approx. 2.1 t

Shaft coupling	
Material	Modular graphite cast EN-GJS-400-18-LT
Weight	approx. 2.4 t

Gearbox	
Type	Two-stage planetary gear, one spur gear stage
Nominal power	approx. 2.1 MW
Speed ratio for 50 Hz / 60Hz	1 : 76.7 / 1: 92.0
Lubrication system	Mechanical and switchable electrical oil pump
Oil volume	approx. 430 l
Oil type	VG 320
Oil change	Annual check, change according to demand
Weight incl. oil and attachments	approx. 21.5 t

Generator coupling	
Type	Steel disk coupling with overload protection
Weight	approx. ca. 525 kg

5 Generator

A low-voltage, air-cooled, three-phase asynchronous slip-ring machine is employed. Mounted on the generator there is an air-water heat exchanger, which dissipates the waste heat into a cooling-water cycle. The slip-ring system is designed such that continuous operation can be ensured for more than one year without maintenance. Flanged to the non-drive end of the generator is an incremental encoder for measuring the rotation speed. The generator is supported by anti-vibration cushioning.

Generator	
Type	Asynchronous slip-ring machine
Protection class	IP 54
Nominal output	2.110 MW
Nominal voltage	690 V 3~
Frequency	50 Hz / 60 Hz
Speed range at 50 Hz / 60 Hz	650 to 1,360 rpm / 780 to 1,632
Poles	6
Weight	approx. 8.2 t
IEC Size	630
Speed sensing	Incremental Encoder with 2048 pulses / rotation
Cooling	Mounted air-water heat exchanger

6 Inverter

The inverter is designed for low voltage and is placed on the bottom inside of the tower (tubular tower) or inside the compact sub-station (lattice tower). It is arranged between the line and the rotor of the asynchronous machine and works according to the principle of the double-fed asynchronous machine. The line-side as well as the machine-side current power inverter is equipped with IGBTs as power-electronic actuators. This technology results in a highly dynamic drive system with superior line characteristics. The control technology allows for the active attenuation of drive train vibrations.

Inverter	
Type	Indirect DC link converter
IGBT	Class 1,700 V
Protection class	IP 44
Rated module current on the line side	500 A 3~
Max. module current on the line side	670 A 3~
Rated module currenton generator side	780 A 3~
Max. module current on generator side	870 A 3~
Nominal voltage	690 V 3~
Frequency (line side)	50 Hz / 60 Hz
Weight	approx. 2.3 t
Dimensions incl. frame (L x H x W)	3,000 mm x 2,400 mm x 600 mm
Cooling	Water
Interfaces	CAN, Ethernet

7 Transformer

The pad-mounted transformer for converting the produced electric power of 690 V into medium voltage is placed inside of the separate compact sub-station, outside the wind turbine tower. The transformer is designed as a dual-winding transformer with the vector group Dyn5 or Dyn11.

Transformer	
Type	mineral oil or MIDEL ® 7131
Nominal output	approx. 2.2 MVA
Nominal voltage low voltage side	690 V 3~
Nominal voltage high voltage side	20 kV 3~ or other
Vector group	Dyn5 or Dyn11
Nominal short-circuit voltage	approx. 6%
Frequency	50 Hz / 60 Hz
Weight	approx. 4.4 t
Fire class according to *IEC 61100*	K3
Cooling	
Standard / Hot Climate Version	ONAN / ONAF

8 Medium voltage switchgear

The medium voltage switchgear is situated inside a compact sub-station too. The switchgear in its gas-insulated metal capsule is equipped with a vacuum circuit-breaker according to *IEC 298* or according to *ANSI/IEEE C37* series, a mechanically locked busbar switch-disconnector, outgoing section busbar-earthing switch-disconnector, and protective relay for installation in closed electrical rooms. If transformer contains adequate overcurrent protection on its high voltage size in series with an adequate load break switch, then MV switchgear is not required.

Medium voltage unit	
Insulation and switch medium	SF6
Nominal voltage	24 kV or other
Nominal current circuit-breaker panel	630A
Nominal current transformer panel	250 A
Nominal surge current	40 kA
Nominal short-time current	1 s / 16 kA
Weight	approx. 400 kg
Dimensions incl. feed in (L x H x W)	700 mm sx 1,400 mm x 775 mm
Protection relay	Overcurrent protection with DEFT characteristics

9 Cooling and filtration

Gearbox, generator and inverter of the W93 each have mutually independent active cooling systems. The water cooling cycles of the generator, of the inverter and of the gearbox are equal in design but three separate units that operate independent of each other. All systems are designed such that optimal operating temperatures will prevail even when the outside temperatures are high. Glycol is added to the cooling water to prevent freezing.

Gearbox cooling and filtration: Heat is dissipated from the gearbox to the oil-water plat heat exchanger via a mechanically and an electrically powered pumping system. The heated oil is cooled by a water-air heat exchangers over the outer ambient air. Through a system of pipes in and around the gearbox, the cooled oil reaches components, which are subjected to a higher degree of thermal stress. With permanent filtration, the filter unit with 50 µm / 10 µm ensures that the appropriate degree of oil purity is reached, namely 17/15/12 according to ISO 4406 or better. The filter is designed for a service life of 12 months.

Cooling the generator: The heat is dissipated indirectly from the generator to the water cycle via an air-water heat exchanger, which is placed above the generator and rigidly connected to it. The water that heats up is cooled by ambient air, which flows through a water-air cooler.

Cooling the inverter: The inverter of the W93 has a water-cooling system for the power electronics. The water that is heated up in the inverter is cooled by ambient air of the tower inside, which flows through a water-air cooler. Cold cooling water is warmed before switching on the inverter.

The generator and gearbox bearings, the transmission oil, the generator windings, the power inverter module, and the cooling media are all automatically temperature-regulated. The cooling cycles are controlled according to operating mode and operating data, which means that the optimal temperature range is maintained as evenly as possible.

In case of rated wind speed and very high environmental temperatures an output power reduction is automatically executed. The intention is to stay on line.

10 Braking system

Aerodynamic breaking is accomplished by means of three independently adjustable rotor blades, which can be moved in a range between 0° and 90°.

In addition to this single-blade adjustment, the W93 is equipped with a hydraulic disc brake. This mechanical brake is supplementary to the rotor-blade braking action, bringing the rotor to a standstill. The brake acts as an active brake. Its sole purpose is operator safety to stop the rotor to a standstill when the W93 is in service mode. Furthermore the brake supports the aerodynamic breaking when the safety system is activated. The mechanical brake applies a torque equivalent to 0.7 times the nominal torque.

After standstill, the rotor can be locked by means of a mechanical locking arrangement on the drive side and alternative on the fast running side of the gearbox.

Aerodynamic brake	
Type	Triple independent single-blade adjustment
Design	electric

Mechanical brake	
Type	Disc brake
Arrangement	on the high-speed shaft
Disc diameter	940 mm
Number of braking calipers	1
Brake lining material	Sintered metal

11 Hydraulics

The decentralized designed hydraulic system consists of two units. It is used for the mechanical disc brake of the drive train and for the azimuth brake.

Hydraulic system	
Hydraulic oil	Tellus TX 32 or Tellus Artic (CCV)
Oil tank	approx. 3 l
Nominal output of the hydraulic pumps	0.75 kW
Monitoring	Temperature, oil pressure, pump running time

12 Nacelle

The nacelle consists of a machine frame and the nacelle housing. The machine frame also functions as the lower portion of the nacelle housing. Additionally, it is used as a containment area for coolants and lubricants in case of leakages. The nacelle housing and the dome, which includes the water-air heat exchangers, are made of a steel construction. Due to the shape of the nacelle housing and the arrangement of the cooler, the ambient air flow is utilized for cooling.

Nacelle	
Type of machine frame	Cast iron
Material	GJS-400-22U-LT
Type of cover	Steel construction

13 Yaw system

The wind direction is continuously measured at hub height with two wind direction sensors. If the admissible deviation is exceeded, the nacelle is actively yawed. The tolerance range of the so-called yaw error, which represents the deviation between wind direction and nacelle position, depends on wind speed. Yawing is accomplished by four gearbox motors, which adjust an internally geared slewing ring. At nacelle standstill, the hydraulic retaining brakes at the slewing ring and the electromagnetically activated brakes of the gearbox motors are locked in place.

The yaw system re-winds the nacelle automatically when the transposition of the cables in the tower has reached a threshold value.

Two wind direction sensors and two anemometers increase the safety and availability of the system.

Azimuth bearings	
Type	Rotary joint
Material	42 Cr Mo4
Weight	approx. 2.3 t

Azimuth drive	
Motor	Three-phase asynchronous motors with short-circuit rotor
Gearbox	4-step planetary gear
Number of drives	4
Lubrication	Oil, ISO VG 620
Yaw speed	approx. 0.5 °/s

Azimuth brake	
Type	hydraulic disc brake
Material of brake linings	organic
Number of brake calipers	4

14 Tower and foundation

The W93 is erected on tubular towers for hub heights of 85 m or 100 m or on a lattice tower. The climbing ladder with safety equipment and the resting and working platforms are inside the tower. An elevator system can be installed in the tubular tower as an option.

Corrosion protection of tubular towers is achieved by means of sandblasting and an epoxy resin surface coating according to *ISO 12944*.

The design of the foundation for the W93 depends on soil conditions at the proposed site.

	Tubular tower
Material	S235 JRG2, S355 J2G3
Corrosion protection	Epoxy resin coating
Tower foot mounting	Flange and bolts embedded in concrete of the foundation

Hub height	**Tubular tower**	
	85 m	**100 m**
Class	IEC 2a, DIBt III	IEC 2a, DIBt III
Number of tower segments	5	6
Weight without built-in components (approx.)	165 t	240 t

15 Safety system

The safety system of the W93 is designed with particular care and meets the strict requirements of the guidelines issued by the certification agency German Lloyd. Purpose of the safety system is to ensure that the W93 remains in safe operational condition under any circumstances, particularly if the supervisory control, individual components or systems should fail. The safety system is designed according the standard ISO 13849-1.

The safety system comprises a safety control device, the overcurrent protection of the circuit breaker, several emergency stop buttons, limit switches for the rotor and the generator speed, a watchdog of the operating control system, limit switches of cable twist, oil pressure and hermetic protection of the medium voltage transformer, a limit switch for the nacelle acceleration (the so-called vibration switch). Furthermore, at each axle of the pitch system a switch is actuated if the pitch inverter fails, or in case of inadmissible deviation between the mutually independent blade angle transducers, or in case of communication lost to the operating control system, or in case of low charge state of the backup.

Depending on the state of releasing devices the emergency relays are switched off or the circuit breaker is switched off or the azimuth is disabled by the safety system. The pitch system is activated. The mechanical brake is activated only in case of emergency stop or in case of overspeed.

16 Controller

The W93 is variable speed controlled by means of inverter operation. An active torque controller in combination with a pitch controller to perform pitch angle regulation operates dependently - in order to achieve maximum power output and minimize loads at the same time. That is, the torque controller calculates the set torque dependent of the present pitch angle and the present generator speed. The rotor blades are adjusted with an electrical pitch system.

Thanks to speed control, the utilization of the air inflow is automatically optimized in the below-rated mode, which is at low and moderate wind speeds, regardless of differences in air density. At and above nominal wind speed, the rotor is set to an optimized rotational speed while the torque of the drive train is held constant.

A sophisticated control system applying active drive train damping for attenuating drive train vibrations is superimposed over the control process, ensuring smooth operation and a minimum of fatigue loading.

17 Grid connection

The W93 allows the operation on a stiff three-phase grid. The electrical behaviour of the W93 is measured according to the *Technical Guidelines for Generator Units* of the FGW, *Part 3: Determining the Electrical Properties of Generator Units at Medium, High and Extra High Voltage* as well as according to *IEC 61400-21*.

18 Operating control and supervisory system

The W93 is controlled and supervised by means of a Programmable Logic Controller (PLC) which queries the sensors and systems of the plant, evaluates the data according to proven algorithms and produces the outputs to the actuators and systems in accordance with the established parameters.

Process control is defined by states and transitional conditions (Petri net). A set of several hundred parameters facilitates the exact fine-tuning and optimization of the system's control. The administration of status and alarm systems is databank-based. Thoroughly tested control structures ensure optimal operation of the plant with regard to power output and load minimization at the below-rated and above-rated modes.

The hardware platform for operating and supervisory control is the WP4100 by Mita-Teknik a/s. It does not require PC technology and Windows-based systems, works without revolving parts, has been developed for rugged environmental conditions and is well-suited to the harsh operating conditions and rigid requirements in terms of availability of the plant and its data. The WP4100 is a platform of modular design. Apart from the actual controller, modules are available for all typical analogue and digital input and output formats including several bus protocols. Additional modules can be added for measuring purposes, and their values are recorded without a change in program.

Communication between separate control modules takes place via a fault-tolerant collision-free Ethernet network. Communication between nacelle equipment and hub equipment takes place via slip rings using CAN.

The plant is operated via control panels in the nacelle and at the tower foot. With PC or laptop, the plant can be comprehensibly remote-operated and observed via telecommunication as well as on the wind farm itself and within the plant by coupling it to the Ethernet. Trends and energy production data can thus be read and analyzed.

Networking between the individual plants of a wind farm also takes place via the Ethernet. However, the wind farm network is designed separately, making it independent of the communication lines within an individual plant. Devices with their own control, such as the inverter or the inverters of the pitch system, are also networked through the Ethernet of the wind farm and therefore have remote access. As a rule, communication between the wind farm network and customer or service computers is established via ISDN connections. Two EURO-ISDN connections according to the Digital Subscriber System No. 1 (DSS1) and a flatrate are required. A higher bandwidth for upload and download as well as a DSL flatrate are recommended.

Thanks to Ethernet technology, it is very simple to install other standardized technologies or devices in the W93. This includes temporarily used measuring devices or computers, but also web cameras or microphones.

The WP4100 has SMTP and HTML protocols, which means that an E-mail-based alarm system and web-based visualization are possible.

The WP4100 has a remanent memory of 64 MB, which is supported via a capacitor in case of power outage. In case of a long-lasting power outage, the contents of the memory are deposited in a nonvolatile memory. The memory can store a large volume of status, alarm and trends data.

To synchronize the lights of the aircraft warning light system, modules for receiving the global positioning system (GPS) signal are used.

Control	
Type	WP4100
Ambient temperature	-20° C to 60° C
Communication between WP line	CAN (near), Ethernet (remote)
Interfaces	RS 232, RS 485, Ethernet
Protocols	M-Net, T.C. 88, SMTP, HTTP
Bus coupling	CAN

19 Lightning protection

In the development of the plant, the greatest attention is paid to lightning protection. Most reliable protection is achieved for all components. The overall plant's lightning and surge protection meets the requirements of the **Class I** Lightning Protection Concept and is based on the following standards: *IEC 62305, part 1 – 4* and *DIN EN 62305, part 1 – 4* and *VDE 0185-305, part 1 - 4* and *DIN VDE 0100 Part 534*.

The lightning protection system of the wind turbine generator consists of an individual adapted combination of several protection measures, which have been chosen from the following areas:

- exterior lightning protection according to *DIN EN 62305-3* and *VDE 0185-305-3* to catch, lead and distribute the lightning current to the earth,
- potential equalisation measures to minimise potential differences,
- spatial shielding to minimise the magnetic field in switch gears and therefore to minimise induced voltages and currents,
- cable routing and cable shielding to minimise induced voltages and currents.

The rotor blades have factory-installed lightning arrestors. As a standard feature, anemometer and vane are equipped with a grounded lightning arrestor cage. The nacelle housing is totally made by a metallic construction.

The foundation of the W93 and (if supplied separately) the medium-voltage unit are designed with a ring earth electrode and potential equalization according to *DIN 18014*. The ring earth electrodes of the structures are connected to iron banding buried in the ground. The tower is connected to the ring earth electrode of the foundation in four places equally distributed around the circumference of the tower.

The wind turbine generator is divided into lightning protection zones. Therefore local differences regarding to number, kind and sensitivity of electrical and electronic devices can be considered. For each lightning protection zone protection measures are chosen based on a risk analyse according to *DIN EN 62305-2* and *VDE 0185-305-2*. Based on this method an optimised protection can be reached with minimal cost.

Surge protection devices with qualified energy absorption capability are used for energy cable, signal cable and data cable. Surge protection devices are placed on input points of the lightning protection zones inside of each switch gear.

The electric installation is designed along the principles of TN-S-systems according to the guideline *DIN VDE 0100*. The advantage is that the neutral line and the earth line are separated in the entire system. Therefore there is no operation current in the earth line.

The 690 V power line of the W93 is designed as TN-C-S-system. The star point of the medium voltage transformer with the vector group Dyn5 or Dyn11 is grounded. An autotransformer with the vector group Yan0 and a voltage ration of 690 V to 400 V supplies small motors, lamps and control units. The 400 V power line is designed as TN-S-system. There is a residual current monitoring. A single phase transformer with galvanic separation supplies a 230 V power line for the controller and the sensors.

All cables are shielded. The shields are connected with the potential equalisation system on both ends. If possible shields are connected to the potential equalisation system by special shield clamps which guarantee a 360° clamp area. Shields of bus cable and high frequency data cable are connected according to their standards. Non shielded cables are used in case of the generator, lamps, power outlets and tower cable. Data cable between nacelle and tower base and between wind turbines of a wind park are carried out as fibre optic cable.

All shielded cable could be routed side by side without distance. For a good EMC quality, unshielded power cable does not routed nearby control or data cable.

20 Power curve

The power curve of the W93 is calculated for the following conditions:

Calculation conditions	
Simulation program	Flex5
Rotor diameter	93.2 m
Type of rotor blades	LM45.3P / WN453
Nominal rotor speed	15.0 rpm
Air density	1.225 kg/m³
Terrain slope	0°
Turbulence intensity	10%
Wind gradient	0.16
Calculation according to	*IEC 61400-12*

Hub height wind speed in m/s	**Electrical power LM45.3P** in kW	**Electrical power WN453** in kW
3.5	15.4	18.7
4	60.8	65.2
5	183.1	188.9
6	360.7	369.4
7	600.0	612.2
8	921.1	934.7
9	1325.5	1319.8
10	1735.8	1679.5
11	1993.0	1946.5
12	2044.5	2032.5
13	2050.0	2050.0
14	2050.0	2050.0
15	2050.0	2050.0
16	2050.0	2050.0
17	2050.0	2050.0
18	2050.0	2050.0
19	2050.0	2050.0
20	2050.0	2050.0
21	2050.0	2050.0
22	2050.0	2050.0
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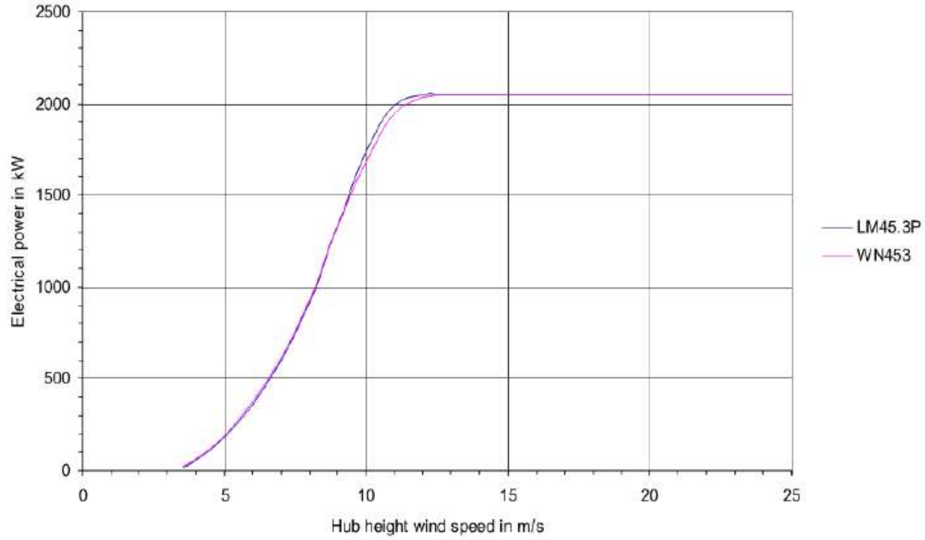

21 Calculated annual energy production

The annual energy production has been calculated according to the *IEC 61400-12* for standard conditions and applies to a theoretical availability of 100% of the individual plant. The calculated annual energy production was determined under the calculation conditions according to section 20 and cannot replace a site-specific forecast.

Annual average of hub height wind speed in m/s	**Calculated annual energy production LM45.3P** in MWh	**Calculated annual energy production WN453** in MWh
5.0	3,284	3,305
5.5	4,169	4,180
6.0	5,069	5,069
6.5	5,956	5,946
7.0	6,808	6,789
7.5	7,613	7,587
8.0	8,362	8,329
8.5	9,049	9,012
9.0	9,670	9,630
9.5	10,224	10,181
10.0	10,709	10,665

22 EEG reference production

The reference production according to the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz; EEG) is calculated based on the following conditions.

EEG reference site	
Annual wind speed at 30 m height	5.5 m/s
Air density	1.225 kg/m³
Roughness length	0.1 m
Rayleigh distribution	k = 2

Hub height in m	**Reference production LM45.3P** in MWh	**Reference production WN453** in MWh
60.0	26,751	26,720
85.0	29,723	29,660
98.2	30,933	30,860
120.0	32,588	32,495
140.0	33,839	33,735

23 Technical Changes

The technical descriptions and data presented above represent the current project state. They are subject to refinement and do not represent guarantees or binding obligations.