Project: “GR-INNO – SGS2 Soft Measures HWEA/ELETAEN’’

Deliverable of Task 1.1

Definition of a typical Greek offshore wind farm and a reference turbine

Definition of a set of technical specifications

Prepared by:

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Table of Contents

Table of Tables

Table of Figures

Abbreviations

a.s.l.	Above Sea Level
IEC	International Electrotechnical Commission
LCoE	Levelized Cost of Electricity
RNA	Rotor-Nacelle Assembly
SWH	Significant Wave Height

1 EXECUTIVE SUMMARY

This is the Task 1.1 deliverable of the project "GR-INNO – SGS2 Soft Measures – HWEA/ELETAEN" granted from the "EEA Financial Mechanism 2014-2021, Business Development, Innovation and SMEs

"Business Innovation Greece" programme. The project promoter is HELLENIC WIND ENERGY ASSOCIATION ELETAEN NON-PROFIT ORGANISATION (ELETAEN NPO) collaborating with the project partner Marin Energi Testsenter As (NOW). The project will contribute to the following outcomes: i) Increased competitiveness of Greek enterprises within the focus area of Blue Growth and ii) Enhanced business collaboration between Greek entities and Beneficiary State entities.

Task 1 of the project aims in the analysis of the supply chain of offshore wind development in Greece. In that, subtask 1.1 defines a typical Greek offshore wind farm and a reference turbine, as well as a set of technical specifications (weights, staging area needed, minimum water depth, etc) needed for the rest of the project.

Two typical Greek offshore wind farms and a reference turbine are defined. The reference wind farms address medium (50m) and higher (200m) sea depths. The installed capacity is 300MW in both cases. The turbines offshore support structures are jackets in the first case and semisubmersible floaters with catenary mooring lines in the second. The metocean conditions assumed for the two cases are typical for Aegean Sea. The bottom-fixed site has a mean annual wind speed of 8.2m/s, significant wave height 0.8m and wave peak period 4.2s. The floating site is rougher, with mean annual wind speed of 9.6m/s, significant wave height of 1.2m and peak period 5.0s.

The IEA 15MW offshore wind turbine is selected as the reference turbine. It is a typical three-bladed upwind design, with variable speed and pitch control, having a rotor diameter of 240m and hub-height 150m.

Using the reference wind farm(s) and turbine characteristics one can obtain a set of prerequisites / technical specifications (weights, staging area, minimum water depth, etc) necessary for assessing the specific needs for harbours and the elements of the supply chain. It is seen, for instance, that the development of the 300MW reference wind farm an area of 25Ha is needed as a minimum for the staging of the "dry" wind turbines' components, the bearing capacity of the staging soil might need strengthening to host heavy equipment, while the exit from the harbour should support a minimum draft of 12m (it might be less for other floater designs and assembly practices).

2 INTRODUCTION

This is the Task 1.1 deliverable of the project "GR-INNO – SGS2 Soft Measures – HWEA/ELETAEN" granted from the "EEA Financial Mechanism 2014-2021, Business Development, Innovation and SMEs "Business Innovation Greece" programme. The project promoter is HELLENIC WIND ENERGY ASSOCIATION ELETAEN NON-PROFIT ORGANISATION (ELETAEN NPO) collaborating with the project partner Marin Energi Testsenter As (NOW). The project will contribute to the following outcomes: i) Increased competitiveness of Greek enterprises within the focus area of Blue Growth and ii) Enhanced business collaboration between Greek entities and Beneficiary State entities.

Task 1 of the project aims in the analysis of the supply chain of offshore wind development in Greece. The starting subtask 1.1 defines a typical Greek offshore wind farm and a reference turbine, as well as a set of technical specifications (weights, staging area needed, minimum water depth, etc) needed for the rest of the project.

Chapter 3 of this report describes two reference wind farms (a bottom fixed and a floating) operating under typical Aegean Sea metocean conditions.

Chapter 4 of the report details the key parameters and technical characteristics of a generic 15MW wind turbine that will be used in the reference wind farms. Depending on the case, the reference turbine is supported by a jacket (bottom-fixed) or a semi-submersible floater (floating) anchored by catenary mooring lines.

Harbour needs for the staging, assembly and transportation of the "dry" components of the reference wind farm are discussed in Chapter 5.

3 REFERENCE WIND FARM

This chapter provides the key parameters of the reference wind farm(s) that will be used in the project. It addresses sizing of the wind farm (installed capacity, turbine type, number of turbines and a typical layout), water depth, as well as metocean conditions for wind and wave (currents are not considered). Two reference offshore wind farms are considered, one with bottom-fix and another with floating wind turbines. The metocean conditions used for the reference wind farms are typical for the Aegean Sea.

3.1 SIZING

For both bottom-fix and floating reference wind farms the installed capacity is **300MW,** comprising **20X15MW** turbines of the “reference” type presented in the next chapter. The reference turbine is of IEC Class IB and has **240m** diameter and **150m** hub-height. The 20 turbines layout assumes **7DX5D** distances between the turbines, 7D (1680m) in the prevailing wind direction and 5D (1200m) in the normal to the prevailing direction. A 5X4 turbines layout requires a deployment area of **~25km^2**.

The mean sea depth for the bottom fixed turbines is **50m** with the offshore support structure being of the jacket type. The mean sea depth for the floating turbines is **200m** with the offshore support structure being of the semisubmersible type with a chain catenary mooring system. Details of the offshore support structures are presented in the following chapters.

3.2 WIND CONDITIONS [1]

The wind conditions assumed for the two reference wind farms at their hub-height are:

For bottom-fixed turbines

- Mean annual wind speed (m/s) : 8.2
- Weibull shape factor k : 2.4
- Prevailing wind direction (°) : 340

For floating turbines

- Mean annual wind speed (m/s) : 9.6
- Weibull shape factor k : 2.0
- Prevailing wind direction (°) : 305

3.3 WAVE CONDITIONS [2]

For bottom-fixed turbines

- Mean significant wave height (m) : 0.8
- 50-years extreme SWH (m) : 4.6
- Spectral peak period (s) : 4.2
- Prevailing wave direction (°) : 8

For floating turbines

- Mean significant wave height (m) : 1.2
- 50-years extreme SWH (m) : 6.9
- Spectral peak period (s) : 5.0
- Prevailing wave direction (°) : 314

4 REFERENCE WIND TURBINE

The IEA 15MW Wind Turbine [1] has been selected as the reference turbine of the present assignment. This is an offshore turbine, originally supported by a monopile. A bottom-fixed version of the same turbine for deeper waters (~50m) supported by a jacket substructure has been obtained in the present context using the INNWIND.EU[1] reference jacket upscaled to 15MW using the INNWIND.EU cost model [4]. A floating version of the IEA 15MW turbine for water depths ~200m has been also defined in [5].

4.1 KEY PARAMETERS FOR THE 15MW REFERENCE WIND TURBINE

4.1.1 Rotor and RNA

Table 1 presents the key parameters of the 15MW Reference Wind Turbine. It has a 3-bladed, upwind, pitch variable rotor with a direct drive drivetrain. The Table shows under the column "IEA 15-MW Turbine" the values of the relevant parameters as provided in [1], while in column "Innwind.EU" the corresponding values have been obtained through the upscaling of the INNWIND.EU 10MW turbine using the upscaling and cost modelling tool of [4]. It is seen that the two parameters' sets are quite identical, strengthening thus the representativity of the 15MW design.

Table 1: Key parameters for the 15MW Reference Wind Turbine

Key Parameters		IEA 15-MW Turbine	Innwind.EU
Parameter	**Units**	**Value**	**Value**
Power rating	MW	15	15
Turbine class	-	IEC Class 1B	IEC Class 1B
Specific rating	W/m2	332	.//.
Rotor orientation	-	Upwind	.//.
Number of blades	-	3	.//.
Control	-	Variable speed Collective pitch	.//.
Cut-in wind speed	m/s	3	.//.
Rated wind speed	m/s	10.59	.//.
Cut-out wind speed	m/s	25	.//.
Design tip-speed ratio	-	9 0	.//.
Minimum rotor speed	rpm	5	.//.
Maximum rotor speed	rpm	7.56	.//.
Maximum tip speed	m/s	95	.//.
Rotor diameter	m	240	.//.
Airfoil series	-	FFA-W3	.//.
Hub height	m	150	.//.
Hub diameter	m	7.94	
Hub overhang	m	11.35	
Rotor precone angle	deg	-4	
Blade prebend	m	4	
Blade mass	t	65	66.5
Drivetrain	-	Direct drive	Medium Speed
Shaft tilt angle	deg	6	
Rotor nacelle assembly mass	t	1,017	1,073

For a more detailed description of the IEA design, we quote below relevant expressions used by the reference [1] authors:

[1] INNWIND.EU (http://www.innwind.eu/) was a European FP7 project. The overall objective of the INNWIND.EU project was the high-performance innovative design of a beyond-state-of-the-art 10-20MW offshore wind turbine and hardware demonstrators of some of the critical components.

«The blade design was driven by the selection of 240m as the rotor diameter and a maximum tip-speed of 95 meters per second (m/s). A fairly traditional structural configuration was selected, comprising of two main load-carrying, carbon-reinforced spars, connected by two shear webs, with reinforcement along the trailing and leading edge and foam fillers. »

« The 15-MW reference wind turbine uses a direct-drive layout with a permanent-magnet, synchronous, radial flux outer-rotor generator in a simple and compact nacelle layout. The assembly consists of a hub shaft supporting the turbine and generator rotors on two main bearings housed on a stationary turret that is cantilevered from the bedplate. The hub is a simple spherical shell, with cutouts for the blades and the flange. The main shaft has a hollow cylindrical cross section, with a constant wall thickness and a tilt angle of 6^o. The main shaft, along with the rotor, is supported by two main bearings. Both these main bearings have rotating outer raceways and fixed inner raceways. The outer raceways and bearing housing are accommodated by a turret held by the bedplate. The entire weight of the turbine rotor, generator rotor, and hub loads are transmitted by the main shaft to the turret via the bearings. The bedplate is a hollow, elliptically curved, cantilever beam with circular cross sections. The yaw system bearings are double-row, angular, contact ball bearings. The generator construction features an external rotor radial flux topology machine with a surface-mounted permanent magnet. »

The drive train design is illustrated in Figure 1.

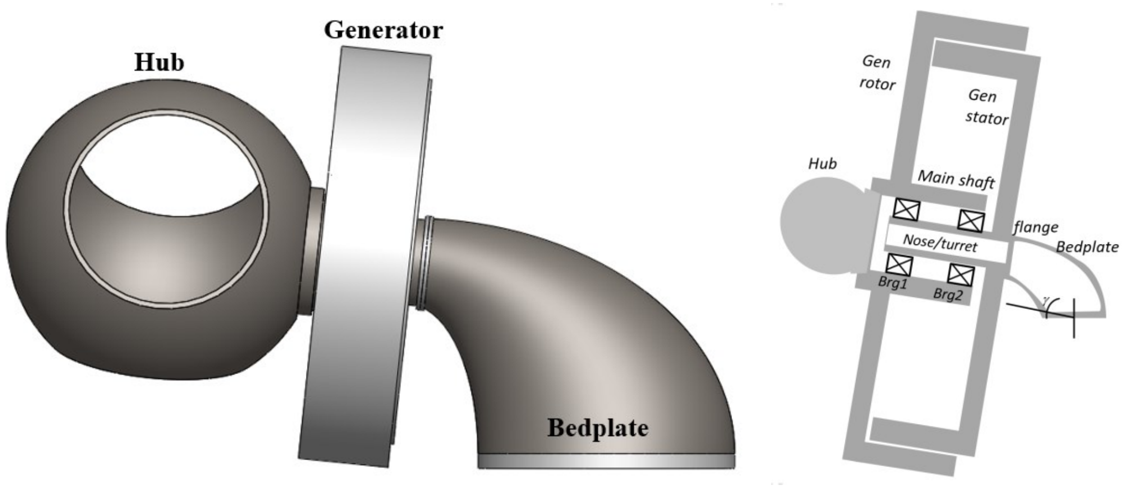

Figure 1: The hub-drivetrain arrangement of the IEA 15MW Wind Turbine (Source: [1])

4.1.2 Offshore Support Structures

Three alternative offshore support structures are considered for the 15MW reference wind turbine. For relatively low (~30m) water depths (w.d.) a monopile design is provided in [1]. For higher water depths (~50m) a jacket substructure can be obtained by upscaling the reference 10MW jacket of the INN-WIND.EU project using [4]. In both the above bottom-fixed cases the same tower is used, starting at 15m a.s.l. and ensuring the hub-height of 150m a.s.l. The third alternative is a semisubmersible floating substructure for deeper waters (~200m) made from steel (see [5]). The floating substructure is accompanied by a new tower design too.

The key parameters of the three offshore support structures discussed above are given in Table 2.

Table 2: Key parameters for the Offshore Support Structures of the 15MW Reference Wind Turbine

Monopile Version (30m w.d.)		IEA 15-MW Turbine	Innwind.EU
Parameter	**Units**	**Value**	
Transition piece height	m	15	
Monopile length (from t.p. to seabed)	m	45	
Monopile embedment depth	m	45	
Monopile base diameter	m	10	
Tower mass	t	860	
Monopile mass	t	1,318	
Jacket Version (50m w.d.)		**IEA 15-MW Turbine**	**Innwind.EU**
Parameter	**Units**		**Value**
Transition piece height	m		15
Jachet length (from t.p. to seabed)	m		65
Piles embedment depth	m		
Jacket base diameter	m		
Tower mass	t		1,043
Jacket overall mass (incl. tp and piles)	t		2,700
Semisubmersible Floater (200m w.d.)		**IEA 15-MW Turbine**	**Innwind.EU**
Parameter	**Units**	**Value**	
Excursion1 (Length, Width, Height)	m	90.1, 102.1, 290.0	
Freeboard	m	15	
Draft	m	20	
Total System Mass (incl. ballast)	t	20,093	
Hull Steel Mass	t	3914	
Platform Mass (incl. ballast)	t	17,839	
Tower Mass	t	1,263	
RNA Mass	t	991	
Water Depth	m	200	
Mooring System	-	Three-line chain catenary	

For more details regarding the floating substructure, we quote below relevant expressions used by the reference [5] authors:

« This part is taken from the work performed by University of Maine (UMaine) VolturnUS-S on defining a reference floating wind turbine to support the International Energy Agency (IEA)-15-240-RWT 15-megawatt (MW) reference wind turbine. The reference floating offshore wind turbine comprises a floating semisubmersible platform, a chain catenary mooring system, a floating-specific tower, and a modified float-specific controller tuning. The semisubmersible is a generic steel version of the UMaine patented concrete floating foundation technology developed in collaboration with the U.S. Department of Energy. The reference platform is a four-column, steel semisubmersible. The arrangement of the hull comprises three 12.5-m-diameter buoyant columns radially spaced with centers that are 51.75 m from the tower's vertical axis. The platform-tower interface is atop a fourth buoyant column located at the center of the platform in the surge-sway plane. This central column is connected to the outer columns via three 12.5-m-wide-by-7.0-m-high rectangular bottom pontoons and three 0.9-m-diameter radial struts attached to the bottom and top of the buoyant columns, respectively. When on station, the total mass of the platform is 17,854 t, of which 3,914 t is structural steel, 2,540 t is fixed iron-ore-concrete ballast, divided equally and placed at the base of the three radial columns, 11,300 t is a seawater ballast that floods the majority of the three submerged pontoons, and a 100-t tower interface connection detail. When installed, the platform has a draft of 20 m with a 15-m freeboard to the upper deck of the columns. The completely assembled unit displaces 20,206 cubic meters (m3) of seawater (with an assumed density of 1,025 kilograms per cubic meter [kg/m3]), which consists of a 1,263-t (metric tonne) tower, a 991-t RNA, and a 17,839-t ballasted platform with 6,065 kilonewtons (kN) of mooring vertical pretension. The system has an assumed deployment depth of 200 m and is held on to the station by a three-line chain catenary mooring system. The lines of the spread catenary system span radially to anchors located 837.60 m from the tower's centerline. »

Part of the information provided above is summarized in *Table 3*.

Table 3: Key parameters for the Semisubmersible Platform and its Mooring system

Semisubmersible Platform Properties		
Parameter	**Units**	**Value**
Hull Displacement	m3	20206
Hull Steel Mass	t	3914
Tower Interface Mass	t	100
Ballast Mass (Fixed/Fluid)	t	2,540/11,300
Draft	m	20
Freeboard	m	15
Vertical Center of Gravity from SWL	m	-15
Vertical Center of Buoyancy from SWL	m	-14
Mooring System Properties		
Parameter	**Units**	**Value**
Mooring System Type	-	Chain Catenary
Line Type	-	R3 Studless Mooring Chain
Line Breaking Strength	kN	22,286
Number of Lines	-	3
Anchor Depth	m	200
Fairlead Depth	m	14
Anchor Radial Spacing	m	837.6
Fairlead Radial Spacing	m	58
Nominal Chain Diameter	mm	185
Dry Line Linear Density	kg/m	685
Extensional Stiffness	MN	3270
Line Unstretched Length	m	850
Fairlead Pretension	kN	2,437
Fairlead Angle from SWL	°	56.4

The floating platform design is illustrated in Figure 2.

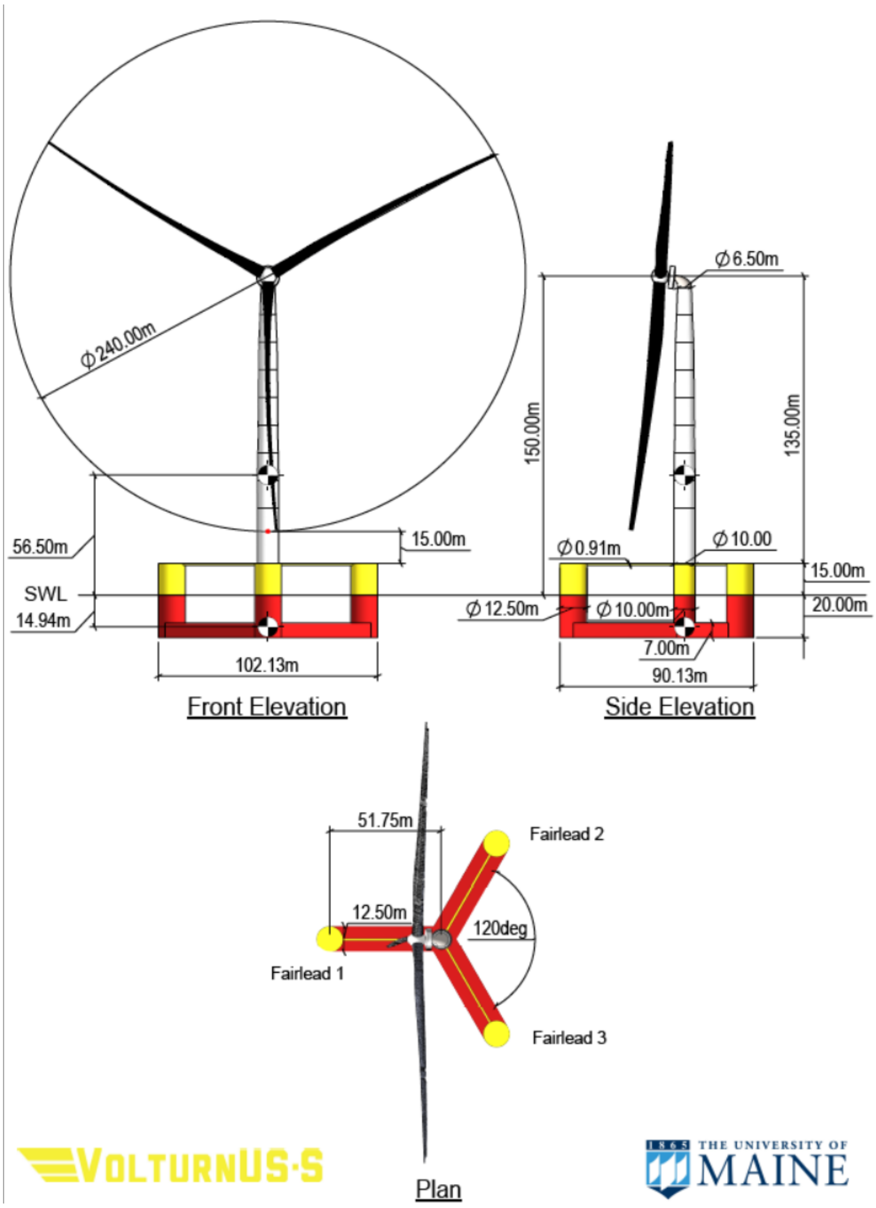

Figure 2: The 15MW floating support structure designed by the University of Maine (Source: [5])

4.2 SUBSYSTEMS' DETAILS AND STAGING NEEDS

In this chapter we provide further information at the subsystems level, addressing the 15MW reference wind turbine blades, drivetrain (and hub assembly) and tower (the floating tower in this case). For each subsystem we also evaluate its port staging needs in terms of its footprint (called "surface area") and its ground pressure. When the ground pressure is less than the affordable limit of the staging area, then the subsystems can be piled vertically to claim less space. This is, for instance, the blades case.

4.2.1 Blades

Important blade properties are listed in Table 4. The mass of 65.25t and the length 117m. The root diameter is 5.2m and the maximum chord 5.77m. The tip prebend is 4m. If the blade was to be stored in a box, the box dimensions would be the blade length, the maximum chord (as the width) and the root radius plus the tip prebend as the height. These dimensions are listed in Table 5. The footprint of the box (or surface area) is the product of its length and height. If the surface pressure of the box on the ground is assumed uniformly distributed, then its measure derives by dividing the blade weight by the surface area. The surface area and pressure are characteristic properties for the staging needs of the dry components of the reference wind turbine.

Table 4: Key parameters for the 15MW reference wind turbine blades

Blade Properties		
Parameter	**Units**	**Value**
Blade length	m	117
Root diameter	m	5.2
Root cylinder length	m	2.34
Max chord	m	5.77
Max chord spanwise position	m	27.2
Tip prebend	m	4
Precone	deg	4
Blade mass	t	65.25
Blade center of mass	m	26.8
Operational		
Design tip-speed ratio	-	9
First flapwise natural frequency	Hz	0.555
First edgewise natural frequency	Hz	0.642
Design CP	-	0.489
Design CT	-	0.799

Table 5: Staging needs for the 15MW reference wind turbine blades

Blade box dimensions & Weight		
Length	m	117
Width	m	6
Height	m	7
Weight	t	65.25
Surface Area	m2	675
Surface pressure	t/m2	0.10

4.2.2 Drivetrain and Hub

Similar considerations to those presented above for the blades apply for the drivetrain and the hub. Table 6 and Table 7 list the relevant values. Table 6 shows lamped masses for the nacelle assembly as provided in [1] and calculated using [4]. It is seen that the nacelle and hub masses estimated with two different approaches are quite close.

Table 6: Key parameters for the 15MW reference wind turbine drivetrain and hub

Lumped Masses for the Nacelle Assembly		**IEA 15-MW Turbine**	**Innwind.EU**
Name	**Units**	**Mass**	**Mass**
Yaw system	t	100	
Turret nose	>>	11	
Inner generator stator	>>	227	
Outer generator rotor	>>	145	
Shaft	>>	16	
Hub	>>	190	194
Bedplate	>>	70	58
Flanges and misc. equipment	>>	54	
Bearings	>>	8	
Nacelle total	>>	**821**	**869**
Nacelle total minus hub	>>	**631**	**675**
Main Shaft Dimensions and Bearings			
Description	**Units**	**Value**	
Shaft tilt angle	deg	6	
Length of main shaft	m	2.2	
Outer radius of the main shaft	m	3	
Inner radius of the main shaft	m	2.8	
Location of generator stator from bedplate flange	m	0.25	
Turret center of mass	m	1.2	
Distance of downwind bearing from bedplate flange	m	0.9	
Turret length	m	2.2	
Outer radius of the turret	m	2.2	
Inner radius of the turret	m	2	
Tapered double outer ring (TDO) mass	kg	2230	
Spherical roller bearing (SRB) mass	kg	5664	
Bedplate Properties			
Description	**Units**	**Value**	
Tower-top (bedplate base diameter)	m	6.5	
Bedplate wall thickness	mm	50	
Bedplate length w/o turret	m	8.3	
Bedplate mass	t	70.3	
Bedplate length with turret	m	10.5	
Bedplate width	m	6.5	
bedplate height	m	6.0	
Directdrive Generator Properties			
Description	**Units**	**Value**	
Air-gap radius	m	5.1	
Core length	m	2.2	
Generator mass	t	372	
Generator Diameter	m	13	
Generator height	m	4	
Hub Properties			
Diameter	m	7.94	

Table 7: Staging needs for the 15MW reference wind turbine drivetrain and hub

Nacelle-hub Assembly Dimensions & Weight		
Length	m	19
Width	m	13
Height	m	13
Weight	t	821
Surface Area	m2	245
Surface pressure	t/m2	3.35

4.2.3 Floating Tower

A similar analysis is performed for the floating tower and the outcome is shown in Table 8 and Table 9. The overall tower height is 129.5m comprising 10 parts of 13m each (except for the tower top part which is slightly shorter). Each part is flanged at its top and bottom area to be assembled with its neighbours. The top part supports the yaw ring and the bedplate above it. The mean weight of each of the 10 tower parts is 126.3t.

Table 8: Key parameters for the 15MW reference wind turbine floating tower

Floating Tower Properties		
Parameter	**Units**	**Value**
Mass	t	1,263
Length	m	129.5
Base Outer Diameter	m	10
Top Outer Diameter	m	6.5
Base thickness	mm	83.0
Top thickness	mm	21.2
No of substructures (flange to flange)	-	10
Length of sunstructures	m	13
1st Fore-Aft Bending Mode	Hz	0.496
1st Side-Side Bending Mode	Hz	0.483

Table 9: Staging needs for the 15MW reference wind turbine floating tower

Tower box dimensions & Weight		
No of sub-elements per tower	-	10
Length	m	13
Width	m	10
Height	m	10
Weight (mean value)	t	126.3
Surface Area	m2	130
Surface pressure	t/m2	0.97

5 HARBOUR NEEDS

5.1 REFERENCE TURBINE AND WIND FARM STAGING NEEDS

The staging needs for the dry parts of the reference turbine are summed up in Table 10. The net staging space needed per 15MW turbine when the individual subsystems are not piled-up is 3,570 m2. For 20 such turbines comprising the 300MW reference wind farm the net needed space is 71,408 m2. Assuming a 3.5 net to gross factor for the spacing needs, so that the individual pieces can be accessed and transported, the gross value of the staging space of the refence wind farm becomes 250,000 m2, or 25 Ha.

Table 10: Staging needs for the reference wind turbine and wind farm

NET STAGING NEEDS	m2
Per 15MW Turbine	3,570
3 Blades	2,025
Nacelle-hub	245
Tower	1,300
300MW Wind Farm (20 WTG)	71,408
Net to gross factor	**3.5**
300MW Wind Farm GROSS	250,000

5.2 SOIL BEARING CAPACITY

The highest value of surface pressure we have estimated for the dry components of the reference wind turbine is 3.35t/m2 for the nacelle-hub assembly, weighting 821 t. This surface pressure derives if the total weight will uniformly transfer to the ground, which is not true given the geometrical particularity of the substructure. We anticipate that the weight load will be undertaken by the ¼ of the projected area, leading to a soil bearing capacity of 4*3.35 ~ 13.5 t/m2. The soil bearing capacity of the areas where the blades and the tower substructures will be stored can be less.

Cranes will be needed for the assembly of the dry parts of the turbines. The heaviest single component to be lift-up is again the nacelle-hub assembly. It is anticipated that the soil bearing capacity under the crane-base area must be of the order of 35 t/m2.

5.3 DRAFT

Assuming that the floater with will be transferred with tag boats having the turbine assembled on top and its fixed ballast in place, the total system mass will be 8,700 t (fixed ballast 2,540 t, hull steel mass 3,140 t, tower mass 1,263 t and RNA 991t). The draft of the fully assembled and moored turbine is 20m where the total system mass, including the water ballast is 20,000 t. It is reasonable to assume that (the less than half-weighted) system during its transfer will have a draft around 10m. Adding a 2m margin to that, we come to a minimum harbour draft of 12m. Evidently, this minimum draft requirement refers to the considered floating platform. Different types of floating platforms may require higher or lower minimum draft values.

6 CONCLUSIONS

This report defines two typical Greek offshore wind farms and a reference turbine. The reference wind farms address medium (50m) and higher (200m) sea depths. The installed capacity is 300MW in both cases. The turbines offshore support structures are jackets in the first case and semisubmersible floaters with catenary mooring lines in the second. The metocean conditions assumed for the two cases are typical for Aegean Sea. The bottom-fixed site has a mean annual wind speed of 8.2m/s, significant wave height 0.8m and wave peak period 4.2s. The floating site is rougher, with mean annual wind speed of 9.6m/s, significant wave height of 1.2m and peak period 5.0s.

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Using the reference wind farm(s) and turbine characteristics one can obtain a set of prerequisites / technical specifications (weights, staging area, minimum water depth, etc) necessary for assessing the specific needs for harbours and the elements of the supply chain. It is seen, for instance, that the development of the 300MW reference wind farm an area of 25Ha is needed as a minimum for the staging of the dry wind turbines' components, the bearing capacity of the staging soil might need strengthening to host heavy equipment, while the exit from the harbour should support a minimum draft of 12m (it might be less for other floater designs and assembly practices).

References

1. Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info"
2. Soukissian, T., Hatzinaki, M., Korres, G., Papadopoulos, A., Kallos, G., Anadranistakis, E., 2007: Wind and Wave Atlas of the Hellenic Seas, Hellenic Centre for Marine Research Publ., 300 pp.
3. Gaertner, Evan, Jennifer Rinker, Latha Sethuraman, Frederik Zahle, Benjamin Anderson, Garrett Barter, Nikhar Abbas, Fanzhong Meng, Pietro Bortolotti, Witold Skrzypinski,,George Scott, Roland Feil, Henrik Bredmose, Katherine Dykes, Matt Shields, Christopher Allen, and Anthony Viselli. 2020. Definition of the IEA 15-Megawatt Offshore Reference Wind. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-75698. https://www.nrel.gov/docs/fy20osti/75698.pdf.
4. Deliverable 1.21 - INNWIND.EU Cost Model, http://www.innwind.eu/publications/deliverable-reports.
5. Allen, Christopher, Anthony Viselli, Habib Dagher, Andrew Goupee, Evan Gaertner, Nikhar Abbas, Matthew Hall, and Garrett Barter. Definition of the UMaine VolturnUS-S Reference Platform Developed for the IEA Wind 15-Megawatt Offshore Reference Wind Turbine. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-76773. https://www.nrel.gov/docs/fy20osti/76773.pdf.