GL Garrad Hassan

LOGISTICAL REQUIREMENTS FOR OFFSHORE WIND PORTS - SUMMARY

SUBTOPIC 5.1: U.S. PORTS ASSESSMENT

Client	U.S. Department of Energy
Contact	Michael Hahn, Gary Norton, Cash Fitzpatrick, Gretchen Andrus
Document No	700694-USPO-R-02
Issue	A
Status	Draft
Classification	Published
Date	19 July 2012

Author

C Garrett, T O'Neill, A Blatiak

Checked by

N Baldock

Approved by

N Baldock

Garrad Hassan America, Inc.

9665 Chesapeake Drive, Suite 435, San Diego, California USA
Phone: (858) 836-3370 | Fax: (858) 836-4069
www.gl-garradhassan.com

IMPORTANT NOTICE AND DISCLAIMER

1. Acceptance of this document by the Client is on the basis that Garrad Hassan America, Inc. (hereafter, "GL GH"), a GL Group member operating under the GL Garrad Hassan brand, is not in any way to be held responsible for the application or use made of the findings and the results of the analysis herein and that such responsibility remains with the Client.

   This Report shall be for the sole use of the Client for whom the Report is prepared. The document is subject to the terms of the Agreement between the Client and GL GH and should not be relied upon by third parties for any use whatsoever without the express written consent of GL GH. The Report may only be reproduced and circulated in accordance with the Document Classification and associated conditions stipulated in the Agreement, and may not be disclosed in any offering memorandum without the express written consent of GL GH.

   GL GH does not provide legal, regulatory, tax, insurance, or accounting advice. The Client must make its own arrangements for consulting in these areas.

   This document has been produced from information as of the date hereof and, where applicable, from information relating to dates and periods referred to in this document. The Report is subject to change without notice and for any reason including, but not limited to, changes in information, conclusion and directions from the Client.

2. This Report has been produced from information relating to dates and periods referred to herein. Any information contained in this Report is subject to change.

3. This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ACKNOWLEDGEMENT

This material is based upon work supported by the Department of Energy under Award Number DE-EE0005369.

KEY TO DOCUMENT CLASSIFICATION

Strictly Confidential	For disclosure only to named individuals within the Client's organization
Private and Confidential	For disclosure only to individuals directly concerned with the subject matter of the Report within the Client's organization
Commercial in Confidence	Not to be disclosed outside the Client's organization
GL GH only	Not to be disclosed to non-GL GH staff
Client's Discretion	Distribution for information only at the discretion of the Client (subject to the above Important Notice and Disclaimer)
Published	Available for information only to the general public (subject to the above Important Notice and Disclaimer)

REVISION HISTORY

Issue	Issue Date	Summary
A	19 July 2012	Initial issue

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 KEY REQUIREMENT SUMMARY

Component	Parameter	Wind Turbine Size [MW]				
		4	5	6	7	8
Wind Turbine	Blade length [m]	59	66	73	80	85
	Quayside for storage (one blade per frame – up to three blades) [m²]	363	440	527	615	696
	Nacelle and Frame Bearing Pressure [t/m²] [1]	7	8	10	7	8
	Tower Bearing Pressure [t/m²]	6	7	8	9	10
Foundation - Monopile	Monopile mass (20 m LAT depth) [t]	500	788	1076	-	-
	Bearing Pressure Under Storage Blocks [t/m²]	13	20	27	-	-
Foundation - Jacket	Bearing Pressure Under Storage Blocks [t/m²]	-	13	14	16	17
Foundation - Gravity Based Structure (GBS)	Total Mass Without Ballast [t]	-	-	5970	8009	9691
	Quayside Construction Area (per GBS) [m²]	-	-	3481	4398	5625
	Bearing Pressure (quayside construction and storage) [t/m²]	-	-	12	11	10
	Minimum Width of Dry Dock for Construction [m]	-	-	45	52	61
	Minimum Construction Barge Width [m]	-	-	43	50	59
Substation	Topside Mass	500 – 4000 Tonnes at approximately 6.5 tonnes per MW				
	Foundation	Generally same foundation as for turbines, or jacket if required				
	Bearing Pressure	Typically 2-9 t/m², dependant on design				

1 Metric tonnes used throughout

Table 1: Summary of Key Offshore Wind Project Component Specifications and Port Requirements

2 DETAILED REQUIREMENTS

Requirements are listed below for each component, with key requirements highlighted in blue.

2.1 Wind Turbine Generators

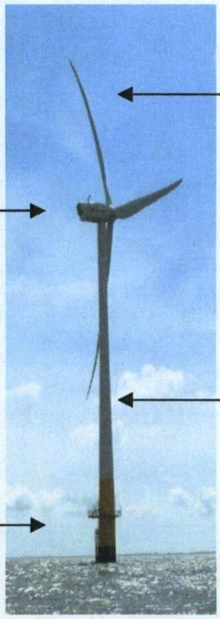


Figure 1: Major Components of an Offshore Wind Turbine

2.1.1 Turbine Blades

Parameter	Wind Turbine Size [MW]				
	4	5	6	7	8
Rotor diameter [m]	120	135	150	164	175
Hub diameter [m]	3	4	4	4	5
Blade length [m]	59	66	73	80	85
Blade mass [t]	19	23	28	34	40
Chord length [m]	4	5	5	6	6
Quayside for storage [1] [m^2]	363	440	527	615	696
Bearing area (2 contact blocks under frame) [m^2]	16	18	20	22	24
Bearing pressure under blocks (3 blades stacked) [t/m^2]	3.6	3.8	4.2	4.6	5.0
Fabrication workshop length [m]	69	76	83	90	95
Reinforced area for mobile crane load-outs (crane capacity) [t]	76	92	112	136	160
Haul route strength between quayside and storage [t/axle]	7.8	8.6	9.6	10.8	12
Haul route strength between quayside and storage [t/m^2]	10	10	10	10	10

2 Assumes 1 m buffer around blade

Table 2: Blade Specifications and Port Requirements

2.1.2 Nacelles

Parameter	Wind Turbine Size [MW] 4	5	6	7	8
Nacelle Mass [t]	162	239	330	390	450
Storage, Lift and Sea Lashing Frame Mass [t]	16	24	33	39	45
Nacelle and Frame Total Mass [t]	178	263	363	429	495
Nacelle Width [m]	5.2	6.3	7.4	8.5	9.6
Nacelle Length [m]	13	16	18	20	21
Nacelle Storage Area [1] [m^2]	111	146	185	226	270
Number of SPMT's	1	1	1	2	2
Number of Lengths of Baulk Timber	2	2	2	3	3
Nacelle Bearing Area [m^2]	27	31	35	59	64
Bearing Pressure (baulk timber under columns) [t/m^2]	7	8	10	7	8
Min Number of SPMT Axles for Nacelle	8	11	15	18	20

1 Assumes 1 m buffer around nacelle

Table 3: Nacelle Specifications and Port Requirements

2.1.3 Tower

Parameter	Wind Turbine Size [MW] 4	5	6	7	8
Tower length [m]	66	74	81	88	94
Tower Mass [t]	185	215	250	280	310
Tower Diameter [m]	5.00	5.50	6.00	6.25	6.75
Number of sections	2	2	2	2	2
Section length [m]	33	37	41	44	47
Section mass [t]	93	108	125	140	155
Storage Area per Section [1] [m^2]	245	291	340	380	427
Bearing Area [m^2]	16	16	16	16	16
Bearing Pressure [t/m^2]	6	7	8	9	10

1 Assumes 1 m buffer around tower section (laid down)

Table 4: Tower Specifications and Port Requirements

2.2 Wind Turbine Support Structures

2.2.1 Monopiles

www.weldex.co.uk

Figure 2: Monopile Transportation on the Quay

Design Depth	Parameter	Wind Turbine Size [MW] 4	5	6
-	TP (Transition Piece) mass [t]	280	415	550
	TP min number of SPMT axles	12	17	22
	TP Storage Area [1] [m²]	82	91	101
	TP Bearing Area [m²]	11	12	13
	TP Bearing Pressure [t/m²]	25	35	42
20	Monopile mass [t]	500	788	1076
	Monopile min number of SPMT axles	20	32	44
	Monopile Base Diameter [m]	5.5	6	6.5
	Length [m]	56	61	66
	Storage Area [2] [m²]	435	504	578
	Total Bearing Area (10 block supports) [m²]	40	40	40
	Bearing Pressure Under Blocks [t/m²]	13	20	27
30	Monopile mass [t]	675	1070	1464
	Monopile min number of SPMT axles	27	43	59
	Monopile Base Diameter [m]	6	6.5	7
	Length [m]	69	74	79
	Storage Area [m²]	568	646	729
	Total Bearing Area (10 column supports) [t/m²]	40	40	40
	Bearing Pressure Under Blocks [t/m²]	17	27	37

1 Assumes 1.5 m around TP to account for walkway, then 20 % buffer in addition
2 Assumes 1 m buffer around monopile

Table 5: Monopile Specifications and Port Requirements

2.2.2 Jackets

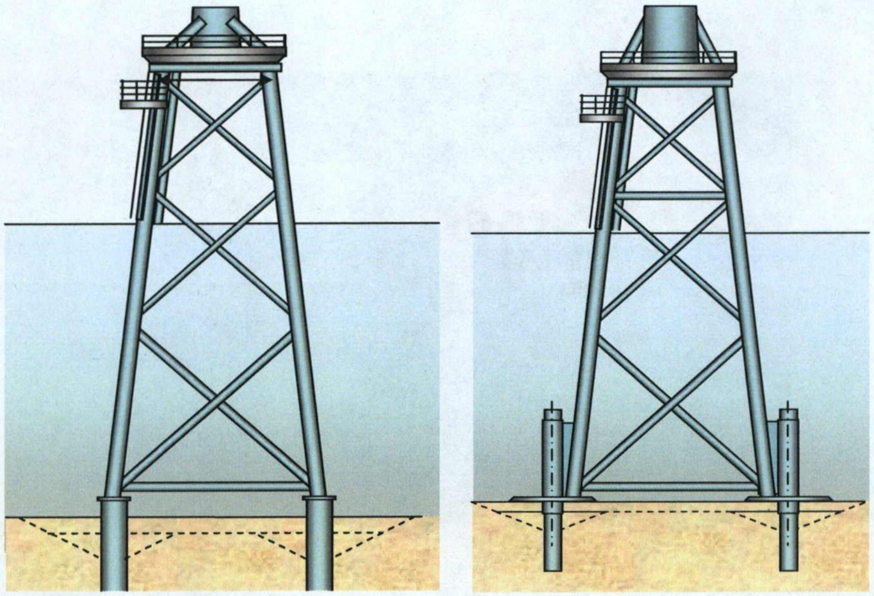


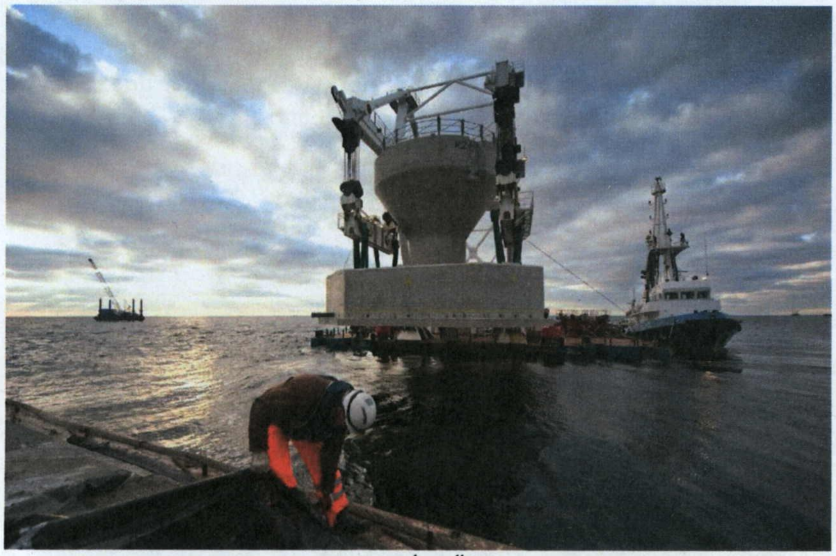
Figure 3: Wind Turbine Substructure Concept – Jacket (pre-piled & post-piled)

Parameter	Wind Turbine Size [MW]			
	5	6	7	8
Jacket Mass [t]	609	684	759	834
Pin Piles (4) Mass [t]	284	328	372	416
Number of SPMT axles	25	28	31	34
Jacket Leg Separation [m]	25	23	20	18
Height (leg base to TP) [m]	58	58	58	58
Storage Area (Laid down) [m^2]	1740	1601	1392	1253
Storage Area (Standing) [m^2]	750	635	480	389
Bearing Area (4 block supports to distribute load) [m^2]	48	48	48	48
Bearing Pressure Under Blocks [t/m^2]	13	14	16	17

1 Assumes a further 20 % buffer around storage area

Table 6: Example Jacket Specifications and Port Requirements for 40 m Design Depth

2.2.3 Gravity Based Structures (GBS)



www.lorc.dk

Figure 4 : GBS Lift-off a Construction Barge using Eide 5 Heavy Lift Barge

Table 7 displays generic specifications of GBS at an assumed design depth of 40 m, or typically 30 m depth at the lowest astronomical tide.

Parameter Type	Parameter	Wind Turbine Size [MW]		
		6	7	8
General	Total Mass Without Ballast [t]	5970	8009	9691
	Diameter [m]	39	46	55
	Area of Base [m^2]	1260	1777	2506
Quayside Construction	Clearance around base during construction [m]	10	10	10
	Construction Area (per GBS) [m^2]	3481	4398	5625
	Bearing Area (quayside construction and storage)[1] [m^2]	504	711	1002
	Bearing Pressure (quayside construction and storage) [t/m^2]	12	11	10
	Number of SPMT axles required to transport GBS	239	320	388
Dry Dock Construction	Un-ballasted Bearing Pressure Distributed [t/m^2]	5	5	4
	Clearance around base during dry dock construction [m]	3	3	3
	Minimum Width of Dry Dock [m]	45	52	61
Barge Construction	Clearance around base during barge construction [m]	2	2	2
	Minimum Barge Width [m]	43	50	59
	Barge Length [m]	100	100	100
	Harbour Area (per barge) [m^2]	4300	5031	5900
	Barge Draft [m]	5	5	5

1 Assumes that the mass of the structure rests on storage blocks that cover 40% of the area

Table 7: GBS Specifications and Port Requirements for 40 m Design Depth

2.3 Offshore Electrical Substation Topsides

Topsides are extremely large and are generally assembled on a frame so that SPMT's can be manoeuvred underneath the substation to jack up and roll the topside to the quayside. Substations typically rest on a jacket foundation (Section 2.2.2), though the foundations will taper less due to the large area of the substation and will have masses in the region of 600 to 1500 tonnes.

www.dongenergy.com

Figure 5 : Substation Assembled in Port

It is important to note that extremely large projects have begun to utilize multiple offshore substations, in particular when converting to HVDC as shown by the two Bard substations in the table below.

Project	Total Power [MW]	Type	Mass [t]	Length [m]	Width [m]	Bearing Area [m^2][1]	Bearing Pressure [t/m^2]
Anholt	400	AC	1800	43	27	581	3.1
Bard - Bard1	400	AC	3400	42	42	882	3.9
Bard- Borwin 1	400	HVDC	3200	50	33.5	838	3.8
Barrow	90	AC	440	23	15	173	2.6
Gunfleet 1 +2	172	AC	1315	20	30	300	4.4
Lincs	270	AC	2250	35.3	31.7	560	4.0
Thanet	300	AC	1460	27	30	405	3.6
Thornton Bank 2	325.2	AC	2000	45	45	1013	2.0
Walney 1	183.6	AC	1300	13	23	150	8.7

1 Assumes that the mass of the structure rests on storage blocks that cover 50% of the area

Table 8: Example Substation Topside Specifications and Port Requirements

2.4 Offshore Electrical Substation Foundation

These are typically jackets in all but the shallowest water.

Project	Foundation Type	Foundation Mass [t]	Water Depth [m]	Foundation Height [m]	Overhead Clearance [m]	Storage Area (Standing) [m^2]	Bearing Area [m^2]	Bearing Pressure Under Blocks [t/m^2]
Bard- Borwin 1	Jacket	1700	40	60	65	1200	48	35
Lincs	Jacket	970	12.4	32.4	37.4	400	48	20
Thanet	Jacket	820	22.5	42.5	47.5	600	48	17
Thornton Bank 2	Jacket	550	19.8	39.8	44.8	1200	48	11
Walney 1	Jacket	1000	23.5	58.5	63.5	900	48	21

Table 9: Example Substation Foundation Specifications