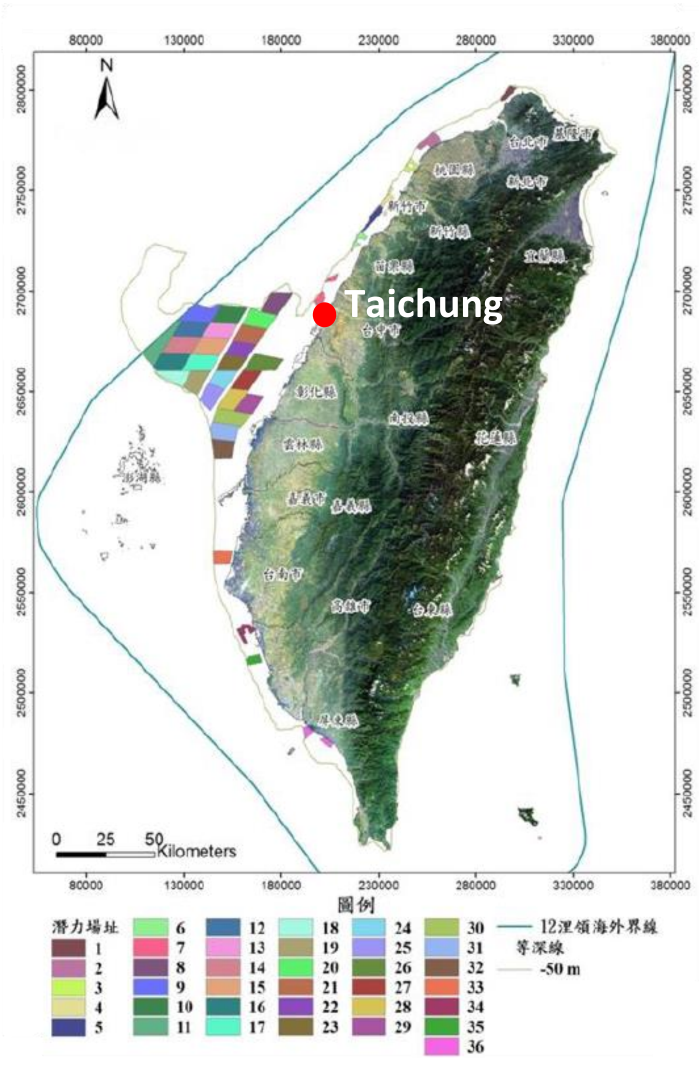
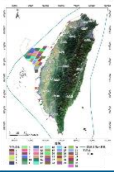
Offshore Wind Port Feasibility Study of Taichung Harbor, Taiwan



Final Report
December 2016

This page is intentionally left blank

Offshore Wind Port Feasibility Study of Taichung Harbor, Taiwan



Location of offshore development zones, Taiwan. Image ITRI

Prepared for	Offshoreenergy.dk and ITRI
Represented by	Mr Morten Basse Jensen and Wei-Hsien Lu

Authors	Morten Basse Jensen, NSG Wind A/S Henrik Kofoed-Hansen, DHI Arne Hansen, NIRAS A/S Lars Mohr Christensen, Port of Grenaa Ltd Mogens Hess and Anders Jørgensen, DIS Marina Hsu, TC Taipei

Date	20 December 2016
Revision	FINAL 1.0
Classification	With restrictions (see below Copyright and Disclaimer clause)

This page is intentionally left blank

CONTENTS

APPENDICES

FIGURES

TABLES

LIST OF ABBREVIATIONS

Abbreviations - General	
MSL	Mean Sea Level
SWL	Still Water Level
CD	Chart datum
CTV	Crew transfer vessel
TWVD2001	Taiwan Vertical Datum 2001, see https://www.nlsc.gov.tw/En/MakePage/154?level=154
HAT	Highest astronomical tide
LAT	Lowest astronomical tide
MHWS	Mean high water spring
MHWN	Mean high water neap
MLWN	Mean low water neap
MLWS	Mean low water spring
OEM	Original equipment manufacturer
CTV	Crew Transfer Vessel
PPE	Personal protective equipment
SLR	Sea Level Rise
WTG	Wind Turbine Generator
WT	Wind Turbine
CECI	CECI Engineering Consultants Inc, Taiwan
BoE	Bureau of Energy, Taiwan
ITRI	Industrial Technology Research Institute of Taiwan
TPIC	Taiwan International Ports Corporation Ltd
TP	Transition Piece
SPMT	Self-Propelled Modular Trailers
PU	Power Unit
TU	Transformer Unit

Abbreviations – Parameters	Description	Unit
D_{10}	Wind direction at 10m height	deg. N, coming from
$H_{1/3}$, H_{m0}	Significant wave height	m
H_{max}	Maximum individual wave height	m
CS	Current speed	m/s
MWD	Mean wave direction	deg. N, coming from
PWD	Peak wave direction	Rad. N, coming from
T_p	Peak wave direction	s
T_{02}	Mean wave period	s
$T_{1/3}$	Significant wave period	s
U_{10}	Wind speed at 10m height (10 min. mean)	m/s

ACKNOWLEDGMENTS

The Port Consortium wishes to thank the following people and organisations for their contributions, fruitful discussion and feedback to the work behind this report:

Wei-Hsien Lu, ITRI
Yung-Shun Lien, ITRI
Yan Syun Lin, ITRI
Chu-Kuan Lin, CECI
Zhen-Kai Huang, CECI
Svend Brogaard, Siemens Wind Power A/S
Anders Midskov, Siemens Wind Power A/S
Tony Lu, Siemens Limited, Wind Power Renewable Division
Henrik Thorn, Siemens Ltd., China, Wind Power Renewable Division
André Jacobsen, NIRAS A/S
Walter Vang Vallentin, MHI Vestas Offshore Wind A/S
Adrian Botwright, MHI Vestas Offshore Wind A/S
Nicholas Enersen, Trade Council of Denmark
Svend Roed Nielsen, Trade Council of Denmark, HVO Office
Hans Schneider, Consultant

1 Introduction

Taiwan's Renewable Energy Development Act was promulgated in 2009. Taiwan Ministry of Economic Affairs, the Bureau of Energy (BoE) set the national installed capacity goal for offshore wind: 16MW by 2016, 520MW by 2020 and 3.0GW by 2025.

In a national renewable energy investment meeting mid-August 2015, Taiwan Ministry of Economic Affairs (MoEA) officially released 36 new adjacent development zones with 100MW per zone to boost the investment prospect in Taiwan. In accordance, Taiwan MoEA estimated the overall investment prospect during 2015-2020 for offshore wind in total, covering from turbine to Balance of Plant, will be DKK 18.5 billion.

Taiwan has excellent wind resources with estimated annual full load hour at 3200-3400 hours, with some areas even up to 4000 hours, that is totally comparable if not better than the North Sea in Europe. Taiwan's legal framework for offshore wind has been well in place since 2009. Taiwan established a 20-year Feed-in Tariff (FiT) model with a transparent pricing committee, and currently the FiT is set at USD 18.5 cents/kWh. Two private developers were awarded BoE's Demonstration Incentive Programme. The programme awarded the developers a grant to compensate their front-end development cost and will provide 50% CAPEX on the first two pilot turbines installed.

The biggest infrastructure challenge in Taiwan in offshore wind development is the lack of designated, purpose-built port(s). Without such ports(such as Port of Esbjerg and Port of Grenaa in Denmark), construction and installation cannot efficiently take place. Meanwhile, the lack of proper quay areas is another issue, which makes the storage of sub-sea structures, transition piece, towers and blades not feasible and corresponding logistics and on-shore transportation non-existing.

Figure 1.1 Taichung Harbor, Taiwan. Image provided by TPIC

Taiwan BoE started to work on this issue through cross-ministerial communication with Ministry of Transportation responsible for port management. During September 2-4, 2015, TC Taipei together with Offshoreenergy.dk coordinated a visit to Esbjerg and an elaborated presentation on Port of Grenaa's planning and management for Taiwan BoE and its offshore wind delegation in Denmark.

This led to a positive outcome, and consequently Taiwan BoE requested TC Taipei to form a consortium from Denmark to assist Taiwan on port planning.

Assisted by TC Taipei, Offshoreenergy.dk applied for Danish Foreign Ministry grant under the HVO programme to form a Danish Port Consortium to deliver a Feasibility Study Project to Taiwan BoE.

The HVO grant was approved and Taiwan BoE has supplemented the grant significantly.

The Feasibility Study Project

The project is structured in two contracts:

Contract 1: Feasibility Study
Contract 2: Presentation Workshop

The purpose of the Feasibility Study Project was to transfer Denmark's 30 years of lessons-learnt on offshore wind, combined with Denmark's purpose-built offshore port management experience, and translate the knowledge into Taiwan's offshore wind development conditions.

The expected outcome is a feasibility study, which will serve as recommendations to engineering design and build of Taiwan's own purpose-built offshore wind port.

1.1 Port Consortium Partners

The consortium consists of the following partners and the liaison partner Offshoreenergy.dk:

Offshoreenergy.dk

Offshoreenergy.dk (OEDK) is the Danish national innovation centre and cluster organisation for offshore oil and gas and offshore wind. OEDK has a broad experience within the offshore wind industry particularly related to the installation and O&M process and the requirements for infrastructure facilities onshore and offshore.

NIRAS A/S

NIRAS is an independent self-owned multidisciplinary consultancy firm founded in 1956, presently with corporate offices in more than 10 countries and on-going operations in more than 85 countries worldwide. NIRAS has at its disposal in-house expertise within basically all technical fields related to environment, infrastructure, building and industry development, energy, climate change, management and capacity development.

DHI

DHI is an independent, international consulting and research-based company established in Denmark 1964 and today represented in all regions of the world in more than 30 offices. DHI's objectives are to advance technological development and competence within the fields of water, environment and health. DHI offers a wide range of consulting services and leading edge technologies and software tools. DHI offers specialised consulting services to companies and authorities within terminal and port planning, design, construction and operations. DHI's main working areas are port and hydraulic engineering and environmental conditions. In addition to that, DHI has been a pioneer in offshore wind technology since 1991. More than 85% of the commissioned European offshore wind farms have had a DHI input.

DIS

DIS delivers consulting and turnkey solutions in product development as well as unique machinery for some of the largest and most innovative wind companies in the industry sector. Today, DIS has more than 250 dedicated and highly competent employees at six different locations in Denmark, Germany and Norway.

Port of Grenaa Ltd

With an optimal location and a large-size capacity and years of experience with bulk goods, offshore projects and loadings, the Port of Grenaa (PoG) has a leading position as one of the largest industry and offshore port in Denmark. PoG provides services to the offshore and onshore wind turbine industry and the oil and gas industry and knows what it takes in terms of space at the hinterland and at quayside, water depth, infrastructure and separation from residential area.

PoG has demonstrated its huge capacity as a pre-assembly, load-out and O&M port for the Anholt Offshore Wind Farm project and that the port has the capability and the process knowledge for very large-scale projects.

1.2 Feasibility project process

The working process was a conventional project process where Offshoreenergy.dk representative was acting as project manager and TC Taipei as liaison partner and coordinator in Taiwan.

The working process consisted of four basic sub-processes:

- **Fact finding**
  Executed as study trips to Taiwan (November 2015 and January 2016)
- **Analysis, design and budgeting**
  Desktop work and project meeting within the Port Consortium
- **Coordination with ITRI and other stakeholders**
  E-mail correspondence, phone conversations, physical and skype meetings with ITRI, TC Taipei and other stakeholders
- **Results presentation**
  Executed a workshop with the customer and stakeholders in Taiwan (October 2016)

This page is left blank intentionally.

2 Executive Summary

Taiwan's Renewable Energy Development Act was promulgated in 2009. Taiwan Ministry of Economic Affairs, the Bureau of Energy (BoE) set the national installed capacity goal for offshore wind: 16MW by 2016, 520MW by 2020 and 3.0GW by 2025.

In recent national renewable energy investment meeting mid-August 2015, Taiwan Ministry of Economic Affairs (MoEA) officially released 36 new adjacent development zones with 100MW per zone to boost the investment prospect in Taiwan.

Two private developers were awarded BoE's Demonstration Incentive Programme. The programme awarded the developers a grant to compensate their front-end development cost and will provide 50% CAPEX on the first two pilot turbines installed.

One of the biggest infrastructure challenges in Taiwan in offshore wind development is the lack of designated, purpose-built port(s). Without such ports (such as Port of Esbjerg and Port of Grenaa, Denmark), construction and installation cannot efficiently take place. Meanwhile, the lack of proper quay areas is another issue, which makes the storage of sub-sea structures, transition piece, towers and blades, not feasible and corresponding logistics and on-shore transportation non-existing.

Cross-ministerial communication in Taiwan, trans-governmental and trans-industrial exchanges between Taiwan and Denmark led to Taiwan BoE requested to Danish TC Taipei to form a consortium from Denmark to assist Taiwan on port planning.

Assisted by TC Taipei, Offshoreenergy.dk formed a Danish Port Consortium to deliver a Feasibility Study Project to Taiwan BoE.

The purpose of The Feasibility Study Project was to transfer Denmark's 30 years of lessons-learnt on offshore wind, combined with Denmark's purpose-built offshore port management experience, and translate the knowledge into Taiwan's offshore wind development conditions. The expected outcome is a feasibility study, which will serve as recommendations to engineering design and build of Taiwan's own purpose-built offshore wind port.

The project is structured in two contracts:

Contract 1: Feasibility Study
Contract 2: Presentation Workshop in Taiwan

Feasibility Study Assumptions

The initial analysis of the feasibility study has determined the market demand for operational capacity and basic assumptions from BoE, evaluated the existing port specifications and environmental load specifications. These basic assumptions and specification of the existing port capacity and infrastructure have been compared with best practice extracted from substantial offshore wind experience in Denmark ranging from single project port operation to multiple project hub operation.

This analysis and comparisons have led to the following preliminary conclusion:

It is clearly seen from the comparison between BoE basic assumptions and the baseline design specification that the gap between them is significant, and the Port Consortium concludes that the BoE basic assumptions are not feasible for the future development of Taichung Harbor.

This has led to a customer review and detailed discussions to determine a way forward in order to be able to provide a feasible port design, which will accommodate the planned build programme and the highest possible compliance with the BoE basic assumptions.

The decision based on these discussions was to divide the feasibility study into three steps based on the possible 3-step development plan provided to the Port Consortium by BoE and ITRI.

Furthermore, it was decided to hold a stakeholder meeting in order to inform about and engage the offshore wind stakeholders in Taiwan in the future development of Taichung Harbor.

The development plan for Taichung Harbor is based on expansion of the offshore wind project area in three steps in order to meet the baseline design requirements best possible in the future and at the same time to support the build programme starting in April 2018.

The three steps are defined as follows:

- **Step 1 design** => 2018: The possible layout combining WTG and foundations
- **Step 2 design** => 2019: Improvement by removing buildings and expanding space – expand site
- **Step 3 design** => 2020: Improvements by removing buildings and expanding space – expand site

Environmental load conditions

The weather and marine water in the Taiwan Strait and at Taichung Harbor are dominated by the East Asia monsoon, from northeast in winter and from southwest in summer. The annual mean wind speed is 9-10m/s. As the southwest monsoon is significantly weaker than the northeast monsoon, the 6-month period April-September is considered as a feasible installation window.

Located on the west edge of the western North Pacific, typhoons form frequently. Those typhoons determine the extreme environmental design criteria to be used for design and operation of offshore wind farms and related infrastructures. Mean wind speed exceeding 40m/s is not unusual in Taichung, and often associated with heavy precipitation. Those two parameters are most likely key design drivers for pre-assembled towers, design of an appropriate drainage system and other infrastructures.

The tide in Taichung Harbor is of semi-diurnal type with a tidal range of approximately 5.4m. The maximum recorded surge height in Taichung Harbor is 0.54m. The tidal dominated currents in the port basin are considered relatively weak.

Very high waves have been measured at the entrance to the Port of Taichung (caused by passing typhoons). As the quays are located in a basin well protected against incident waves, offshore wind-generated waves and swell are not considered to impact vessel operability significantly.

For detailed design, more accurate environmental criteria need to be established.

Feasibility of Step 1 Development Plan

Step 1 Development Plan comprises the Quays 4C, 5B and 5A and the associated back area and connected infrastructure plus the back area behind the building at Quay 5, see Appendix C-2 2018 Step 1.

The size of the port basin is sufficient to ensure an efficient and safe navigation towards Quays 5A and 5B. The water depth at Quay 5A (11mCD) is sufficient for existing vessels, but dredging is required at Quay 5B as the present depth is significantly smaller and unknown. The present quay lengths are sufficient to support berthing of modern offshore wind vessels.

As the present seabed does not support jacking up for loadout, the costs of upgrading the seabed shall be encountered. Alternatively, floating loadout may be considered.

The following conclusions have been made by the Consortium in respect to design criteria:

a. The quay in sections 5A and 5B should be aligned. The new quay front is assumed to be at a short distance in front of the existing alignment of Quay 5A. This alignment will facilitate construction works and will not reduce the basin width more than absolutely necessary. Consequently, the existing short section that protrudes at the intersection 5A/5B shall be demolished.

b. A quay level of +6.5mCD is recommended as compared to the existing level of +6.2mCD in order to prepare for future sea level rise.

c. A navigable water depth of 11mCD, similar to present depth in the main part of the existing basin, should be provided. This depth will possibly allow for construction of stone beds for jacking up with an anticipated surface level of -9-10mCD. The delimitation of the extended 11m-basin towards adjoining quay structures other than 5B shall be considered in the detailed design in terms of structural stability of existing quays.

d. Load requirements in offshore wind terminal shall be defined to meet all foreseeable peak loads now and in the future. The Consortium recommends the following loads for the preliminary design of new or upgraded quay structures:

   - Uniform quay load: 150kN/m^2
   - Belt pressure/ WT-components: 600-800kN/m^2 within an area of 3.0x3.0m^2

A completely new quay structure will be required in section 5B.

In section 5A, a significant upgrading will be required for this quay to meet load requirements for WT-operations as proposed in the previous section of this report.

Compliance with an anticipated tight construction schedule is a precondition for choice of structural solution. The Consortium therefore recommends one basically consistent design along the entire quay 5A/5B.

Jacking manoeuvres imply significant penetration of jacking legs into the seabed (~2-5m) a short distance in front of the quay structure. Such penetration into existing sand/silt layers should be accounted for in the design of the quay structure and could, moreover, result in an irregular seabed that in the worst case represents a risk of damage to jacking-up legs. Therefore, purpose-made stone beds are often installed on the seabed to provide controlled jacking conditions and to limit leg penetrations.

WTG components should be stored in the harbour quay area in a way allowing transportation to be done without obstacles using the required vehicles (heavy lifter, SPMT, etc.). In addition, minor areas for final assembly of i.e. hub on nacelle are necessary, as the components may arrive separately by sea.

The Step 1 pre-assembly layout includes both WTG components and monopile foundations. It will be necessary to have a remote storage facility for monopiles and transition pieces due to the large size of these.

The conceptual pre-assembly layout and the project scenarios for Step 1 (2018) presented in this report are based on the following assumptions:

- A capacity of 30 x 4MW turbines and corresponding monopile foundations
- Applicable for one project and one OEM considered

- The monopiles must be stored in remote facilities, while the transition pieces are stored in the harbour area
- Blades are double-stacked in order to fit all components into the area
- Load-out area is also used for in-load of components coming from sea
- 2 x four-packs are required towards the quay edge in order to assemble the towers prior to load-out
- Indoor, insulated storage facilities are required for electrical components and other components that require protection
- The outer end of Quay 4C is used for crew transfer area, and must be designed for CTV, welfare buildings, PPE storage, etc.
- The perimeter of the area must be secured including controlled access

Feasibility of Steps 2 and 3 – FINAL Design

It has been a very interesting and challenging task for the Danish Port Consortium to undertake a feasibility study for the development of a wind hub in Taichung Harbor.

It has involved a very dedicated and competent collaboration with ITRI and CECI, and it has received a significant interest from BoE in particular as well as from the offshore wind industry and other stakeholders in Taiwan.

We have also experienced a continuous and increasing interest from the Port Authority and an admirable increasing flexibility and determination in terms of finding ways of developing the available space for the development of an offshore wind hub for the Taiwanese Offshore Wind development. This plays an important role in achieving the objectives for the FINAL design.

Conclusions

Based on our studies, environmental load and structural analysis, design and layout considerations and our financial analysis, we have concluded the following:

Port basin and vessel berthing/operation

The size and layout of the port basin are assessed sufficient to ensure an efficient and safe navigation. The water depths are larger than 11mCD west of Quay 5B, which is deemed adequate for modern installation vessels.

As the present seabed does not support jack-up operations, purpose-made stone beds have to be constructed to ensure controlled jacking conditions and to limit leg penetrations. Alternatively, floating loadout may be considered. The feasibly of this option has not been considered.

Quays

According to information made available to the Port Consortium, the quay structures in berth nos. 5-8 are substantially identical to those in Quay 5A. The quays are open piled structures with a RC deck structure of bearing capacity ~30kN/m^2.

In order to fulfil load requirements in an offshore wind terminal, the Port Consortium recommends the following loads:

- Uniform quay load 150kN/m^2
- Belt pressure/ WT-components 600-800kN/m^2 within an area of 3.0x3.0m^2

The proposed amendment means that the previously discussed upgrading/construction of quay structures in Section 5B will not be needed.

The present bearing capacity of 3t/m^2 is assumed sufficient to meet the requirement for the intended use of the apron at berth nos. 5B and 8 for stacking of WTG-wings.

Assembly area and layout

Provided the above conclusions, it is feasible to design and build a dual project offshore wind hub in Taichung Harbor with a load capacity of 100 WTG within the assumed 6-month operational window. It is, however, not feasible to mix the WTG assembly and load-out with final assembly and load-out of foundations. As an interim solution, and until another site has been developed, monopile foundations can be loaded out from Taichung Harbor for projects in 2018 and 2019.

The Port Consortium has shown in its proposed FINAL design how the layout of the offshore wind hub can be designed. We have also shown how the overall transport infrastructure can be planned to fulfil the basic assumptions made by BoE. The FINAL design requires a total area of 271,000m^2 at the Quays 4C, 5B, 5A, 5, 6, 7 and 8.

Assembly, storage and administration buildings

In order to make the layout feasible, it will be necessary to remove all existing buildings from the area of Quays 5, 6 and 8 and build seven new buildings with a total covered area of 9,350m^2.

The building requirements are particularly affected by the basic assumption that the site must host minimum two separate projects at time.

Support installations and equipment

A number of installations need to be made, none of them particular challenging to the local industry, which is why we conclude that this will just be a matter of initiating the detailed design and the following construction. It is also concluded that the development of flexible tower packs will contribute to cost reduction and increased efficiency of the site.

The provided equipment list is for reference; however, the conclusion is that the current heavy lifting capacity in Taiwan will most likely struggle to deliver adequate equipment for this site.

Financial investment for FINAL layout

The total investments required are estimated to:

Quays and seabed:	~35 MUSD
Surface:	~27 MUSD
Process equipment:	~ 3 MUSD
Total	~65 MUSD

Excluding other auxiliary equipment (as specified), site investigation, design studies, tendering process, etc.

Recommendations

In the light of the developments of the political and industrial support of the renewable energy in Taiwan, and the offshore wind development in particular, and based on our findings in the feasibility study, The Danish Port Consortium recommends the Taiwanese Bureau of Energy to do the following:

- To initiate the build project for the basic infrastructure immediately
- To build Step 1 and continue directly towards the FINAL layout
- Seabed to be reinforced for multiple jack-up vessels
- To utilize Quays 4C, 5B, 5A, 5, 6, 7 and 8 and follow the FINAL design layout concept to minimize cost as much as possible and still meet the required capacity
- When fully built, to use Taichung Harbor for WTG assembly and load-out only and to explore the development of flexible tower packs
- To secure governmental investments in the basic infrastructure
- To identify Public/Private operator investments in auxiliary infrastructure.

This page is left blank intentionally.

3 Feasibility Study Assumptions

The purpose of the feasibility study assumptions is to determine the market demand for operational capacity and basic assumptions from BoE and to evaluate the existing port specifications and environmental load specifications. Once this has been completed, the basic assumptions and specifications of the existing port capacity and infrastructure will be compared to best operating practice extracted by the Port Consortium from the substantial offshore wind experience in Denmark ranging from single project port operation to multiple project hub operation.

The above analysis and comparisons will result in engineering design specifications, which will be input to the final analysis, design and budgeting phase of the project.

3.1 Taiwan Offshore Wind Policy (Ref. Appendix A)

Taiwan's Renewable Energy Development Act was promulgated in 2009 and has set the national installed capacity goal for offshore wind: 16MW by 2016, 520MW by 2020 and 3.0GW by 2025.

The recent change in government has increased attention to the development of renewable energy in Taiwan in general and to offshore wind in particular. International and global developers have now supplemented national developers, and the Taiwanese offshore wind development has become one of the most promising new markets in the world.

It is assumed that an increased goal of close to 500MW by 2020 is not unrealistic as a short-term market volume, which constitutes a build demand of roughly 120 turbines and hence 60 turbines per year in 2018 and 2019 based on a turbine output capacity of 4MW.

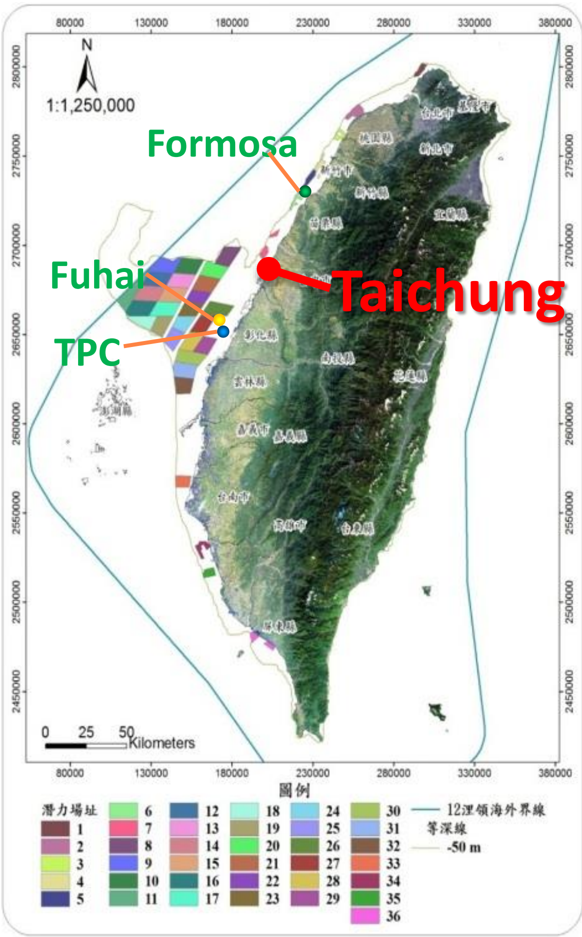
With a further target of approximately 3GW over 10 years from 2016 to 2025, the build demand is approximately 40 turbines based on an average turbine capacity of 8MW. All in all, a very positive outlook and platform for the demands for planning, construction and O&M within offshore wind development in Taiwan.

One of the biggest infrastructure challenges in Taiwan's offshore wind development is the lack of designated, purpose-built port(s). Without such adequate port capability, pre-assembly and installation cannot properly take place in an effective way.

Furthermore, the lack of proper quay capability, operating and storage area near the quay makes the handling and storage of sub-sea structures, transition pieces and WTG components, not feasible and corresponding logistics and on-shore transportation very challenging.

Offshore Wind Port Planning

Taichung Harbor has the best potential considering the distance to sites, water depth and overall features of the Taiwan west coast ports.



Potential Zones near Taichung Harbour

Taichung Harbour (Source TIPC 2014)

Potential Zones near Taichung Harbour

Key parameters for the preliminary planning:

- **Quay #2**
  - **Available**
  - **4 WTGs of DIP by 2016**
- **Quay #5A & #5B**
  - **Need to be constructed**
  - **200~300 MW/yr 2019~2025**
    - **4 quays at Northern breakwater**
  - **Need to be constructed**
  - **300~400 MW/year 2026~2030**
    - **Green Energy Industrial Park**
  - **74 ha**
  - **Reserved for offshore wind manufacturing facilities**

Bureau of Energy (BoE) basic feasibility study assumptions

Based on the above policy and the port planning presentations, BoE has specified the following basic feasibility study assumptions to the Port Consortium:

- Capacity: 60WTG per year
- Capacity split: 50WTG 4MW + 10WTG 6MW
- Scope of assembly: WTG and foundations
- Weather window: 6 months offshore – April to September
- Design Option: 1: two parallel projects – **one** OEM
- Design Option: 2: two parallel projects – **two** OEM's
- Available area: Quay 5A, 5B will be used

3.2 Best practice for pre-assembly and logistic operation

The purpose of this section is to present the best practice operation from Denmark, which will then be compared to the existing port specifications with the view to determine the engineering design specifications, which will be input to the final analysis, design and budgeting phase of the project.

Best practices within offshore wind port planning, operations and infrastructure are shown from the following Danish ports:

- Port of Grenaa
- Port of Esbjerg
- Port of Odense, Lindoe Industrial Park

3.2.1 Port of Grenaa: (Siemens Wind Power Project Port)

Port layout and infrastructure

Port of Grenaa has developed the following port layout and infrastructure specifications for the Siemens Wind Power project port:

- Seabed conditions for jack-up: reinforced by stone bed and spots – one position each
- Water depth at load-out quay: 11m
- Load-out quay dimensions: 360m long x 40m wide – 2 load-out positions
- Quay load capacity: 22.5kN/m^2 (uniform load)
  367kN/m^2 (belt pressure/WTG-components)
- Pre-assembly packages: One quay side six pack for final assembly and load-out
- Other external pre-assembly areas: One 12 pack for tower pre-assembly
- Internal pre-assembly areas: Building A (isolated) 1000m^2 for electrical assembly
- Other buildings: Building B (cold) 2000m^2 for storage of components, 1210m^2 office building and 2,500m^2 parking area
- Offshore support area: Separate quay for CTV's and crew facilities part of the area
- Project area: 138,000m^2 – top surface partly rolled gravel and shives
- Infrastructure and auxiliary equipment:
  - Separate access for heavy and light traffic
  - Permanent perimeter fence and gate
  - Power stations, light poles and IT
- Project concept: Purpose build, single project offshore wind port
- Build capacity: 60WTG per year – 0 foundation

Port operation concept

Port of Grenaa offshore wind project port is a purpose build, single project offshore wind port.

The Siemens Wind Power project port is developed by Port of Grenaa and Siemens Wind Power A/S for the installation of the DONG Energy's Anholt Offshore Wind Farm[1]. The project consists of 111 Siemens 3.6MW WTGs, a total capacity of 400MW. The 3.6MW WTG is in terms of size and weight similar to the 4MW WTG.

The WTG pre-assembly and offshore installation was completed in 18 months and the pre-assembly and load-out area was servicing up to four installation vessels (3 first generation and 1 second generation) simultaneously.

All components are transported and arrive from the onshore side. The project area is designed to store 30 nacelles, 30 tower sets (3 tower sections per tower) and 30 rotor sets (3 blades per rotor).

---

1 http://www.dongenergy.com/en/our-business/wind-power/where-we-operate/anholt

The pre-assembly and load-out process consists of the following main activities:

- Receipt of main components, inspection, securing and storage in storage area
- Receipt of secondary components, inspection and storage in buildings A and B
- Preparation of main components in storage area
- Sub-assembly of secondary components in building A
- Tower sub-assembly in 12 pack (electrical + tower sections 1+2)
- Tower final assembly in 6 pack
- Nacelle preparation for load-out
- Blade preparation for load-out.
- Final pre-assembly tagging
- Quality walk-down and hand-over of documentation
- Load-out

No foundation assembly is executed in Port of Grenaa.

Cable and transformer preparation and load-out are executed in another area of the port.

3.2.2 Port of Esbjerg: (Siemens Wind Power Hub)

Port layout and infrastructure

Port of Esbjerg has developed the following port layout and infrastructure specification for the Siemens Wind Power Hub:

- Seabed conditions for jack-up: Mixture of sand and clay, penetration holes are filled with stones during projects

- Water depth at load-out quay: 10.5mMLWS

- Load-out quay dimensions: 1,400m long x 40m wide – 6 load-out positions

- Quay load capacity: N/A (uniform load) and N/A (belt pressure/WTG-components)
- Pre-assembly packages: 6 tower packs (6-12 packs)
- Other external pre-assembly areas: Tower packs for PU/TU sub-assembly
- Internal pre-assembly areas: D6 main assembly building – 2,000m^2. Storage incl. building 376,000m^2 for storage of components, 16,000m^2 office building and parking area
- Offshore support area: Separate quay for CTW and crew facilities not part of the area
- Project area: 450,000m^2
- Infrastructure and auxiliary equipment:
  - Separate access for heavy and light traffic
  - Permanent perimeter fence and gate
  - Power stations, light poles and IT
- Project concept: Project hub for several parallel projects
- Build capacity: 400 WTG per year – 0 Foundation

Port operation concept
Port of Esbjerg is developed over several years as an offshore wind hub to support the build programme within offshore wind in Denmark, Germany, The Netherlands and the United Kingdom. The Port of Esbjerg offshore wind hub is servicing several wind turbine manufactures at separate sites.

The Siemens Wind Power Hub is designed as an industrial set-up capable of supplying several projects with different WTG types in parallel. This is characterised by:

- Common storage location for all offshore projects out of Esbjerg
- High utilisation of cranes, storage areas and quays
- Improved, full compliance and low variation of the preassembly quality
- One organisation handles all pre-assembly, keeping and evolving knowhow
- Lower the cost of pre-assembly

All components are transported and arrive from the onshore side. The project area is designed to store N/A nacelles, N/A tower sets (3 tower sections per tower) and N/A rotor sets (3 blades per rotor).

The pre-assembly and load-out process consists of the following main activities:

- Receiving inspection, registration and tagging
- Dehumidifying, turning of bearings and motion of hydraulics
- Cleaning before transport to pre-assembly
- Preparation of main components:
- Nacelle; Mounting of helihoist platform and sensor
  - Towers; Mounting of lifting brackets
  - Blades; Turning into sea transport position, mounting of blade bearing cover
  - Repair; Transport damages
- Sub-assembly; PU/TU
- Sub-assembly, Staking of towers, electrical and mechanical completion
- Sub-assembly; Mounting of hub, mounting of electrical, hydraulic and mechanical components
- Final pre-assembly tagging
- Quality walk-down and hand-over of documentation
- Load-out

No foundation assembly is executed at Port of Esbjerg.

No cable and transformer preparation and load-out are executed at Port of Esbjerg.

3.2.3 Port of Odense, Lindoe Industrial Park (Port)

Port layout and infrastructure

Port of Odense has developed the following port layout and infrastructure specification in the Lindoe Industry Park for a manufacturing site for a WTG jacket foundation manufacturer:

- Seabed conditions for jack-up: Mixture of sand and clay, no stone reinforcement
- Water depth at load-out key: 10-15mMSL
- Load-out key dimensions: Approximately 100-120m long. Width depending on other ships at quay, but approximately 40m. One load-out position (gantry crane work area)
- Quay load capacity: 400kN/m^2 (uniform load) at jacket locations (concrete reinforcements in soil), 100-150kN/m^2 generally around the area. 1000MT gantry crane available at quay. Five positions for foundations at load-out area
- Internal pre-assembly areas: Approximately 76,000m^2 indoor assembly facilities, including office facilities
- Other buildings: Approximately 10,500m^2 service building (currently used for painting). 2,500m^2 building for electrical installations inside and testing of TP components
- Storage area for final foundations: Approximately 90,000-100,000m^2 for storage of WT foundations

- Storage areas for steel components: Approximately 10,000m^2 for incoming steel components. Up to 100,000m^2 outdoor storage area for subassemblies from Workshops 1 and 2
- Access roads: Main access corridor runs through entire area including through main gate. Delivery of steel components through main gate or from water side
- Project concept: Foundation manufacturing for single project
- Build capacity: Approximately 20-30 foundations (jacket type) per year (from first sub-assemblies of final assembly and loadout) depending on size

Figure 3.1 Port of Odense (Lindoe Industrial Park, upper, Google earth, 2015) and 600t jackets ready for load-out (lower)

Manufacturing concept

- Steel components delivered in the corresponding area
- First 2D sub-assemblies in Workshop 1
- Second 2D sub-assemblies and 3D top-structure in Workshop 2
- Transport of sub-assemblies using SPMT's to storage area or Workshop 3. Finalization of 3D structure in Workshop 3
- Preparation and testing of TPs in Service Building 1
- Painting of top-structure in Service Building 2
- Lifting, up-rising and storage of 3D structure outside Workshop 3. Installation of TP and final welding and painting
- Transport of final foundations to load-out area
- Load-out to barge/vessel

3.3 Existing port specifications

The state-owned Port of Taichung started its construction in 1969 and officially commenced operation in 1976. Being the biggest international commercial port in central Taiwan, the port is bounded by River Dajia to the north and River Dadu to the south, covering a vast area of more than 4,000 hectares, see Figure 3.2.

The multi-purpose port maintains a main channel of 350m in width, a south northbound channel of 400m in width, and both channels are 16m in depth at low tide. Presently, the port operates more than 50 berths (see Figure 3.3) handling container, bulk & general, coal, grain, and liquid cargoes as well as passengers. The annual cargo tonnage handled exceeds 100 million metric tons.

Figure 3.2 Port of Taichung. Image: Google earth (2015)

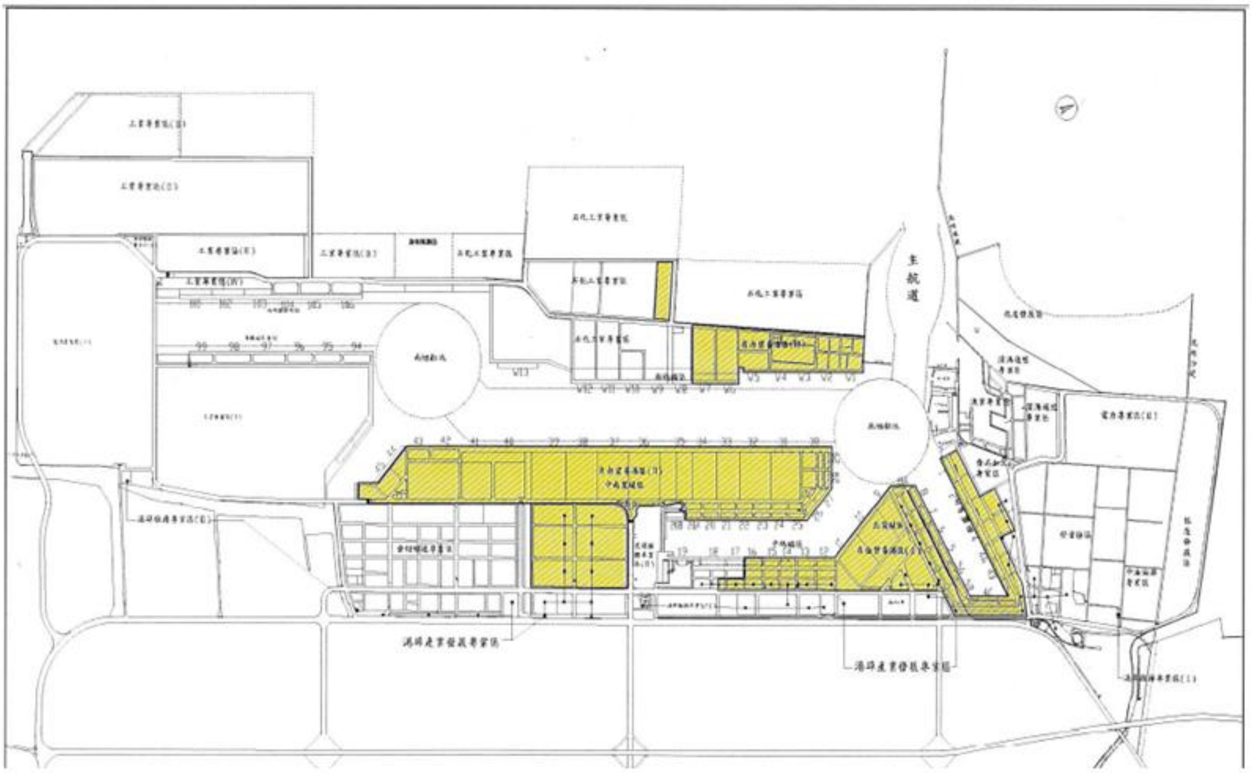


Figure 3.3 Port of Taichung has today more than 50 operational quays. Yellow areas indicate FTZ zones. Image: TIPC

Port of Taichung is considering to become an important wind port supporting Taiwan's offshore wind development targets. The potential area in question is sketched in Figure 3.4, where Quays 5A, 5B and 4C are pointed out in basic assumptions for Step 1 development and Quays 5-8 for FINAL layout design.

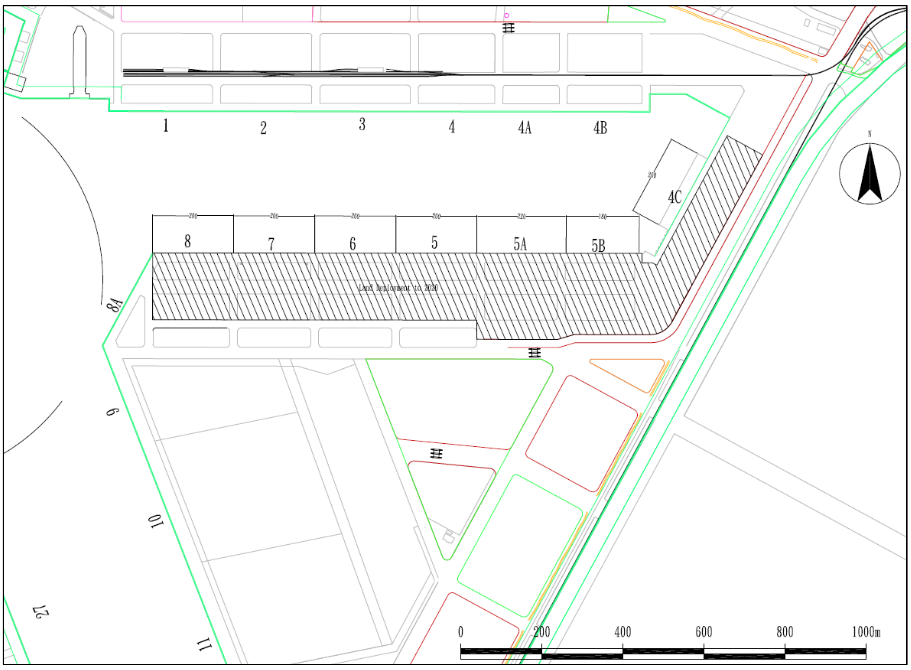


Figure 3.4 Area considered supporting the future offshore wind industry. Image: CECI

3.3.1 Existing conditions for quay areas 5A, 5B and 4C (Step 1) and 5-8 (Final)

Below information is retrieved from site visit, interviews with port representatives and other available information. A summary is presented in Table 3.1.

Table 3.1 Summary of present quay conditions

Quay	Present usage	App. quay length (m)	Expected load capacity (t/m^2)	Water depth (mCD)
5A	Parking	220	3*	11-12
5B	Storage	180	N/A	< 2
4C	N/A	200	N/A	< 4
5	Storage	200	< 5**	11-12
6	Storage	200	< 5**	11-12
7	Storage	200	< 5**	11-12
8	Storage	200	< 5**	11-12

**) Source: Port of Taichung, TPIC. (LAT: -0.1m CD)*

***) Estimated*

Figure 3.5 Quays 5A,5B, 4C (Step 1) and 5-8 (Final) pointed out in the basic assumptions. Image: Google earth (2015)

Figure 3.6 Inner part of basin. Image: Google earth (2010)

Water depths

The water depths in front of quays in the enclosed basin are shown in Figure 3.7 as recorded from recent bathymetric surveys.

Figure 3.7 Bathymetric survey (mCD). Image: CECI

Depths in the inner part of basin are limited to 2-4mCD, whereas the main part of the basin has been deepened to 11mCD or more.

3.3.2 Soil conditions

The available description of the soil conditions in the area of interest is limited to conventional soil investigation borings close to the landward end of the basin at Quay 4C, as shown in Figure 3.8. The positions do not directly cover any of the berths under consideration in this study. Soil profiles can therefore only be considered as preliminary indications that should be verified in the context of further project development.

However, the available results show a relatively homogeneous sequence of in-organic layers consisting mainly of fine sand (designation SM) with interbedded thin strata of silt, poorly graded sand (SP) and thin clay strata (CL).

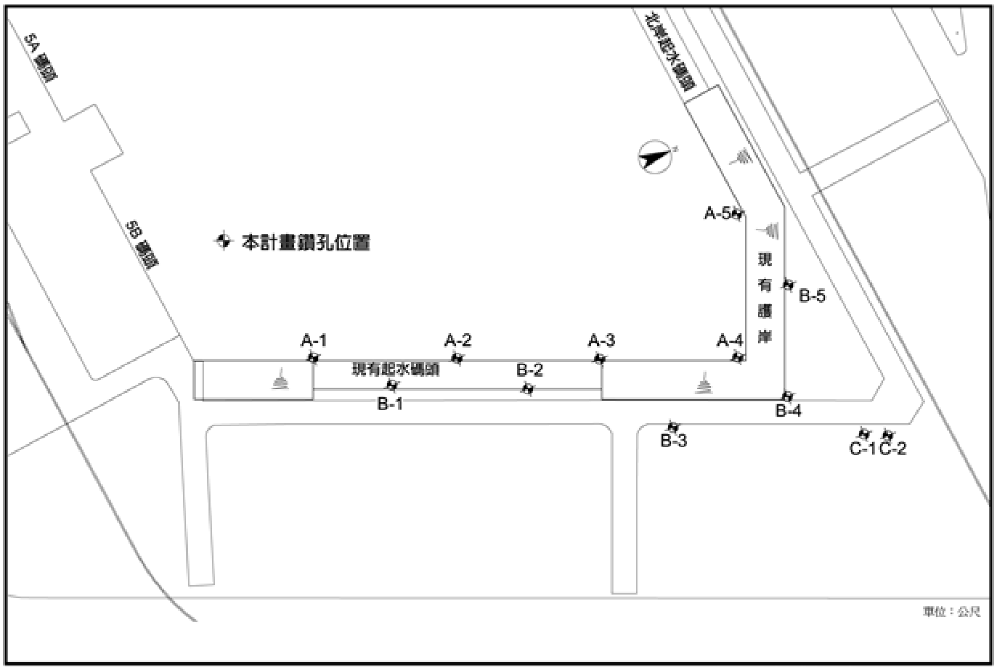


Figure 3.8 Location of existing soil borings. Image: CECI

The reported SPT-results confirm the general picture of relatively uniform soil conditions, generally 10 < N < 30, which the Consortium estimates to point at mostly medium dense strata with an angle of internal friction of 32-33°. Only in the uppermost zone of the borings do the SPT-results show a risk of loose soils. A few high SPT-results at some depths may indicate the presence of scattered stones or some cemented sand layers.

The soil conditions are assessed to be suitable for construction of quays on piles, as in Quay 5A, for caisson foundation of quays, as in Quay 2, as well as for tied-back quay walls.

The soil conditions as observed will most likely cause significant leg penetration (estimated to 3-6m) of legs from jack-up WT installation vessels if the bed is not protected with a suitable stone bed.

3.3.3 Quay 5A

According to the drawing below (from 1988), the existing quay level is +6.2mCD.

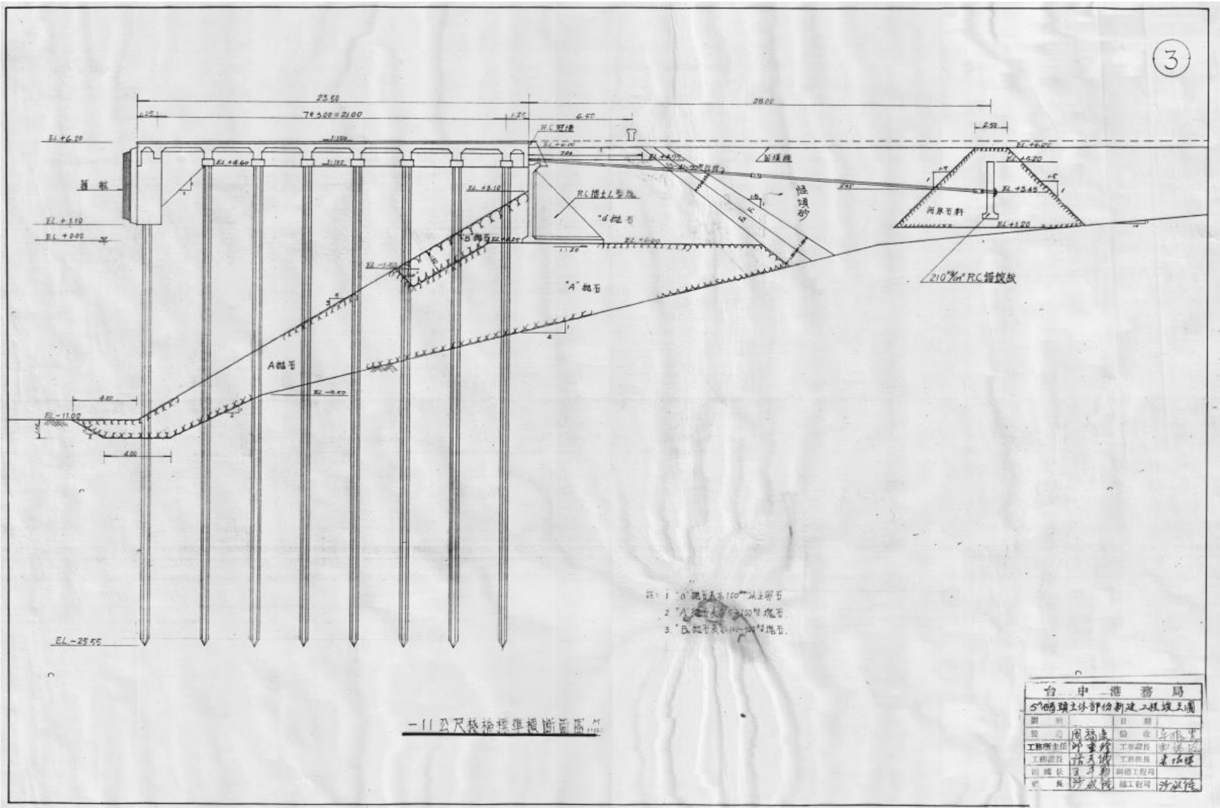


Figure 3.9 Quay 5A. Existing structure. Image: CECI

The berth is constructed as an open piled quay structure with a RC deck slab as shown in Figure 3.9.

The bearing piles (octagonal pre-fabricated RC piles of dimension 0.6m) are installed in a pattern of 6.0m by 3.0m.

For Quay 5A, according to information received, a nominal service load of 30kN/m^2 is authorised by the Port Authority.

The Consortium has carried out an independent assessment of the pile bearing capacity and concludes that the designated service load corresponds roughly with the estimated load bearing capacity of the piles.

Thus, mainly due to limited capacity of the piles, it is found that there is no or very limited room for increase of service loads on the existing quay to a level substantially higher than 30kN/m^2. The Consortium concludes that a significant upgrading of the quay structures will be required to meet requirements to an offshore wind terminal.

3.3.4 Quay 5B

Section 5B is framing the south side of the innermost part of the basin that has a water depth of only 2-4mCD. The design of retaining structures along Quay 5B is not known in detail, but structures are assumed as follows:

- The protruding section on the quay alignment at the intersection 5A/5B is designed as a block wall as shown in Figure 3.10 below.

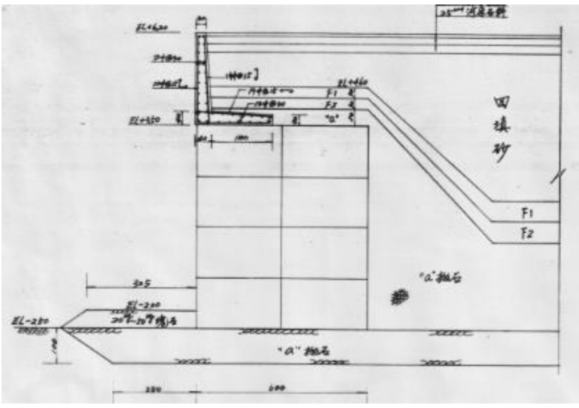


Figure 3.10 Protruding section 5A/5B. Quay of block wall. Image: CECI

- The inner part of Quay 5B is believed to be constructed with an angular retaining wall as shown in Figure 3.11 below

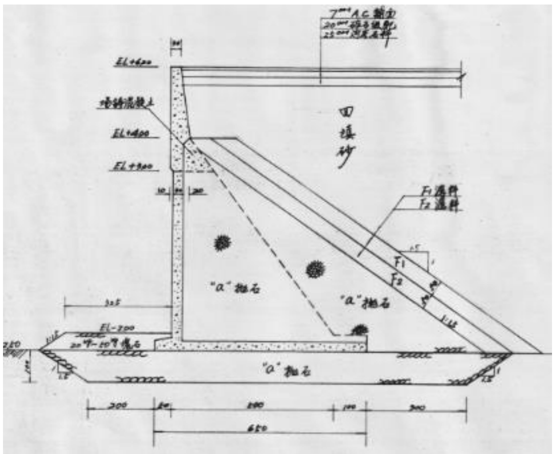


Figure 3.11 Quay 5B. Angular retaining wall. Image: CECI

- The present water depths in front of Quay 5B are clearly incompatible with requirements to an offshore wind terminal.

The Consortium concludes that new quay structures will be required together with a substantial increase of the navigable water depth in the basin.

3.3.5 Quay 4

No information has been made available regarding the structures of Quay 4.

3.3.6 Quays 5-8

According to available information, the Quay Nos. 5 to 8 were constructed in the same context as Quay 5A. The design is substantially as described in Section 3.3.3 and as shown in Figure 3.9.

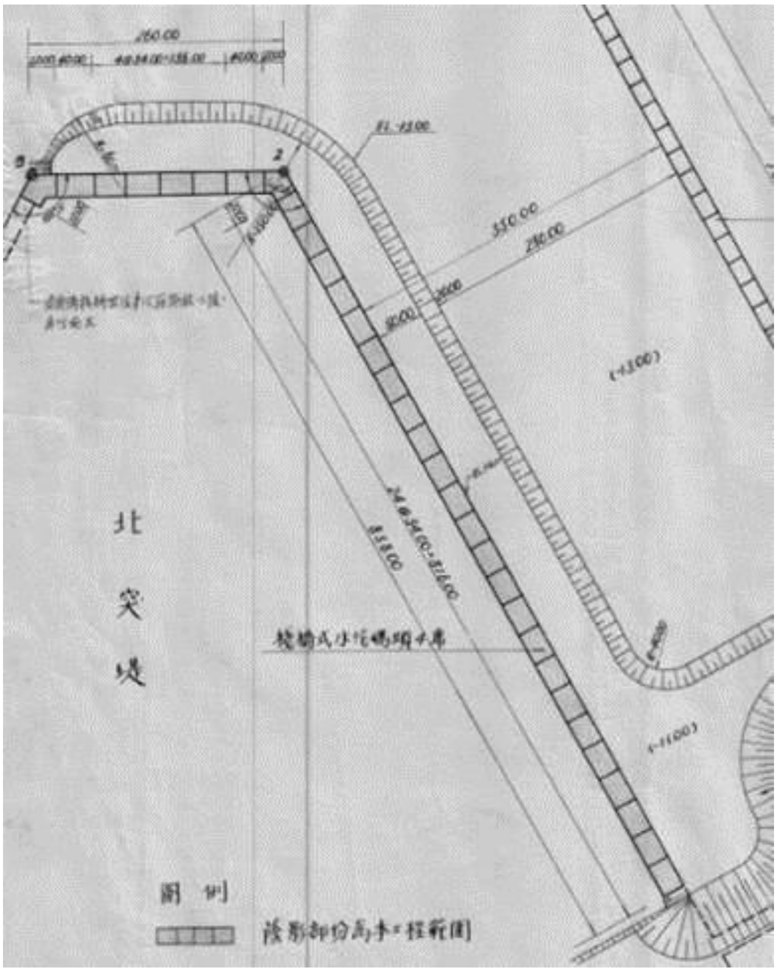


Figure 3.12 Drawing 'As Built' of Quay Nos 5A to 8. Image: CECI

3.4 Environmental load conditions

The weather and marine water in the Taiwan Strait and at Taichung Harbor are dominated by the East Asia monsoon, from northeast in winter and from southwest in summer. The northeast monsoon begins in September, peaks from October to January, and weakens continuously thereafter. By comparison, the southwest monsoon in June and July is much weaker.

Taiwan Strait is on the west edge of the western North Pacific where tropical cyclones (or typhoons) form frequently. There are about four typhoons or strong tropical cyclones affecting the Taiwan Strait every year. Those typhoons determine the extreme environmental design criteria to be used for design and operation of offshore wind farms and related infrastructures.

There are mainly nine (9) different typhoon tracks around Taiwan as illustrated in Figure 3.13. The figure shows the number and probability of the different tracks based on 114 years of observations.

The optimal operational weather window for offshore work is the 6-month period from around April to September though with high risk of typhoon passages associated with transient strong winds, high waves, heavy precipitation and reduced visibility.

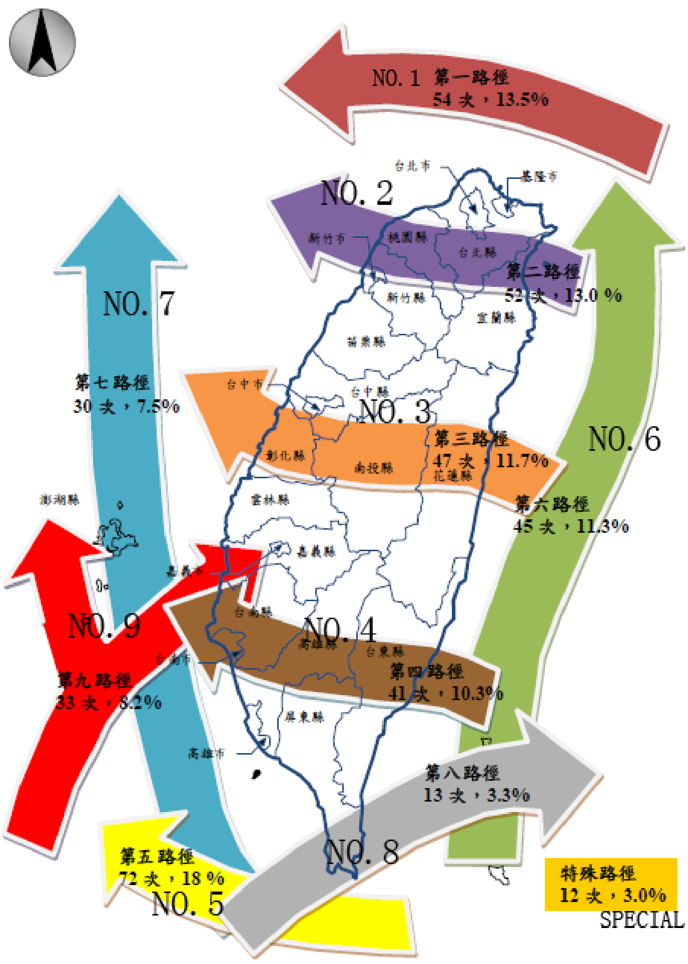


Figure 3.13 Typhoon track distributions around Taiwan. The figure shows the number of typhoons and probability (for each type) based on data for the 114-year period 1897-2010. From /1/.

3.4.1 Observations in Taichung Harbor

To our knowledge, observations in Taichung Harbor started in 1972 and cover wind, wave, currents and water levels. Table 3.2 shows the location of the various observation stations, from /2/ and /3/. We have been informed that the wind is measured at the tip of the northern breakwater at 20m height and represents 10-min values.

Table 3.2 Location of measurements in Taichung Harbor. From /2/ and /3/ (wind).

Type	Depth (MSL)	Latitude, Longitude	Time	Instrument
wave(X0)	44m	24°17'54"N, 120°29'39"E	1999/10-2000/08	AWAC
wave(X1)	25m	24°18'02"N, 120°29'05"E (24.3006,120.4817)	2003/08-now	AWAC
current(X1)	25m	24°18'02"N, 120°29'05"E	2003/08-now	AWAC
wind(W1)	+20m, 10min	24°17'59"N, 120°29'12"E (24.2997,120.4867)	2001/07-now	2009-now 2D Gill
tide(T)	-	24°17'16"N, 120°31'57"E	1999/10-1999/10 2001/04-now	Water log
tide(X1)	-	24°18'02"N, 120°29'05"E	2003/08-now	AWCP
tide	-	24°17'16"N, 120°31'59"E	1999/01-1999/10 2002/01-now	Aquatrak

Wind

Wind statistics for the 13-year period 2001-2013 are presented in Table 3.3. Figure 3.14 shows time series of measured monthly mean and monthly maximum wind speed. The measured annual mean wind speed (20m, 10min) is 9.6m/s. The maximum wind speed was 40m/s.

Wind data from the synoptic station may be used (conservatively) to derive design wind criteria for the dedicated offshore wind areas (Quays 5A and 5B).

Table 3.3 Monthly wind statistics (year 2001-2013) at station W1 Taichung Harbor northern breakwater; see Table 3.2. From /2/.

NO.	Month	Mean speed (m/s)	Max. wind speed/ direction	Wind speed				Direction			
				<5m/s (%)	5-10m/s (%)	10-15m/s (%)	>15m/s (%)	N-E (%)	E-S (%)	S-W (%)	W-N (%)
1	Jan	13.8	28.4/NE	7.3	19.5	24.9	48.3	90.9	2.3	1.1	5.7
2	Feb	11.7	27.8/N	18.8	22.1	24.1	35.0	82.8	3.8	6.1	7.1
3	Mar	10.5	32.4/NE	25.2	23.9	23.5	27.5	76.0	5.0	10.6	8.0
4	Apr	7.9	30.1/NNE	32.6	37.8	18.4	11.3	58.9	7.8	22.5	10.6
5	May	7.0	27.6/NE	35.1	44.3	15.6	5.0	50.5	7.0	32.4	9.9
6	Jun	7.1	21.1/SW	28.8	51.5	17.2	2.5	27.4	10.0	54.9	7.6
7	Jul	6.6	37.5/NNE	34.8	53.4	8.7	3.2	21.1	10.3	54.3	14.2
8	Aug	5.7	35.5/NNE	52.6	36.0	8.0	3.4	24.5	15.3	43.4	16.6
9	Sep	7.6	36.3/N	40.4	31.8	15.8	12.1	61.4	9.5	16.6	11.2
10	Oct	12.4	40.0/NNE	15.9	21.9	21.8	40.4	88.6	3.0	4.2	4.1
11	Nov	12.1	32.2/NNE	19.9	19.5	19.9	40.8	87.0	4.3	4.1	4.7
12	Dec	12.8	30.3/NNE	16.0	17.3	27.1	39.7	92.2	3.0	1.5	3.3
Mean		9.6	31.6/NNE	27.3	31.6	18.7	22.4	63.4	6.8	21.0	8.6

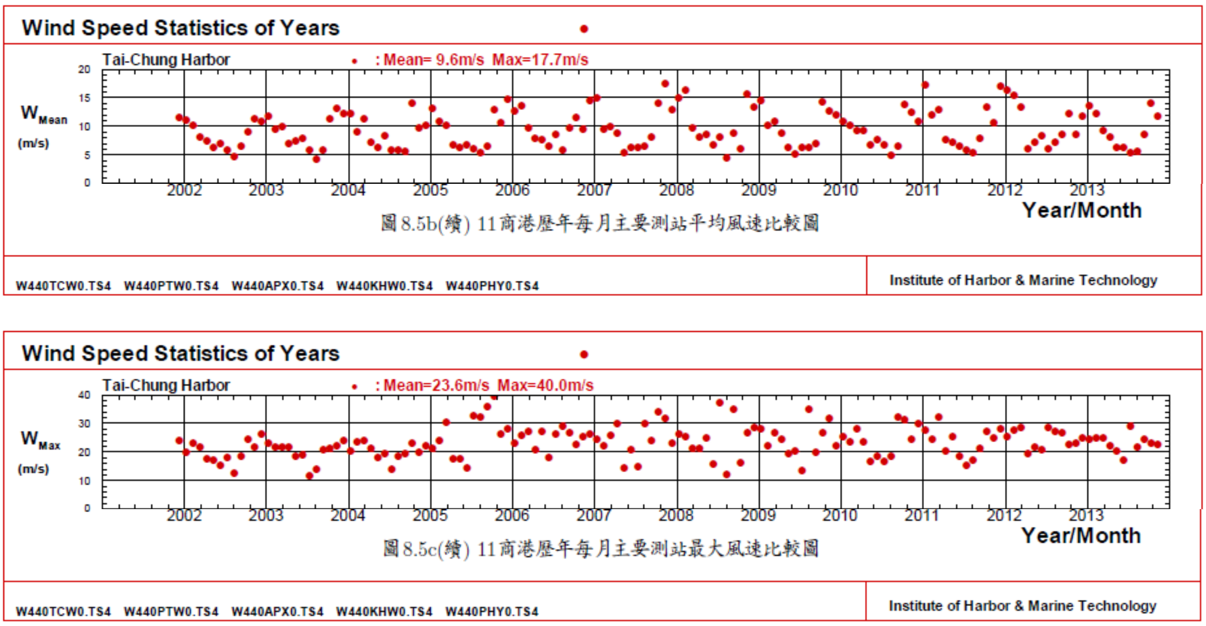


Figure 3.14 Comparison of **monthly mean/maximum mean wind speed** for the period 2001-2013.

Waves

As illustrated in Figure 3.15, high waves have been measured (caused by typhoons) at the entrance to the Port of Taichung. As the quays are located in a basin well protected against incident waves, offshore wind-generated waves and swell are not considered to impact operational and design criteria significantly.

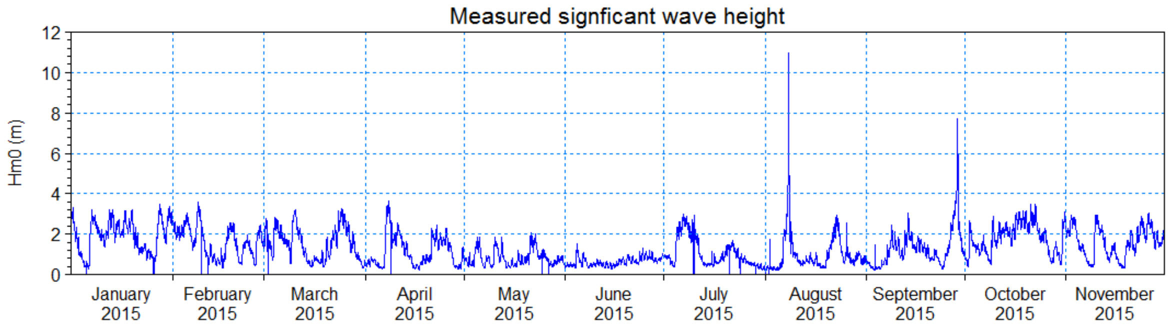


Figure 3.15 Measured significant wave height at the entrance to Port of Taichung during 2015. Two instants with typhoons are clearly identified.

Currents

Currents around Taichung are dominated by tide, a branch of the Kuroshio current, and drift currents. Figure 3.16 gives an overview of current speeds and directions in the Taiwan Strait. The maximum current speed is typically less than 1m/s offshore Taichung, which is also supported by /5/.

Month	direction	speed (knots)
Jan	SW	0.5-1.7
Feb	SW	0.4-0.6
Mar	SW turns to NE	0.4-0.9
Apr	NE	0.5-0.8
May	NE	0.4-1.0
June	NE	0.5-1.7
July	NE	0.5-1.5
Aug	NE	1.0-2.0
Sep	NE	0.5-1.0
Oct	W turns to SW	0.3-0.8
Nov	W turns to SW	0.2-0.5
Dec	SW	0.5-1.0

Figure 3.16 Seasonal variation of current speed and direction (going to) in Taiwan Strait. From internal DHI report.

As shown in Table 3.2, current measurements have been executed near the entrance to Taichung Harbor. The Harbor and Marine Technology Center of Taiwan has studied the current records from August 2003 to November 2013, /2/. Table 3.4 shows statistics of the 11-year time series of the current measurements. It shows that the current is predominantly from northerly directions with an average current speed less than 0.5m/s. In less than 5% of the time, the current speed exceeds 1m/s. Maximum recorded current speed was almost 2.5m/s (in 2005). It is likely that the maximum current speeds measured at the tip of the northern breakwater at 25m depth are strongly affected by wave-induced currents during passage of typhoons.

Table 3.4 Statistics of current measurements (AWAC) at Port of Taichung. From /2/.

Year	Mean speed (cm/s)	Maximum speed (cm/s)	Dir. (°)	Current speed				Current direction			
				<25cm/s (%)	25-50cm/s (%)	50-100cm/s (%)	>100cm/s (%)	N-E (%)	E-S (%)	S-W (%)	W-N (%)
2003	40.8	153.8	W	34.6	34.9	26.3	4.3	23.7	7.2	18.8	50.3
2004	45.3	173	W	27	34.3	34.7	4	10.2	7.6	19.1	63.1
2005	49.2	248.3	W	19.9	36.9	37.7	5.5	9.3	1.4	16.2	73.2
2006	45.9	171.9	W	26.1	35.4	32.8	5.7	5.4	0.7	26.8	67.1
2007	43.5	193.9	WSW	24.7	38.8	34.2	2.3	10.8	2.1	22.1	64.9
2008	51.3	240.2	WNW	23	33.8	35	8.1	17.5	19.4	26.1	37
2009	45.5	189	WNW	24.9	39.4	31.5	4.2	28.1	0.9	30.1	41
2010	39.1	168.8	WSW	27.9	45.7	24.5	1.8	36.8	1.6	25.4	36.2
2011	29.7	143.6	WSW	47.6	38	13.1	1.3	42.1	11.7	23.6	22.7
2012	34.5	124.6	WSW	37.3	41.9	20	0.8	36.1	1	33.4	29.5
2013	34.5	148.6	SE	39.4	41	18.1	1.4	22.2	4	34.8	39
Max/mean	41.8	248.3	W	30.2	38.2	28	3.6	22	5.2	25.1	47.6

As the quays are located in a semi-enclosed basin, the current conditions (dominated by the tide) are assessed significantly weaker compared to observation site.

Tide and surge water levels

According to /2/, the highest (total) water level measured in Taichung Harbor during the period 1971-2014 was +5.86mTWVD2001[2] (~ +3.21mMSL) and the lowest water level -0.55mTWVD2001 (~ -3.20mMSL).

Tidal levels are presented in Table 3.5, which shows HAT-LAT = 5.4m in Taichung Harbor. The tide is of semi-diurnal type.

The maximum recorded surge height in Taichung Harbor is 0.54m, which occurred under the influence of typhoon Dan in 1996, /4/. This figure may be used for preliminary design considerations.

Table 3.5 Characteristic astronomical water levels at Taichung [mTWVD2001] and [mMSL]. From Total Tide by UKHO

Reference	Taichung Harbor	
	mTWVD2001	mMSL
HAT	+5.3	+2.65
MHWS	+4.8	+2.15
MHWN	+3.9	+1.25
MSL	+2.65	0.00
MLWN	+1.5	-1.15
MLWS	+0.5	-2.15
LAT	-0.1	-2.75

2 Taiwan Vertical Datum 2001, see https://www.nlsc.gov.tw/En/MakePage/154?level=154

3.4.2 Environmental parameters used in feasibility study

Table 3.6 includes a summary of fit-for-purpose key parameters considered in this feasibility study. For FEED and detailed design, more accurate criteria need to be established.

Table 3.6 Summary of key environmental parameters used in the feasibility study

Parameter	State	
	Design conditions	Operational conditions
Wind	U_{10} > 40m/s (10 min.)	U_{10} < 15m/s (10 min.)
Waves *	H_{m0} < 0.5m, T_p ~2-3s (locally wind-generated) H_{m0} < 1m, T_p > 8s (offshore generated)	H_{m0} < 0.3m, all periods
Currents	CS < 0.2m/s	CS < 0.1m/s
Tidal range	HAT-LAT ~ 5.4m	MHWS- MLWS ~ 4.3m MHWN-MLWN ~ 2.4m
Surge	~0.6m	-
Precipitation**	Yearly precipitation: ~1300mm (95 rainy days annually) Max. monthly: 220mm (May) Min. monthly:10mm (October)	
Air temperature**	Mean annual temperature: 23°C Max. mean monthly temperature:30°C (July) Min. mean monthly temperature 14°C (February)	
Humidity**	Mean annual relative humidity: 78% Max. mean monthly relative humidity:89% (February) Min. mean monthly relative humidity 59°C (November)	

**) Sea and swell. Existence of infragravity waves has not be considered.*

***) From TIPC*

3.5 Baseline design and assumptions

The results of the initial analysis to determine the feasibility assumption are presented in this section as a baseline design specification. It is determined by comparing best practice to BoE basic assumptions for pre-assembly and logistic operation. Furthermore, the existing port specification and environmental load conditions are considered and the conclusion presented.

Pre-assembly and logistic operation

Table 3.7 Comparison of best practice in Denmark, BoE basic assumption and baseline design specification

Scenario	Total area (m^2)	Load-out area m	Pre-assembly area (m^2)	Storage area (m^2)	Buildings, access and parking (m^2)	Foundation area	In-load area m2	WTG capacity per year units	Operating window (months per year)
Port of Grenaa	138,000	360x40	26,000	98,000	14,000	No	0	60	12
Port of Esbjerg	450,000	1,400x40	2,000 indoor	376,000 incl. outdoor assembly	16,000	No	0	400	12
Port of Odense Lindoe/Bladt Foundations	300,000	120x40	76,000 indoor 100,000 outdoor	100,000	12,500	Yes only	0	Up to 30	12
BoE Basic Assumption	149,000	400x40	0	133,000 incl. transport areas	0	Yes	Not considered	30 incl. foundations	6
Baseline design specification	253,000	2 * 320x40	0	122,000	7,250	Yes	300x40	60	6

When looking at best practice from Denmark, the future Taichung Offshore Port should be a combination of Port of Grenaa and Port of Esbjerg. The two Danish ports/scenarios are the extremes between a highly industrialised hub port (Esbjerg) and a purpose build single project port (Grenaa).

There are significant differences between the two Danish scenarios, and the BoE basic assumptions are:

1. because WTG components are supplied from the seaside in Taipei, an in-load area is required
2. the requirement of foundation final assembly and load-out area from the WTG pre-assembly area
3. the 6-month installation/operating window doubles relative capacity

Furthermore, BoE basic assumption required the possibility of running two independent projects in parallel.

Based on best practices and experience for foundation manufacturing and assembly from Port of Odense (Bladt Industries at Lindoe), a total area of 600,000m^2 will be required to build sub-components and final assembly of 60 jacket foundations, see Appendix B.

The required area for monopile foundations has not been accessed, but it will be significantly less.

Baseline design specification

Based on the above evaluation of best practice against existing port specifications, environmental load conditions and BoE basic assumptions, we have determined the following baseline design specification:

- Option 1: two parallel projects – **one** OEM
- Option 2: two parallel projects – **two** OEMs
- Quays 5, 5A, 5B, 6 and 7 will be used
- Total of ~ 235,000m^2 gross surface area
- All buildings will have to be removed and new buildings build along the two sides
- Foundation pre-assembly and load-out not possible from the pre-assembly area – will have to be done elsewhere
- Wharf 4C (corner area used for ramp for tree logs) to be transferred into crew transfer area – access to be designed for CTV and building back-up for welfare, PPE storage containers

See conceptual baseline design in Appendix C.

Conclusion

It is clearly seen from the comparison between BoE basic assumptions and the baseline design specification that the gap between them is significant, and the Port Consortium concludes that the BoE basic assumptions are not feasible for the future development of Taichung Harbor.

This has led to a customer review and detailed discussions to determine a way forward in order to be able to provide a feasible port design, which will accommodate the planned build programme and the highest possible compliance with the BoE basic assumptions.

The decision based on these discussions is to divide the feasibility study into three steps based on the possible 3-step development plan provided to the Port Consortium by BoE and ITRI.

Furthermore, it was decided to hold a stakeholder meeting in order to inform about and engage the offshore wind stakeholders in Taiwan in the future development of Taichung Harbor.

Finally, the feasibility study schedule was revised to fit the above decisions.

3.6 3-step development plan and revised feasibility study schedule

The development plan for Taichung Harbor is based on expansion of the offshore wind project area in three steps in order to meet the baseline design requirements best possible in the future and at the same time to support the build programme starting in April 2018.

The three steps are defined as follows:

- **Step 1 design** => 2018: The possible layout combining WTG and foundations
- **Step 2 design** => 2019: Improvement by removing buildings and expanding space – expand site
- **Step 3 design** => 2020 – Improvements by removing buildings and expanding space – expand site

The 3-step expansion of Taichung Harbor from 2018 to 2020 is shown in Figure 3.17.

3.6.1 Revised feasibility study schedule

The feasibility study schedule is revised to implement the 3-step development plan into the feasibility study. The revised feasibility study schedule is shown below.

Development plan and Step 1

- Apply development plan to baseline layout and develop Step 1
- Finalise layout concept design and description for Step 1
- Detail port site requirements for Step 1
- Complete financial calculations for Step 1
- Submit documentation for Step 1 – **15/8**

Review of Step 1

- Customer review – Port Consortium/BoE/ITRI meeting – **22/8 in Taipei**
- Stakeholder Review – Stakeholder meeting called by BoE – **24/8 in Taipei**

Development plan and Steps 2 and 3

- Apply development plan to baseline layout and develop Steps 2 and 3
- Finalise layout concept design and description for Steps 2 and 3
- Detail port site requirements for Steps 2 and 3
- Complete financial calculation Steps 2 and 3

Port Consortium recommendations

- Complete feasibility study documents items 1, 2 and 3
- Approve feasibility study documents items 1, 2 and 3 and submit to ITRI
- **Customer approval 26/9 – 30/9**
- **1st October – 31st October**

Workshop development

- Develop workshop programme and contents
- Submit draft workshop programme and contents to ITRI
- Submit final report
- **Execute workshop in Taipei during the week 24/10-28/10**

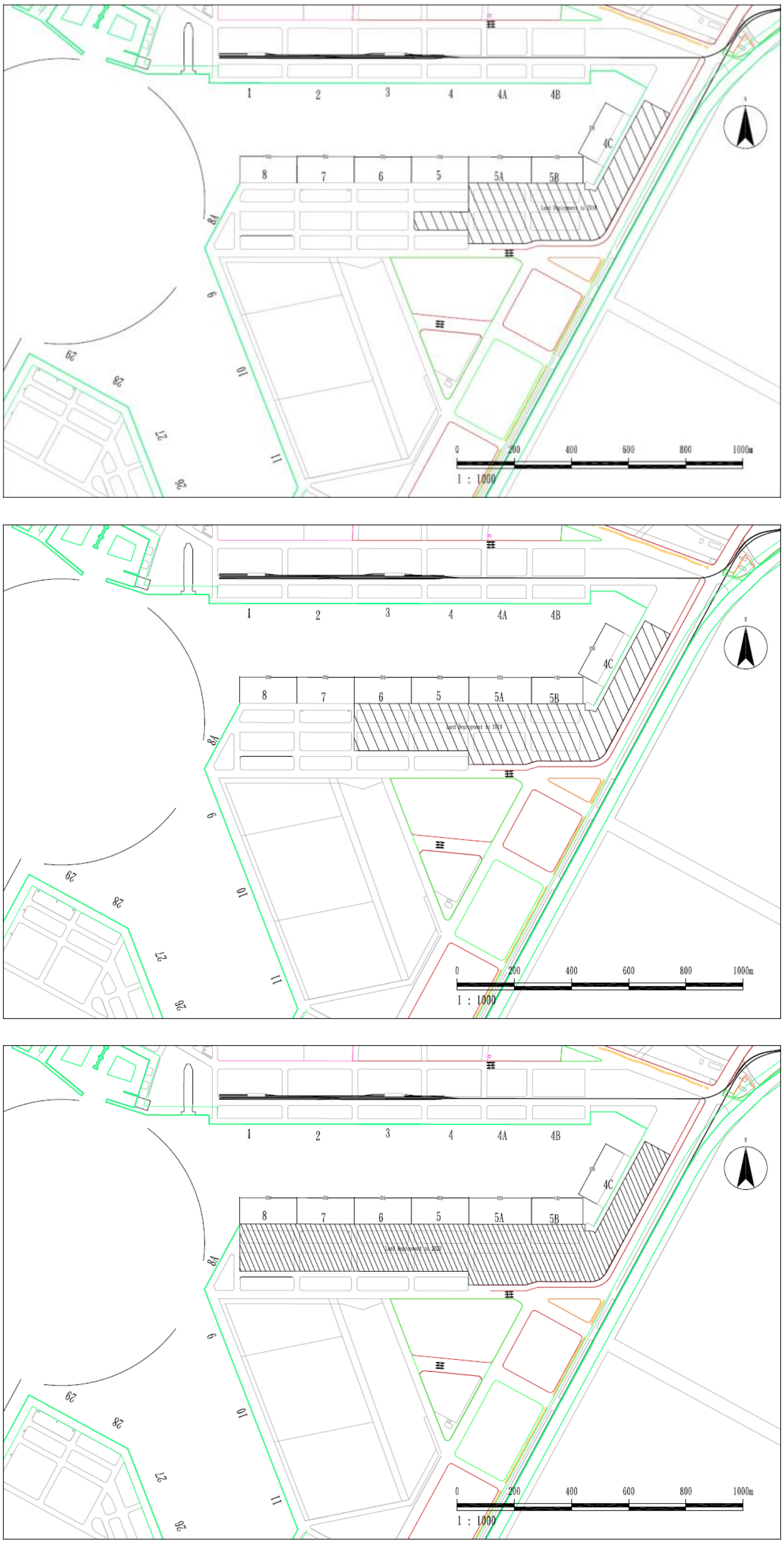


Figure 3.17 3-step development plan proposed by ITRI. Upper: 2018, middle: 2019 and lower: 2020. Drawings provided by CECI.

This page is left blank intentionally.

4 Feasibility of Step 1 Development Plan

A fundamental part of this study was to identify the logistical requirements for moving offshore wind-related components through the Port of Taichung intended facilities. This information was to a great extent informed by the Port Consortium's comprehensive knowledge base and network developed by decades of experience in Denmark and Northern Europe. The information was shared and discussed with relevant industry stakeholders through workshops, webinars and other types of communication.

In the following, quay design specifications, pre-assembly area layout, buildings, access areas, support infrastructure and equipment are specified for Step 1 in the development plan.

4.1 Port basin, seabed and vessel berthing/operation

In terms of maritime limitations, technical requirements stem from the physical dimensions of the vessels used either for the installation/construction phase or for transportation and storage.

As described in Section 3, it has been assumed that several of the vessels likely to be utilised for the turbine (and other structures) erection in early projects will be foreign-flagged 2nd generation European heavy lift DP jack-up vessels. These 2nd generation vessels operated by approximately ten different companies are characterised by having:

- Overall length ~80-140m
- Beam ~40-50m
- Leg length ~60-105m
- Draft < ~6m
- Crane lift capacity 800-1200t @ 25-30m

The size of the port basin is sufficient to ensure an efficient and safe navigation towards Quays 5A and 5B[3]. The water depth at Quay 5A (11mCD) is sufficient, but dredging is required at Quay 5B as the present depth is significantly smaller and unknown. The present quay lengths are sufficient to support berthing of modern offshore wind vessels.

It shall be observed, however, that existing structures, other than the upgraded Quay 5B, framing the inner part of the basin will not be upgraded for 11m water depth. The required safety distance to these structures shall be assessed in the detailed design phase.

As the present seabed does not support jacking up for loadout, the costs of upgrading the seabed shall be encountered, see Section 4.7. Alternatively, floating loadout may be considered. The feasibly of this option has not been considered in the present study.

4.2 Quay structures

Quay structures for step 1 will be designed for both short-term and long-term purposes as Quays 5A and 5B will be part for the overall future solution in 2019.

Seabed reinforcement for jack-up will also be considered. As there is no information available for Quay 4C, the load bearing capacity will have to be evaluated in Steps 2 and 3.

---

3 Please note the event of overhanging components (beam up to 75m has not been considered)

4.2.1 General considerations and design criteria

The proposed development of Step 1 of an offshore terminal encompasses Quays 5A and 5B. In order to meet all operational and capacity requirements, it is assumed that the entire length of these two berths may be developed for flexible use in connection with loading and unloading of heavy-duty wind turbine components.

The following conclusions have tentatively been made by the Consortium in respect of design criteria:

a. The quay in sections 5A and 5B should be aligned. The new quay front is assumed to be at a short distance in front of the existing alignment of Quay 5A. This alignment will facilitate construction works and will not reduce the basin width more than absolutely necessary. Consequently, the existing short section that protrudes at the intersection 5A/5B shall be demolished.

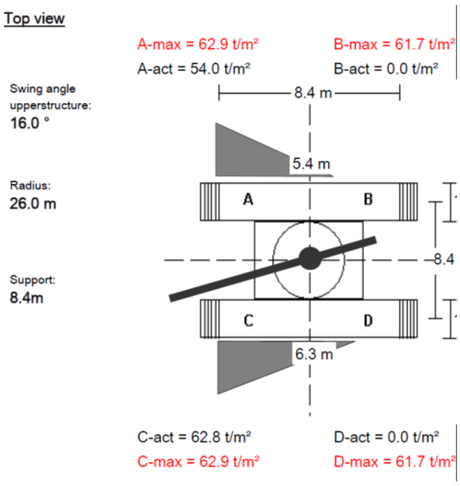
b. A quay level of +6.5mCD is recommended as compared to the existing level of +6.2mCD in order to prepare for future sea level rise.

c. A navigable water depth of 11m (below CD), similar to present depth in the main part of the existing basin, should be provided. This depth will possibly allow for construction of stone beds for jacking up with an anticipated surface level of -8mCD. The delimitation of the extended 11m-basin towards adjoining quay structures other than 5B shall be considered in the detailed design in terms of structural stability of existing quays.

d. Load requirements in offshore terminals shall be defined to meet all foreseeable loads now and in the future. The Consortium recommends the following two live loads to be considered in the composition of load combinations for the design of new or upgraded quay structures. The two live loads are alternative, and only one of the loads should be considered in the same load case.

    1. Uniform quay load: 150kN/m^2
    A uniform live load of 150kN/m^2, distributed across large areas, will in the opinion of the Consortium cover most requirements in a modern offshore terminal with regard to distributed loads.

    2. Belt pressure/ WT-components: 600-800kN/m^2 within an area of 3.0x3.0m^2
    However, much larger peak pressures can occur on relatively small areas under link-belts of large cranes (as shown in the figure below) or under supporting pads of heavy components (nacelles and equivalent). Therefore, the quay structure shall be designed also for this load – to be placed at any position behind the quay front.



4.2.2 Structural quay design

A completely new quay structure will be required in section 5B.

In section 5A, a significant upgrading will be required for this quay to meet load requirements for WT-operations as proposed in the previous section of this report.

Compliance with an anticipated tight construction schedule is a precondition for choice of structural solution. The Consortium therefore recommends one basically consistent design along the entire Quay 5A/5B.

The main components of the proposed solution, as shown in Figure 4.1, are:

- Main quay wall: Steel combi-wall of tubular piles (≈Ø1600x25) alternating with Z-piles (module ≈ 3.0m)
- Ties: ≈M133 ties, up-set ends, L ≈ 35m. One tie per module
- Anchor piles: tubular piles (≈Ø1600x16). One pile per module
- Reinforced concrete capping beam
- Back-fill with sand/gravel materials including adequate compaction of initial and new fill

Items such as bollards and fenders may to some extent be recovered from Quay 5A and reused.

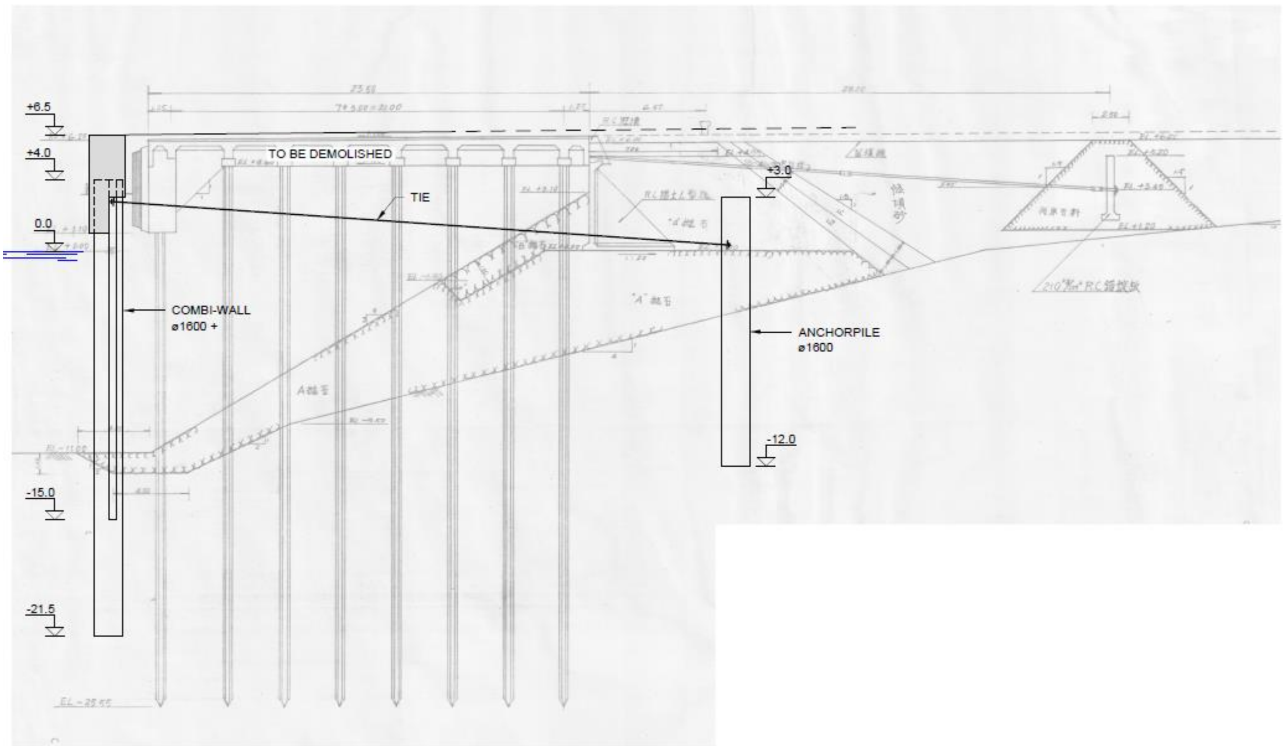


Figure 4.1 Section 5A. Proposed quay structure.

The proposed solution, designed for a general quay load of 150kN/m^2, will also be able to sustain concentrated quay loads, as defined above.

The deck structure of reinforced concrete in Quay 5A shall be demolished for installation of ties.

The triangular volume established between the new quay wall and the existing stone revetment shall be filled with sand/gravel. A stone filter is required on top of the existing slope to prevent loss of fill materials seeping into the voids of the existing stone revetment.

The design of end sections shall be considered in the detailed design. Possibly a provisional solution can be accepted towards berth 5 preparing the way for future extension of the WT-terminal.

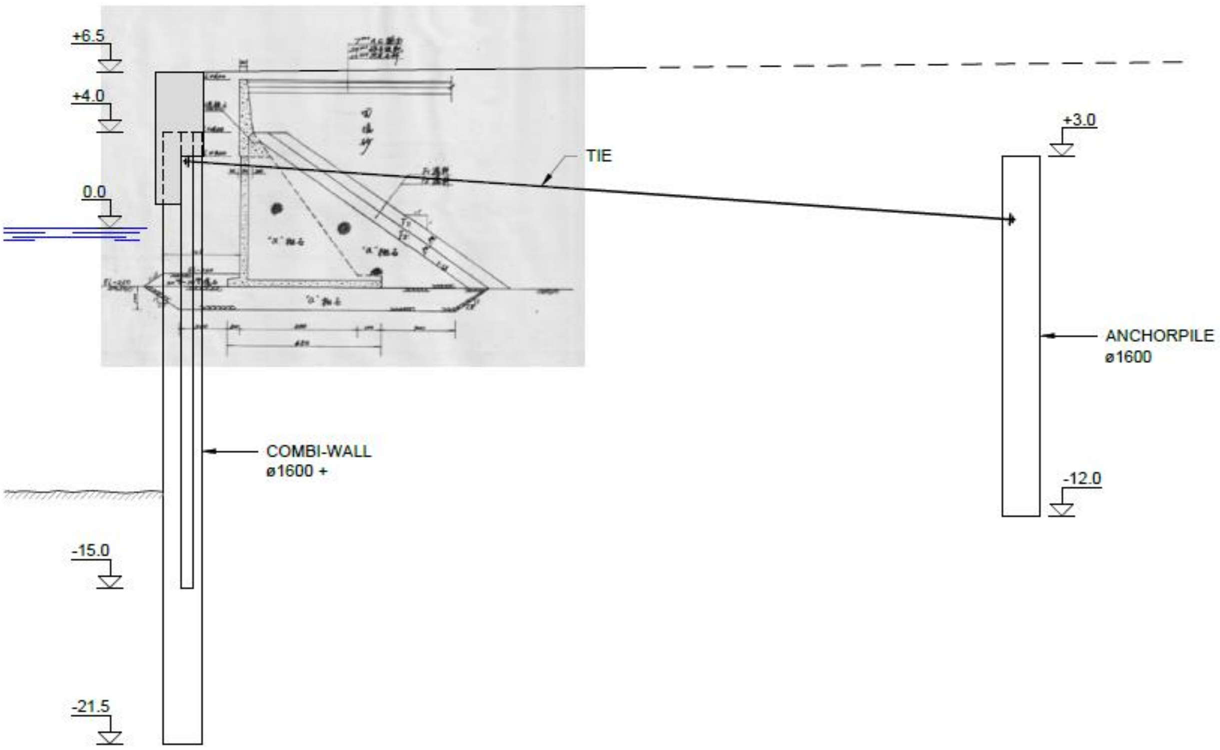


Figure 4.2 Section 5B. Proposed quay structure

4.2.3 Stone beds for jacking-up vessels

Most WTG-installers prefer, or even require, that there is opportunity for jacking up of their installation vessels at quay-side for loading of WT-components.

Jacking manoeuvres imply significant penetration of jacking legs into the seabed (≈ 2-5m) a short distance in front of the quay structure. Such penetration into existing sand/silt layers should be accounted for in the design of the quay structure and could, moreover, result in an irregular seabed that in the worst case represents a risk of damage to jacking-up legs.

Therefore, purpose-made stone beds are often installed on the seabed to provide controlled jacking conditions and to limit leg penetrations. An example is shown in Figure 4.3.

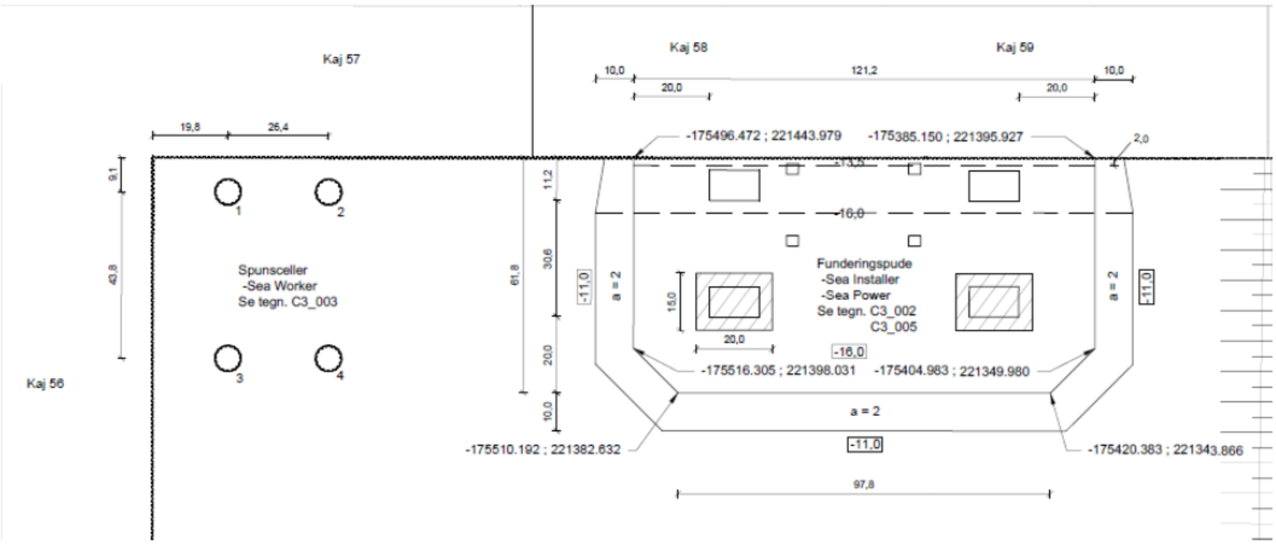


Figure 4.3 Stone bed arrangement (2 positons) from Port of Grenaa.

Experience from existing offshore terminals in Denmark shows significant scatter regarding the design criteria for such stone beds, i.e. jacking-load, area of leg base (spud-can) and resulting ground pressure.

The Consortium has indicatively deducted the following characteristics from some projects in Denmark. Figures derive from recently built installation vessels.

Spud-can base area (m^2)	Installation load (MN)	Ground pressure (kPa)
~100	60 – 90	~900

A dedicated stone bed to accommodate such vessels may typically be designed with two layers of the following approximate dimensions:

1.5-2.5m of crushed stone (60-180mm)
2-3m of crushed stone/gravel (0-32mm)

Spud-can penetration will typically reach 1.5-2.5m into the stone bed.

The top level of the stone bed shall not be located higher than at level -8 to -9mCD.

The properties indicated above shall be verified against the properties of the actual installation vessel(s) as some installation vessels may exert higher ground pressure than stated above.

When considering the horizontal extension of the stone bed, it may equally be discussed whether to adapt the stone bed to one (or two) installation vessel(s) of known leg geometry and berthing modes at well-defined positions along the quay or whether to provide flexibility for accommodation of different vessels at different positions.

As the position of installation vessels may be closely bound to the position of tower racks at the quay front, it may be an option to adapt stone beds to these well-defined positions at the quay.

For a c/c-distance of the legs of ≈30m perpendicular to the berth, a stone bed of approximately 55m width will be required.

4.3 Pre-assembly area and layout

WTG components should be stored in the harbour quay area in a way allowing manoeuvring to be done without obstacles using the required vehicles (heavy lifter, SPMT, etc.). In addition, minor areas for final assembly of i.e. hub on nacelle are necessary, as the components may arrive separately by sea.

The foundations for the WTGs will be of the type monopiles. A monopile foundation consists of a monopile (steel tube to be driven into the seabed) and a transition piece (steel tube to be mounted over the monopile). It will be necessary to have a remote storage facility for monopiles and transition pieces due to the large size of these.

A conceptual pre-assembly layout and the project scenarios for Step 1 = 2018 are shown in Figure 4.4. In addition, the pre-requisites for the layout are described in bullets below:

- 30 x 4MW turbines and corresponding monopile foundations are assumed in the harbour area for 2018
- Only one project and one OEM considered
- The monopiles should be stored in remote facilities, while the transition pieces are stored in the harbour area. Further logistic analysis is required
- Blades are double-stacked in order to fit all components into the area
- Load-out area is also used for in-load of components coming from sea
- 2 x four-packs are required towards the quay edge in order to assemble the towers prior to load-out.
- Indoor storage facilities are needed for electrical components and other components that require protection
- The outer end of Quay 4C is used for crew transfer area, and must be designed for CTV, welfare buildings, PPE storage, etc
- The perimeter of the area must be secured including controlled access

Table 4.1 Pre-assembly area metrics for Step 1.

Scenario	Total area (m^2)	Load-out area (m^2)	Pre-assembly area (m^2)	Storage area (m^2)	Buildings, access and parking (m^2)	Foundation area	Inload area (m^2)	WTG capacity per year units	Operating window (months per year)
Step 1	138,000	360x40	26,000	98,000	14,000	Shared	0	60	6

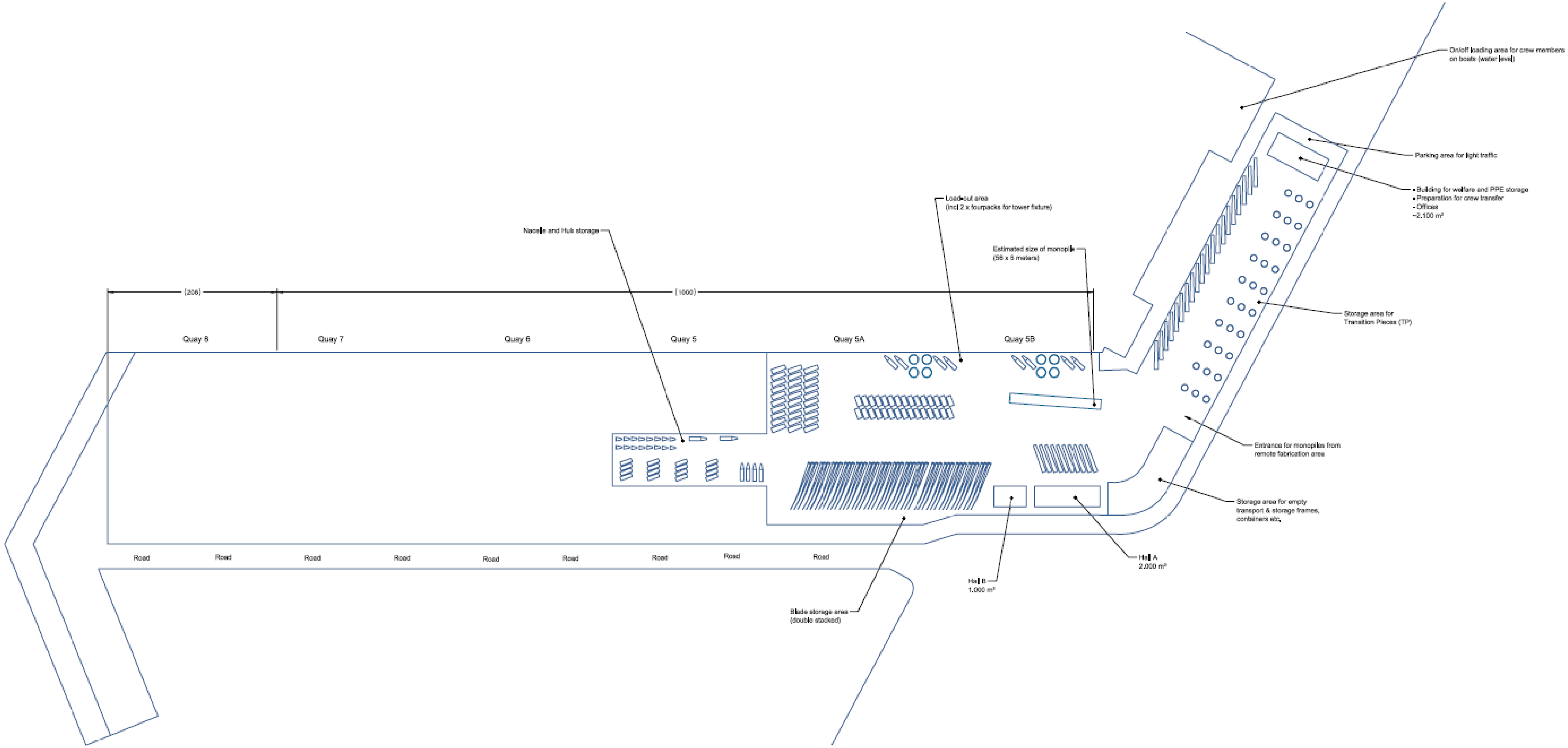


Figure 4.4 Proposed layout of Step 1 development plan

This page is left blank intentionally.

4.4 Sub-assembly, storage and administration buildings

To complete the design specification for sub-assembly, storage and administration buildings, further discussion and clarification with ITRI/CECI is required. The agreed level of design specification will be provided in Steps 2 and 3.

Indoor sub-assembly area (heated) – 2,000m^2

Indoor storage building (cold) – 1,000m^2

Administration building containing:

- Technical staff facilities
- Site management facilities
- Subcontractor facilities
- Welfare facilities

4.5 Support installations and equipment

To complete the design specification for support installations, further discussion and clarification with ITRI/CECI is required. The agreed level of design specification will be provided in Steps 2 and 3.

- Process related constructions (tower packs, etc.)
- Fencing incl. gates
- Light poles
- Power stations
- Power outlet in nacelle area

Equipment list

Due to time constraints, the list of handling, lifting and logistic equipment will be included in Steps 2 and 3.

4.6 Overall infrastructure

The description of the overall infrastructure will follow in Steps 2 and 3 as it needs further logistic analysis in the port area and should take all three faces into account.

4.7 Financial analysis, investment budget and business models

The financial analysis is incomplete for Step 1 and will require further discussions and consulting with ITRI/CECI. At this stage, we have provided some estimated cost levels for quays and stone bed reinforcement.

The remaining cost analysis and the overall investment budget will be provided in Steps 2 and 3.

4.7.1 Port basin, seabed and vessel berthing/operations

See section 5.7.1.

4.7.2 Quays

A cost estimate for the upgraded quay structure is presented below in USD based on recent experience (international price level):

Estimate at **Quay 5A** (per ℓm of quay)	USD
- Demolition of RC superstructure:	4,000
- Steel piles in quay wall: 9.9t @ 1,500:	14,850
- Steel anchor piles: 3.2t @ 1,500:	4,800
- Ties and accessories: 1.4t @ 2,700:	3,780
- RC capping beam: 5m³ @ 800:	4,000
- Fill materials: 240m³ @ 7:	1,680
	33,110
- Mob/demob + contingencies (≈15%):	4,890
Total estimate per ℓm of quay*:	38,000 USD

**) Excluding pavement, dredging and stone bed*

Estimate at **Section 5B** (per ℓm of wall):	USD
- Demolition of RC superstructure:	1,000
- Steel piles in quay wall: 9.9t @ 1,500:	14,850
- Steel anchor piles: 3.2t @ 1,500:	4,800
- Ties and accessories: 1.4t @ 2,700:	3,780
- RC capping beam: 5m³ @ 800:	4,000
- Fill materials: 70m³ @ 7:	490
	28,920
- Mob/demob + contingencies (≈15%):	4,580
Total estimate per ℓm of quay*:	33,500 USD

**) Excluding pavement, dredging and stone bed*

4.7.3 Stone bed

The following unit rate is indicatively estimated per m² of a stone bed for jacking-up of installation vessels at the quay side:

- Per m²: 100 – 150 USD*

**) Dependent on leg characteristics of installation vessel*

The proposed rate does not include costs related to maintenance of the stone bed during operations cost exclusive of site investigation, design and dredging activities.

4.7.4 Sub-assembly, storage and administration areas

See Section 5.7.

4.7.5 Support installations and equipment

See Section 5.7.

4.7.6 Overall infrastructure

See Section 5.7.

4.7.7 Overall investment budget

See Section 5.7.

4.7.8 Business models

The business model for the port is very much depending on the investment opportunities available to the port enterprise. For public-owned ports in Europe (particularly Denmark), the common model is exemplified below. The revenue stream is divided into two types; recurring and non-recurring. The spilt between the two is normally at the surface deck:

Recurring revenue
The seabed, the quay and the surface deck are built and paid for by the port and the ROI is generated by renting out the area and quay infrastructure to the project customer/s plus charging goods fee and a port call fee for vessels.

Non-recurring revenue
All pre-assembly specific constructions, support infrastructure and facilities, buildings and fencing are provided by the port and paid for by the customer with or without overhead.

The ROI is normally very low (paid to cost or with low overhead) depending on the port involvement.

An alternative model to the above is for the port to long-term lease the project area (the seabed, the quay and the surface deck) to a base operator, who will then configure the area as required for pre-assembly and provide the area including its base services to the offshore wind customers.

This model is transferring risk and involvement from the port the operator.

Below an (unspecified) example of revenue streams from Port of Grenaa:

Recurring revenue
- Rent of primary area – x NTD per month in y months
- Rent secondary area – x NTD per month in y months
- Rent exclusive quay utilisation – x NTD per meter per week
- Goods fee for WTG parts over the quay – x NTD per ton
- Installation vessels – x NTD per port call
- Crew boats – monthly fee including unlimited number of port calls – x NTD per month
- Support equipment, power station/take off – x NTD per month in y months, power paid by customer

Non-recurring revenue
- Pre-assembly process-related constructions (tower packs, etc.) – cost price
- Pluming and pipes for fiber cable – cost price
- Fence – cost price
- Buildings – cost price similar to rental price for equal quality tent hall
- Support equipment, light poles – cost price, power paid by customer

All non-recurring costs should be paid by customer by 50% at contract signature and 50% at contract start.

Actual cost levels will be provided in Steps 2 and 3 after further discussion and cost level conversion with ITRI/CECI.

4.8 Stakeholder meeting in Taipei in August 2016

The stakeholder meeting took place on 24/8 2016 in Taipei.

Date and Time: Aug 24 10AM

Address: Conference Room D, 6F, No. 99, Fuxing North Rd., Taipei, Taiwan

Agenda

1. Opening remarks BoE Director Su and TC Taipei Marina Hsu
2. Presentation from DK
3. Q&A and discussion
4. Conclusion

Invitees

1. Taiwan Harbour Company: Taichung Harbor branch office
2. Taiwan Power Company Renewable Energy Division
3. Swancor Formosa (private developer)
4. TGC Fuhai (private developer)
5. Eolfi (French private developer)
6. Yushan Energy (Singaporean private developer)
7. WPD Infravest (German developer)
8. China Steel Corp (and its 4 subsidiaries)
9. Century Steel Corp
10. DONG Energy (private developer)
11. China Ship Building Corp
12. CECI (local partner)
13. TECO (potential local turbine supplier but rather far away behind schedule)
14. Ship & Ocean Investigation Center
15. Metal Industries Research and Development Center (focus on R&D for steel structure)

4.9 Layout revision after Stakeholder meeting in Taipei in August 2016

During the process of developing Step 1 design, BoE has updated the official build programme targets to a projected installed capacity of 3 GW in 2025. This is intentionally rolled out as 520 MW by 2020 and thereafter 500 MW per year from 2020 to 2025.

Based on this new policy, the result of Step 1 and the discussions with BoE and feedback from the stakeholder meeting held in Taipei in August 2016, it is the Port Consortium’s opinion and recommendation that Step 2 and Step 3 are merged. We have revised Step 1 layout for 4C, 5B and 5A accordingly to be applicable directly to the FINAL design.

An overview of the revised proposed Step 1 layout is presented in Figure 4.5 and Figure 4.6 (WTG components included).

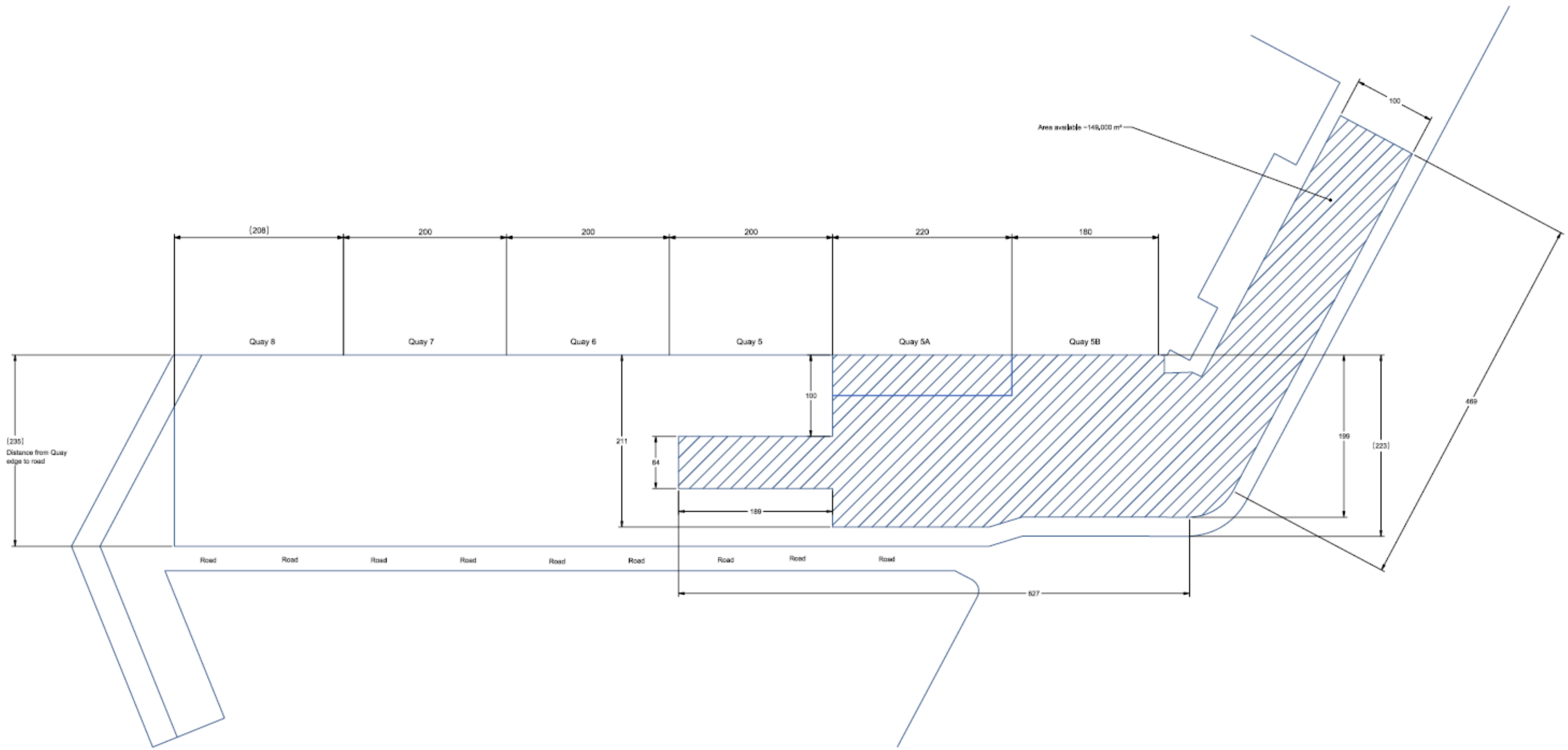


Figure 4.5 Overview of the revised proposed layout of Step 1 development plan, see also Appendix C

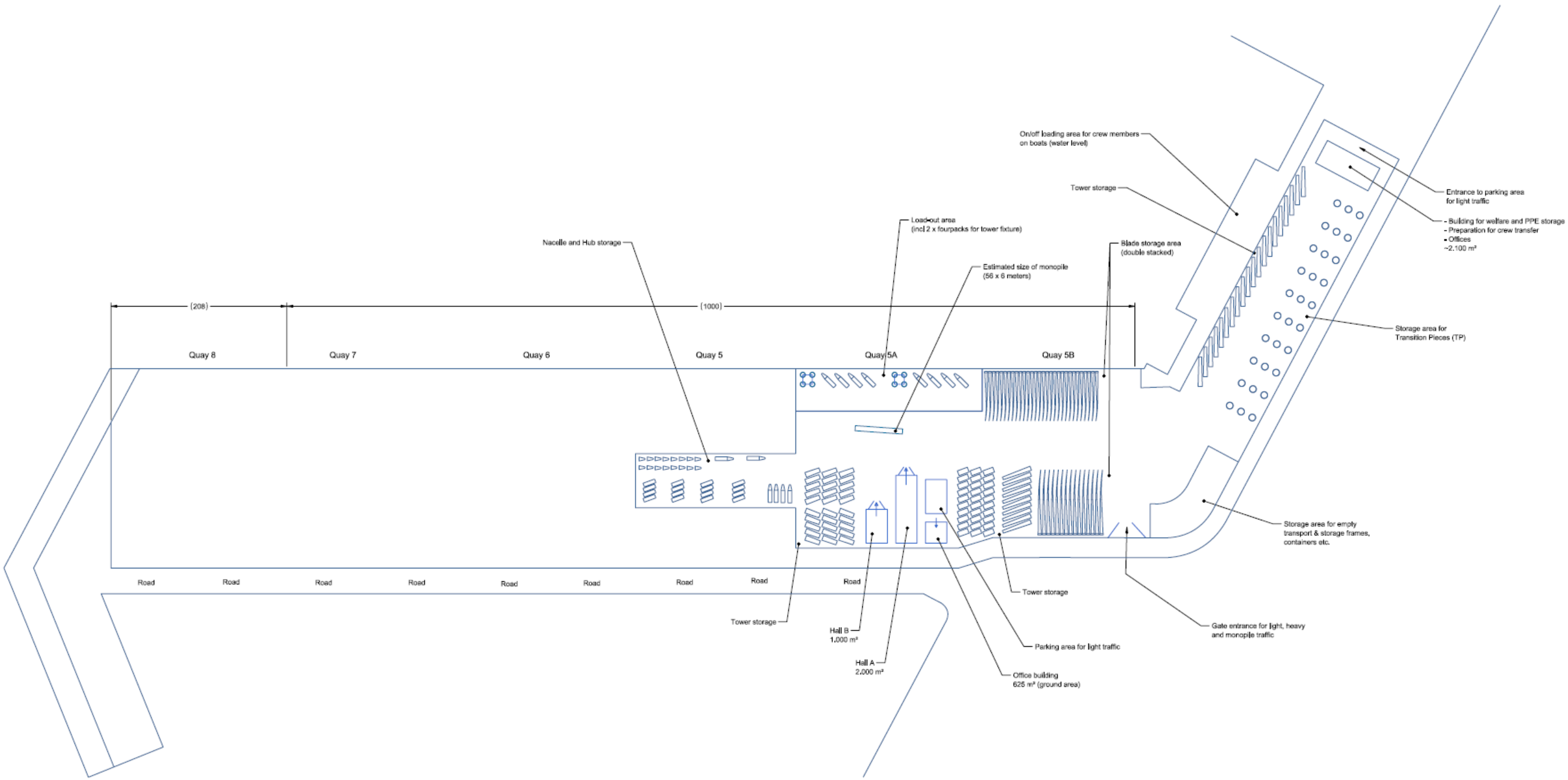


Figure 4.6 Revised layout of the proposed Step 1 development plan including WTG components, see also Appendix C

5 Feasibility of Steps 2 and 3 – FINAL Design

Based on the updated policy, the result of Step 1, Step 2 and Step 3 are merged and presented as a FINAL site design.

The construction process for the port development will consequently be a continuous building process starting in the beginning of 2017, scheduled to deliver Step 1 in April 2018 and the FINAL design layout in April 2020.

5.1 FINAL design specifications

Based on the conclusions from Step 1, the amended proposed design, the revised build programme and the baseline design assumptions, we have determined the following FINAL design specifications:

- The pre-assembly site must have the capability of running two parallel projects with potentially two developers and two OEMs
- Quays 5, 5A, 5B, 6, 7 and 8 will be used as main site for in-load, pre-assembly and load-out
- Quay 4C will be used as back-up storage area and marine support and crew transfer area
- Total of ~ 271,000m^2 gross surface area
- All buildings will have to be removed and new buildings built
- Foundation pre-assembly and load-out not possible from the pre-assembly area
- The structural design and quay load definitions from Step 1 are applied to Quays 5, 6, 7 and 8 also
- The required seabed reinforcement is applied to load-out position 2 also

An overview of the proposed FINAL layout is presented in Figure 5.1. In the following, the design and layout conclusions for FINAL design are presented.

This page is left blank intentionally.

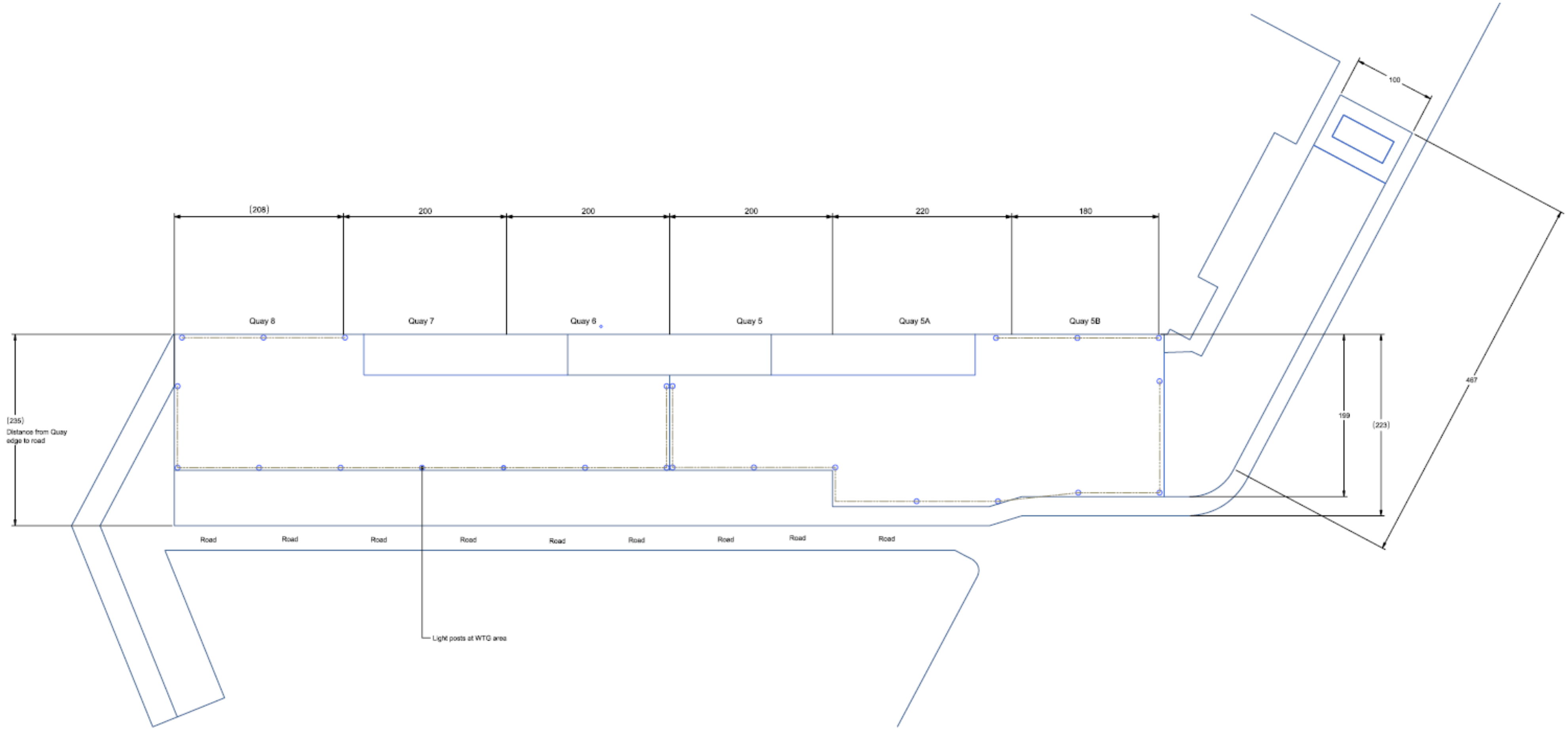


Figure 5.1 Overview of the proposed FINAL layout, see also Appendix C

This page is left blank intentionally.

5.2 Port basin, seabed and vessel berthing/operation

As for the Step 1 layout (see Section 4.1), the size and layout of the port basin are assessed sufficient to ensure an efficient and safe navigation towards Quays 5-8. The existing water depths in the basin (11.5-14mCD, see Figure 3.7) are deemed adequate for WT-operations. The water depth at the quays (11-12mCD) is sufficient for modern installation vessels.

As Quays 7-8 are located closer to the port entrance, wave disturbance here may be marginally stronger than in the inner part of the basin. The difference, however, is believed to be of minor importance for the vessel operability.

It is unlikely that the present seabed can support jacking-up for loadout. Hence, costs of upgrading the seabed shall be encountered (as in Step 1). Alternatively, floating loadout may be considered. The feasibly of this option has not been considered in the present study.

5.3 Quay structures

According to information made available to the Port Consortium, the quay structures in berths nos. 5-8 are substantially identical to those in Quay 5A (see Section 3.3.3 and Figure 3.9). The quays are open-piled structures with a RC deck structure of bearing capacity ~30kN/m^2.

5.3.1 General considerations and design criteria

The extension of the WT-terminal is assumed to meet the same load bearing criteria described in Section 4.2.1 for berth nos. 5A and 5B, i.e.:

- Uniform quay load: 150kN/m^2
- Belt pressure/WT-components: 600 – 800kN/m^2 within an area of 3.0x3.0m^2

See also Section 4.2.1.

5.3.2 Structural quay design

The initially proposed solution for upgrading of berth 5A is assumed suitable also for upgrading of Quays 5 – 8. The solution is described in Section 4.2.2 and is shown in Figure 4.1.

5.3.3 Stone beds for jacking-up vessels

Considerations regarding strengthening of the seabed for jacking-up in front of berth nos. 5 – 8 are similar to the description in Section 4.2.3.

5.4 Assembly area and layout

The overall site concept is based on a common in-load area in the middle between the two independent symmetrical assembly sites. A fence marking the neighbouring line between the sites separates the assembly sites.

The tower pre-assembly areas are placed next to the load-in areas for each site. The WTG components are stored in the quay area and the back area allowing for manoeuvring without obstacles for the required heavy lifting equipment. The lightest components (blades) are placed at the quayside in order to save quay reinforcement. It is, however, necessary to use the quay area for storage because of space constraints.

Buildings are placed just behind the tower pre-assembly area for each site for easy transport of PU/TUs and other components to the pre-assembly area. Each site has its own entrance and security gate with direct access to storage area, storage buildings, administration building and parking area.

Quay 4C is used as a back-up storage area and a separate marine service centre for CTV and service support vessel mooring and crew service area.

A conceptual assembly FINAL layout is presented in Figure 5.2, and the key design assumptions are listed below:

- Site capability: two parallel projects: two developers and two OEMs
- Load-out capacity: 100 WTG per load-out season - 60 x 4MW and 40 7-8MW WTG
- Storage area for 2 x 30 WTG (20 x 4MW and 10 x 7-8MW)
- Shared in-load area and separate assembly and load-out sites
- 4 x four-packs at quay side for alternating tower assembly
- Cold (2 x 2,000m^2) and insulated (2 x 1,000m^2) storage buildings
- Administration buildings (2 x 625m^2) and parking for light vehicles (1,000m^2)
- The perimeter of the area must be secured including controlled access through gates

As the site is influenced by heavy winds caused by typhoons, it is most likely the winds, which will be design driver for pre-assembled towers at the quay (and other infrastructures). Passage of typhoons is typically associated with heavy precipitation. Hence, it is important to design an appropriate drainage system mitigating standing water on surface areas and reduce the risk of flooding in sensitive areas.

The overall metrics for the total site are shown in Table 5.1.

Table 5.1 Pre-assembly area metrics for Step 1 and FINAL layout

Scenario	Total area (m^2)	Load-out area (m)	Assembly area (m^2)	Storage area (m^2)	Buildings, access and parking (m^2)	Foundation area (m^2)	In-load area (m^2)	WTG capacity per year units	Operating window/load-out (months per year)
Step 1	138,000	360x40	26,000	98,000	14,000	15,000	Shared	60	6
FINAL	271,000	2x250x50	70,000	178,000	23,000	0	250x50	100	6

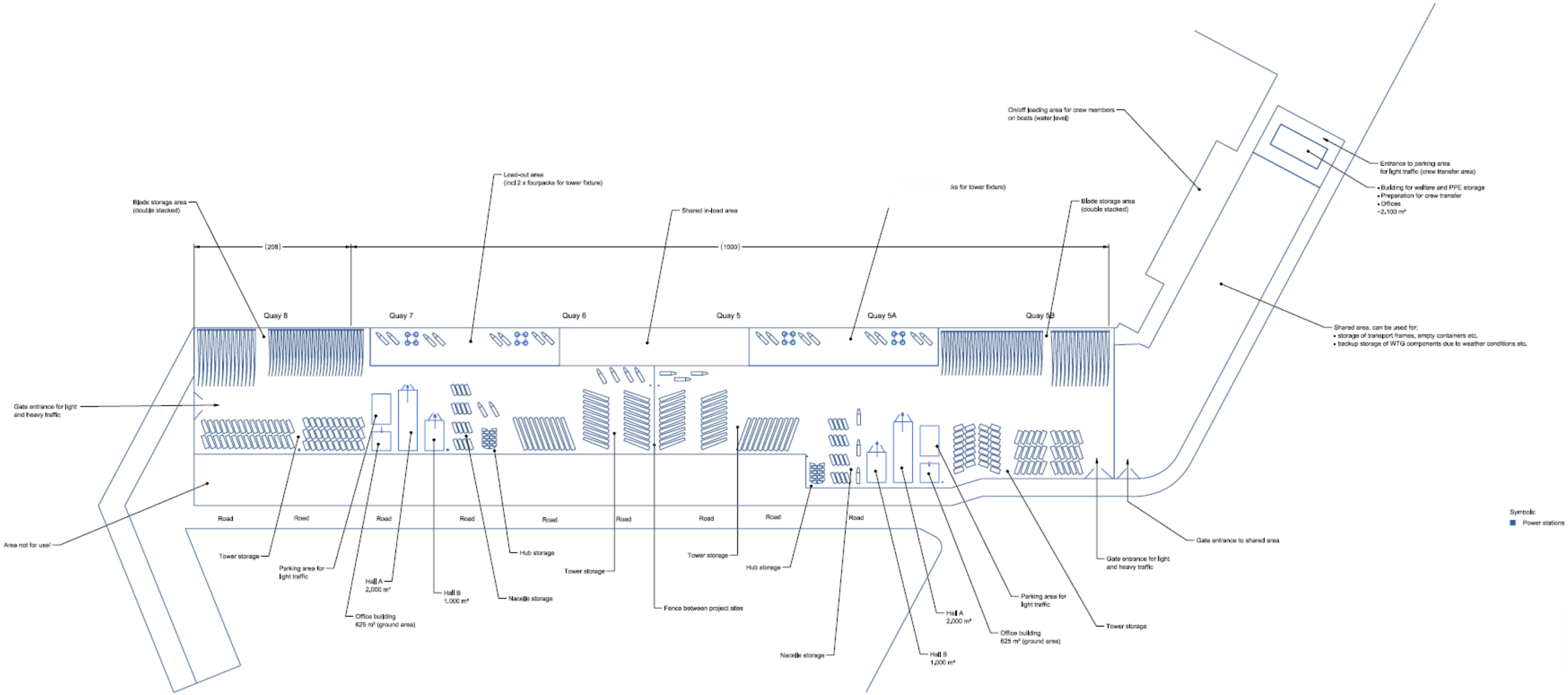


Figure 5.2 Proposed FINAL layout, see also Appendix C

This page is left blank intentionally.

5.5 Assembly, storage and administration buildings

This section gives a detailed description of the FINAL design layout including assembly process and its impact on the site area. Furthermore, the buildings and their purpose are defined.

5.5.1 The assembly process

The assembly process can be divided into five sub-processes:

Goods Inwards

Goods Inwards is the initiating process, where all components and parts are received from the seaside and from the landside. Components received from the seaside are coming in via the common in-load area and are transported to the storage location on the respective site and/or storage building.

Parts received from the landside are coming in via road and through the site gate and then transported to the storage location and/or storage building.

The main activities after internal transport are:

- Receiving inspection
- Registration
- Component marking

Once the Goods Inwards process has been completed, the components are ready for the assembly process.

Storage

As the sites will contain up to 60 WTG sets in storage (see below), there is a storage process, which needs to be performed. This process consists of two main activities:

- Maintenance of components
- Cleaning

The maintenance of components includes tasks like dehumidifying, turning of bearings and hydraulics, which is why the sites need power installations in the storage area.

Preparation

The main components need to be prepared for either pre-assembly or load-out. The preparation process consists of the following main activities:

- Nacelle – mounting of external components
- Towers – mounting of lifting brackets
- Blades – preparation for sea transport and mounting of external components
- Repair of transport damages

Once the components are prepared, they can go to pre-assembly or load-out.

Pre-assembly

The pre-assembly process includes the Power Unit (PU), the transformer unit (TU), the tower sections and the nacelle. Blades go directly to load-out after preparation. The main activities in the pre-assembly process are:

- PU/TU assembly
- Tower assembly, electrical/mechanical completion
- Mounting of Hub (if not mounted from factory) and other components
- Final marking

The PU/TU assembly process takes place in Building B, which is insulated to be suitable for electrical assembly. Once finished, the PU/TU is transported to the tower assembly area (four packs) at the quay area.

Tower assembly includes installation of PU/TU in the bottom tower, stacking of tower sections and completion of cabling and mechanical work and it is performed in the tower fixtures (four packs) at quayside.

Load-out

Once having received all the components (nacelle, tower and blades) in the load area and completed the pre-assembly, the load-out process can begin. The main activities are:

- Quality walk down
- Handover of documentation
- Load-out

Once having finished the quality walk down (official approval of components) and handover of documents, the load-out process (stevedoring and carnage) takes place and the assembly process is finished.

Production output and in-load sequence

The sites production sequence is very much a pull-process, as the offshore installation sequence will determine the load-out sequence. The basic assumption here is that we have an offshore installation window of 6 months from April to September. This means approximately 25 working weeks. With a production rate of four WTG per week, this will generate an output of 100 WTG per offshore season.

It is our opinion that four WTG per week is conservative and hence allow for an efficiency under 100%.

The output rate of four WTG per week will require an in-load transport sequence as follows:

- First delivery 1 February – 20 WTG sets (20 nacelles, 20 towers and 60 blades + various components).
- Hereafter delivery of 10 WTG sets every fortnight from 1 March for 16 weeks.

The storage area has consequently been designed for 30 WTG (20 x 4MW and 10 x 7-8MW) per site – 60 WTG in total in storage.

5.5.2 Storage, administration and support buildings

The site buildings consist of the following:

- Storage Building A (in total 2)
- Storage Building B (in total 2)
- Administration Buildings (in total 2)
- Support Building

Storage Building A

Storage Building A is an uninsulated building of an estimated size of 2,000m² (25 x 82m), see Figure 5.3. Storage Building A is a warehouse for storage of smaller components and consumables. It should be fitted both for storage on pallets and on shelves. Also a smaller office for four persons and a meeting room will be required.

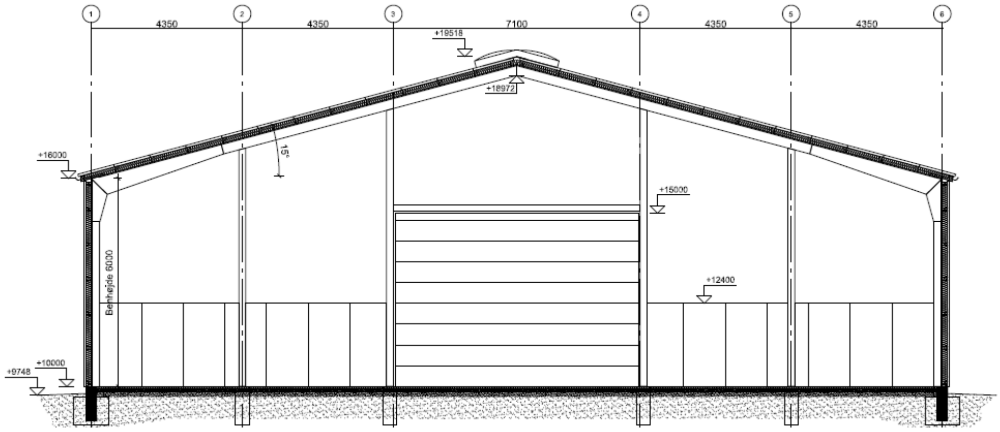


Figure 5.3 Example of Storage Building A. See also Appendix C.

Storage Building B

Storage Building B is an insulated building of an estimated size of 1,000m² (25 x 41m). Storage Building B is a pre-assembly area and storage for electrical components (PU/TU). It should be prepared for pallets storage and floor assembly. It will require air-condition.

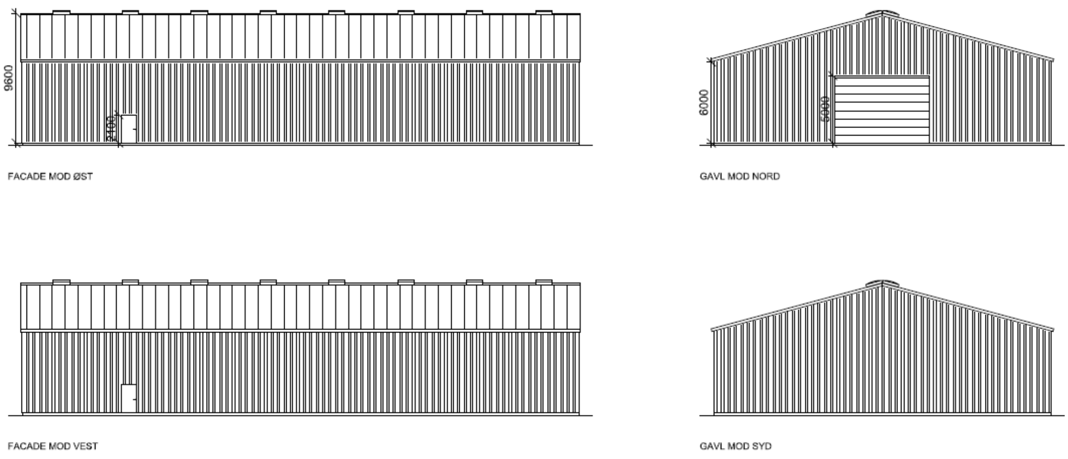


Figure 5.4 Example of Storage Building B. See also Appendix C.

Administration Building

The Administration Building is the central base for site management from three stakeholders:

- Developer
- OEM (Original Equipment Manufacturer) – WTG supplier
- Marine Contractor (Installation Vessel)

The size of the building is estimated to be 625m^2 (one floor) and must include separate offices for each of the above stakeholders: Developer 4 places, Marine Contractor 4 places and OEM 12 places and meeting rooms, cantina, welfare facilities for up to 60 persons.

Parking area for light vehicles is estimated to 1,000m^2.

Support Building

The Support Building is placed at the far end of Quay 4C with individual access for light vehicles. The building is the central base for crew management from two stakeholders:

- Developer
- OEM (Original Equipment Manufacturer) – WTG supplier

The size of the building is estimated to be 2,100m^2 and must include offices and meeting room, PPE storage area and welfare facilities for up to 60 persons.

Support Quay

Quay 4C is proposed for CTVs and other support vessels used by the Developer and the OEM during offshore installation work (April – September).

Support Area

The area behind Quay 4C is used as an off-loading area for empty transport frames/equipment and as back-up area for WTG components in case of load-out stop due to weather or otherwise.

5.6 Support installations and equipment

In order to support the assembly process, a number of installations will be required. This section provides a short description of the most important installations. Furthermore, it presents a list of typical equipment used to execute the assembly work on a typical assembly site.

Support installations

Support installation can be divided into the following categories:

- Process installations
- Power and light installations
- Security

Process installations

The main process installations apart from the quays and buildings are the tower packs (example from Port of Grenaa is shown in Figure 5.5). In this case (Taichung) designed as four packs (four spaces in one pack). It is a permanent foundation consisting of a concrete block casted into the ground with a steel structure mounted on top. The top surface of the steel structure has an integrated flange with a hole pattern matching the hole pattern of the bottom flange of the bottom tower section. Surface coverage of the gaps between positions (floor) is mounted to allow easy and safe access to the towers for technicians working on the pre-assembly.

To allow flexibility between projects, it should be considered to develop interface equipment, so that the same tower pack can be used on different WTG type/sizes.

Figure 5.5 Examples of tower packs at Port of Grenaa, Denmark

Power and light installations

Power and light are needed on the site. For power units in the storage area, a capacity of 3 x 400V 125 Amp is suggested. The placement and number of units are shown in Figure 5.2.

For power units in Buildings A and B, a capacity of 3 x 400V 125 Amp is suggested.

For light poles, it is suggested to use poles of 31m of height with a capacity of 2 x 200W and 2 x 4000W beams. The position and number of the poles are shown in Figure 5.2.

Security and communication

Security is generally a matter of perimeter fencing and a security gate. The site concept is based on two individual sites, and it is designed with two sets of gates for light, respectively heavy, vehicles and fence all around the perimeter.

Communication is a matter of telephone coverage (land line and mobile) and high-speed Internet with high data transfer capability on site and in buildings.

Typical equipment

The below equipment list is for readily information, but is typical for offshore wind projects in Europe. The actual choice of equipment will depend on availability, but the capability of the listed equipment should be noted.

Cranes

Below a list of crane types relevant to handling main components between 4 and 8 MW size is shown. See also Figure 5.6 and Figure 5.7.

Crane	Model	Boom length	Hook block / wire	Rated capacity	Radius
Liebherr	LR 11350 crawler crane	SDB 90 SDB 108	24 T Hook 7 T runner	326 T / 292 T	R 20 m R 20 m
Liebherr	LR 1750 Crawler crane	SDB 91	17,5 T Hook 5 T runner	295 T	R 20 m
Liebherr	LR 1200 200T crawler crane	50m	3,0 T	45,6 T	R 18 m
Liebherr	LR1280 – 280T crawler crane	49,1m	4,6	126,6T	R 8 m

Other equipment

Different miscellaneous lifting equipment is also required to operate an offshore wind assembly site. Below is a list of the most common equipment:

- 150T Reach Stacker (see Figure 5.7)
- 75T Reach Stacker
- Reach Stacker incl. container frame
- Cassettes
- Flex Master
- 37T Truck
- Terminal tractor
- Various equipment for lifting and fastening

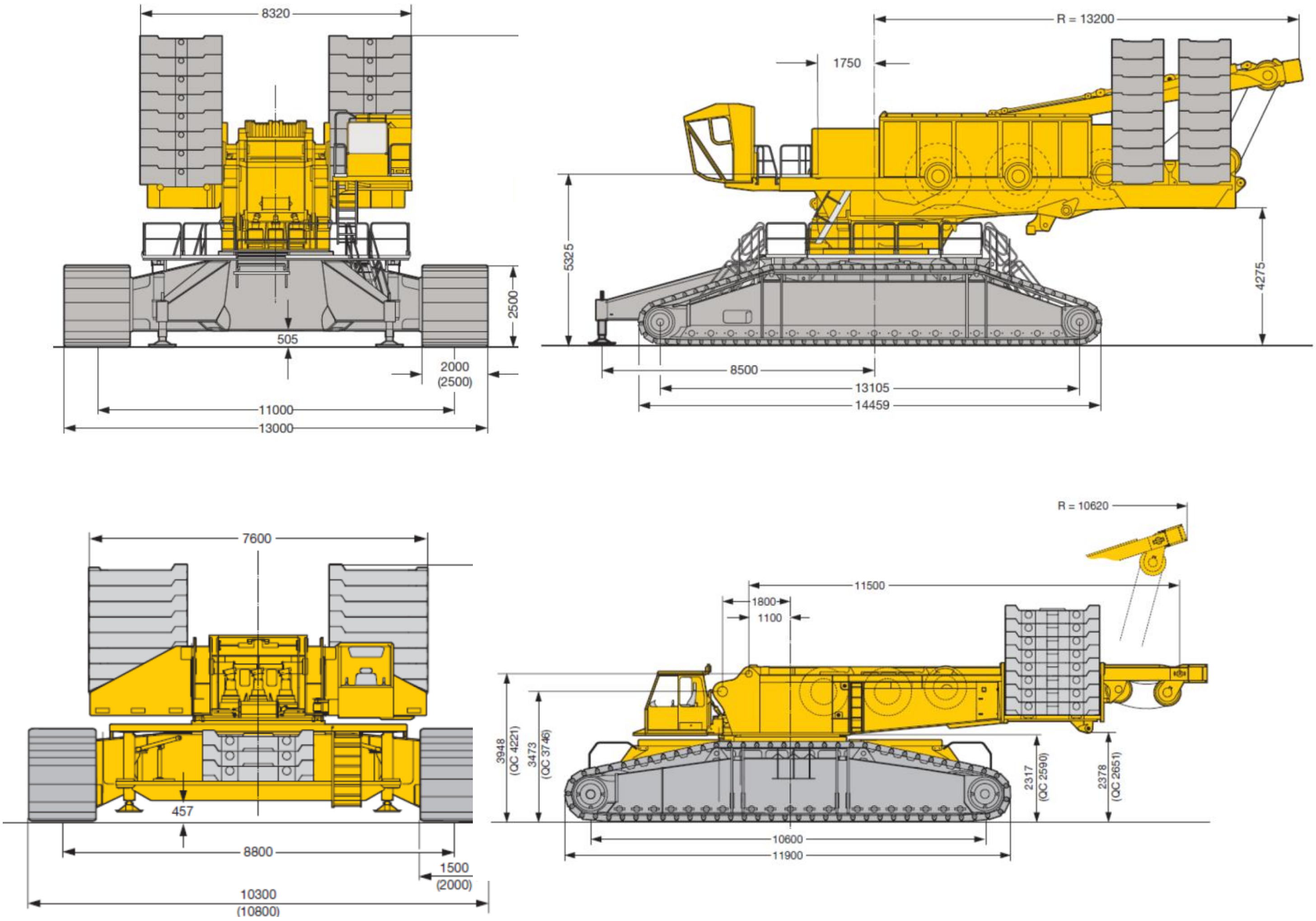


Figure 5.6 Examples of cranes used in Europe. Upper: LR11350, lower: LR1750 (from above table)

Figure 5.7 Reach Stacker incl. container frame

5.7 Financial analysis, investment budget and business model

The financial analysis is based on European standards and cost levels. It will have to be converted into local standards and cost levels for detailed design. The analysis is meant to give a relative indication particularly for the seabed, quay and surface area upgrade. For buildings, support facilities and equipment, it is deemed not relevant to provide a detailed analysis based on European standards and hence, it should be costed directly on local terms in detailed design.

However, for the particular process equipment of tower packs, we have included a cost specification in Section 5.7.3. For all other auxiliary equipment, we have accumulated the required number of units and m^2.

5.7.1 Port basin, seabed and vessel berthing/operations

The description in Section 4.1 of installation vessels and required draft in the basin is deemed valid also for the FINAL development of the WT terminal.

However, due to the proposed amendment of the general layout as shown in Figure 5.2, berth 5B will no longer be needed for quayside operations, but only for stacking of wings. This amendment will apply for Step1 development as well as FINAL site layout.

As a consequence of this amendment, no or very limited dredging will be required in the inner part of the basin with shallow and unknown water depth.

5.7.2 Quays and stone bed

The proposed amendment also means that the previously discussed upgrading/construction of quay structures in Section 5B will not be needed.

The present bearing capacity of $3t/m^2$ is assumed sufficient to meet the requirement for the intended use of the apron at berth nos. 5B and 8 for stacking of WTG-wings.

So the investment shall include upgrading of approximately 750m quay length (berth nos. 5–7). A technical solution is proposed as described in Section 4.2.2 and shown in Figure 4.1.

A stone bed of approximately 50m width shall be installed on the seabed in front of the upgraded quays to accommodate jacking-up of installation vessels. Vessel characteristics and operational policies will determine whether the protection shall cover the entire quay length (750m) or can be limited to pre-defined sections of the berths. For the cost assessment below is assumed that 60% of the quay length shall be protected with a stone bed.

Thus, the budget for capital investment in quay upgrading is assessed to include the following:

• Reconstruction of quay: 750m of 38,000USD	28.5 MUSD
• Quay interfaces:	2.5 MUSD
• Stone bed: 25,000m^2 of 150USD	4.0 MUSD
Total	**~ 35 MUSD**

5.7.3 Overall infrastructure

The investment budget consists of two budget lines:

- Investment in basic infrastructure
- Investment in auxiliary infrastructure

Investment in basic infrastructure
The investments in basic infrastructure include:

Quays and seabed:	~35 MUSD
Surface: 271,000m^2 of 100USD*	~27 MUSD
Total:	**62 MUSD**

*) *The estimated rate is only tentative and will depend on several factors: Demolition works, compaction treatment of ground, drainage installations and pavement design (a pavement of gravel and crushed rock is assumed).*

Investment in auxiliary infrastructure
The investments in auxiliary infrastructure include:

Tower Packs:
Step 1: 1 x 1 4Pack + 1 x 1 4Pack interim ~ 0.9 MUSD
FINAL: 3 x 1 4Packs + removal of interim ~ 2.0 MUSD

Please note that additional cost for typhoon load specifications has not been considered at this stage.

Buildings:
Step 1: 3,625m^2
FINAL: 5,725m^2

Cost to be calculated in detailed design phase.

Power and light:
Step 1: 12 light poles
Step 1: 8 transformers

FINAL: 24 light poles
FINAL: 14 transformers

Cost to be calculated in detailed design phase.

Total investment budget estimate – FINAL Layout: 65 MUSD

Including tower packs - excluding remaining auxiliary infrastructure.

5.7.4 Business model

The business model for an offshore wind base is somewhat different from a general port business case. It is first of all a project-based business, and the work executed at the base/site is much wider and more complex than normal port operation, and in most countries the port authority is not allowed to perform these tasks.

It is also of great importance to the business model, who is going to invest in the base infrastructure (seabed, quays and surface). At this point in time, this is unknown to the Port Consortium. Therefore, we have designed a business model, where the owner can also be a leaseholder and/or an operator, see Figure 5.8 below. See also Appendix C.

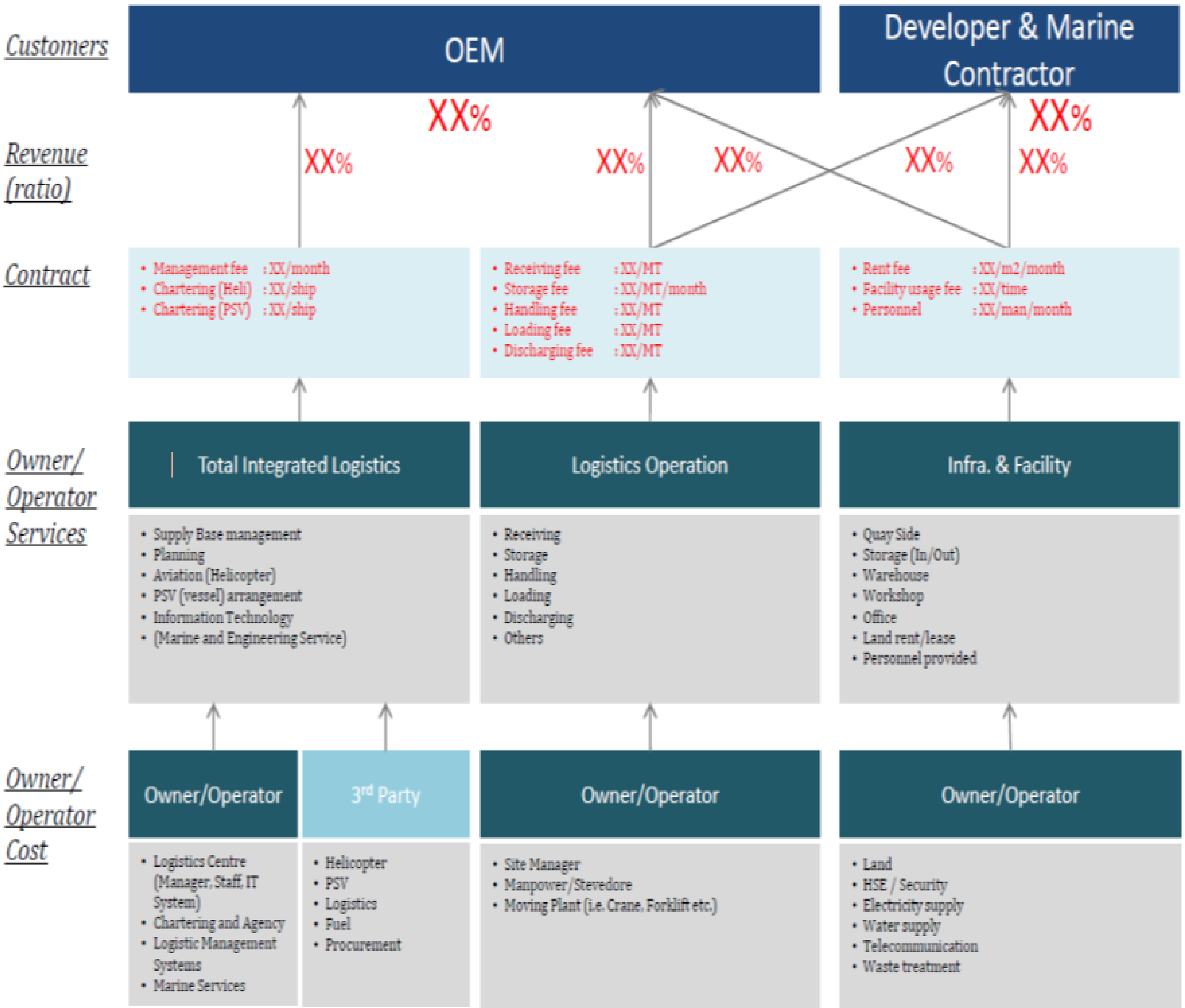


Figure 5.8 Proposed offshore wind base business model

Owner/Operator cost

The assumption here is that the infrastructure investment has been done by the owner and will be covered either directly if the owner is also the operator or indirectly if there is a leaseholder, who is operator. We see the following combinations:

- Owner/operator
- Owner + leaseholder/operator
- Owner + leaseholder + operator

Depending on the combination, the revenue must be shared on a cost/activity based principle.

Owner/Operator Services

The services provided are defined in three categories:

- Infrastructure & Facilities
- Logistic Operation
- Total Integrated Logistics

The decision of “who is doing what” is depending on the choice of combination from above.

Contract

The contract will be based on the scope of services and is divided into two revenue streams:

- Recurring
- Fixed per time unit (month, project period)

Recurring

The recurring revenue is simple based on price per unit used (man-hours, port calls, ton, equipment hours etc.), hence the usage of the service.

Fixed per time unit

The revenue coming from the time-based cost is typically related to the long-term investments in infrastructure, buildings, etc. The charges in terms of lease, rent and fee must be based on the business case derived from the long-term market volume. In case of Taichung Harbor ,it could e.g. be based on a volume of 100 WTG per year for 10 years and hence a depreciation of the investment over 10 years plus profit.

Customers

On an offshore wind base, there are two types of customers; the OEM and the developer/marine contractor. It varies who is the main customer, but in Europe it is normally the OEM (WTG manufacturer), who is the main customer and the other two the minor customers. This is also the way the model has been designed and the buildings configured. However, in some cases the developer is the main customer and may even provide the site as “customer furnished” for the main contractors.

This page is left blank intentionally.

6 Conclusions

Based on our studies, environmental load and structural analysis, design and layout considerations and our financial analysis, we have concluded the following:

Port basin, seabed and vessel berthing/operation

The size and layout of the port basin are assessed sufficient to ensure an efficient and safe navigation. Except for the inner part of the basin, the water depths are larger than 11mCD, which is deemed adequate for modern installation vessels.

It has been assumed that 2nd generation heavy lift DP jack-up vessels will be utilized for WT loadout. As the present seabed does not support jack-up operations, purpose-made stone beds have to be constructed to ensure controlled jacking conditions and to limit leg penetrations. Alternatively, floating loadout may be considered. The feasibly of this option has not been considered.

Quays

According to information made available to the Port Consortium, the quay structures in berth nos. 5-8 are substantially identical to those in Quay 5A. The quays are open-piled structures with a RC deck structure of bearing capacity ~30kN/m^2.

In order to fulfil load requirements in an offshore wind terminal, the Port Consortium recommends the following loads:

- Uniform quay load 150kN/m^2
- Belt pressure/ WT-components 600-800kN/m^2 within an area of 3.0x3.0m^2

The proposed amendment means that the previously discussed upgrading/construction of quay structures in Section 5B will not be needed.

The present bearing capacity of 3t/m^2 is assumed sufficient to meet the requirement for the intended use of the apron at berth nos. 5B and 8 for stacking of WTG-wings.

Assembly Area and Layout

Provided the above conclusions, it is feasible to design and build a dual project offshore wind hub in Taichung Harbor with a load capacity of 100 WTG within the assumed 6-month operational window. It is, however, not feasible to mix the WTG assembly and load-out with final assembly and load-out of foundations. As an interim solution, until another site has been developed, monopile foundations can be loaded out from Taichung Harbor for projects in 2018 and 2019.

The Port Consortium has shown in its proposed FINAL design how the layout of the offshore wind hub can be designed. We have also shown how the overall transport infrastructure can be planned to fulfil the basic assumptions made by BoE. The FINAL design requires a total area of 271,000m^2 at the Quays 4C, 5B, 5A, 5, 6, 7 and 8.

Assembly, Storage and Administration Buildings

In order to make the layout feasible, it will be necessary to remove all existing buildings from the area of Quays 5, 6 and 8 and build seven new buildings with a total covered area of 9,350m^2.

The building requirements are particularly affected by the basic assumption that the site must host minimum two separate projects at a time.

Support Installations and Equipment

A number of installations need to be made, none of them particularly challenging to the local industry, which is why we conclude that this will just be a matter of initiating the detailed design and the following construction. It is also concluded that the development of flexible tower packs will contribute to cost reduction and increased efficiency of the site.

The provided equipment list is for reference; however, the conclusion is that the current heavy lifting capacity in Taiwan will most likely struggle to deliver adequate equipment for this site.

Financial Investment for FINAL layout

The total investments required are estimated to:

Seabed:	
Quays and Seabed:	~35 MUSD
Surface:	~27 MUSD
Process equipment:	~ 3 MUSD
Total	**~65 MUSD**

Excluding other auxiliary equipment (as specified), site investigation, design studies, tendering process, etc.

7 Recommendations

In the light of the developments of the political and industrial support of the renewable energy in Taiwan, and the offshore wind development in particular, and based on our findings in the feasibility study, The Danish Port Consortium recommends the Taiwanese Bureau of Energy to do the following:

- To initiate the build project for the basic infrastructure immediately
- To build Step 1 and continue directly towards the FINAL layout
- Seabed to be reinforced for multiple jack-up vessels
- To utilize Quays 4C, 5B, 5A, 5, 6, 7 and 8 and follow the FINAL design layout concept to minimize cost as much as possible and still meet the required capacity
- When fully built to use Taichung Harbor for WTG assembly and load-out only and to explore the development of flexible tower packs
- To secure governmental investments in the basic infrastructure
- To identify public/private operator investments in auxiliary infrastructure.

This page is left blank intentionally.

8 Final Feasibility Workshop

The Final feasibility Workshop has taken place in Taipei:

Date and Time: October 28th 2016 at 1 PM

Address: Conference Room D, 6F, No. 99, Fuxing North Rd., Taipei, Taiwan

8.1 Objective

The objective of the workshop was to present the findings and recommendations of the Port Planning Feasibility Study, Taichung Harbor.

The workshop aimed at both presenting and discussing the recommendations with industry stakeholders in order to get best possible feedback to BoE as background for the future planning of the Offshore Wind Hub in Taiwan.

8.2 Participation

BoE to provide input.

8.3 Tentative Programme and presentation

1. Opening remarks BoE Director Su and TC Taipei Marina Hsu
2. Feasibility Study Overview
3. Structural Design – Quays and Surfaces
4. Pre-assembly process layout
5. Equipment and Facilities
6. Financial Study
7. Recommendations

This page is left blank intentionally.

9 References

/1/ Harbor & Marine Technology Center (2014). Impact analysis of coastal and harbor structure on extreme waves (in Chinese).

/2/ Harbor & Marine Technology Center (2012). Investigation of long-term wave statistics and design wave for main harbors of Taiwan (in Chinese).

/3/ Kuo-Tung Chang, Chi-Min Chiu, Kuo-Chyang Chang, Dong-Jiing Doong, Hui-Lin Chen (2004). Regression Analysis on the Typhoon Surge in Taiwan (in Chinese).

/4/ Harbor & Marine Technology Center (2013). Oceanographical Observation Data – Annual Report 2013 (Wind:Part II), (in Chinese).

This page is intentionally left blank

APPENDICES

This page is intentionally left blank

APPENDIX A

Policy and Promotion of Offshore Wind Power in Taiwan

ITRI Presentation 2016

This page is left blank intentionally.

Policy and Promotion of Offshore Wind Power in Taiwan

Thousand Wind Turbines Promotion Office

operated by **Industrial Technology Research Institute**

supervised by **Bureau of Energy, MOEA**

Overview

- Targets & Strategies
- Phases of Promotion
- Domestic Industry
- Summary

Taiwan Offshore Wind Potential

Shallow Water (5-20 m)

- **Area:** 1,779.2 km^2
- **Potential:** 9 GW
- **Feasible:** 1.2 GW

Deep Water (20-50 m)

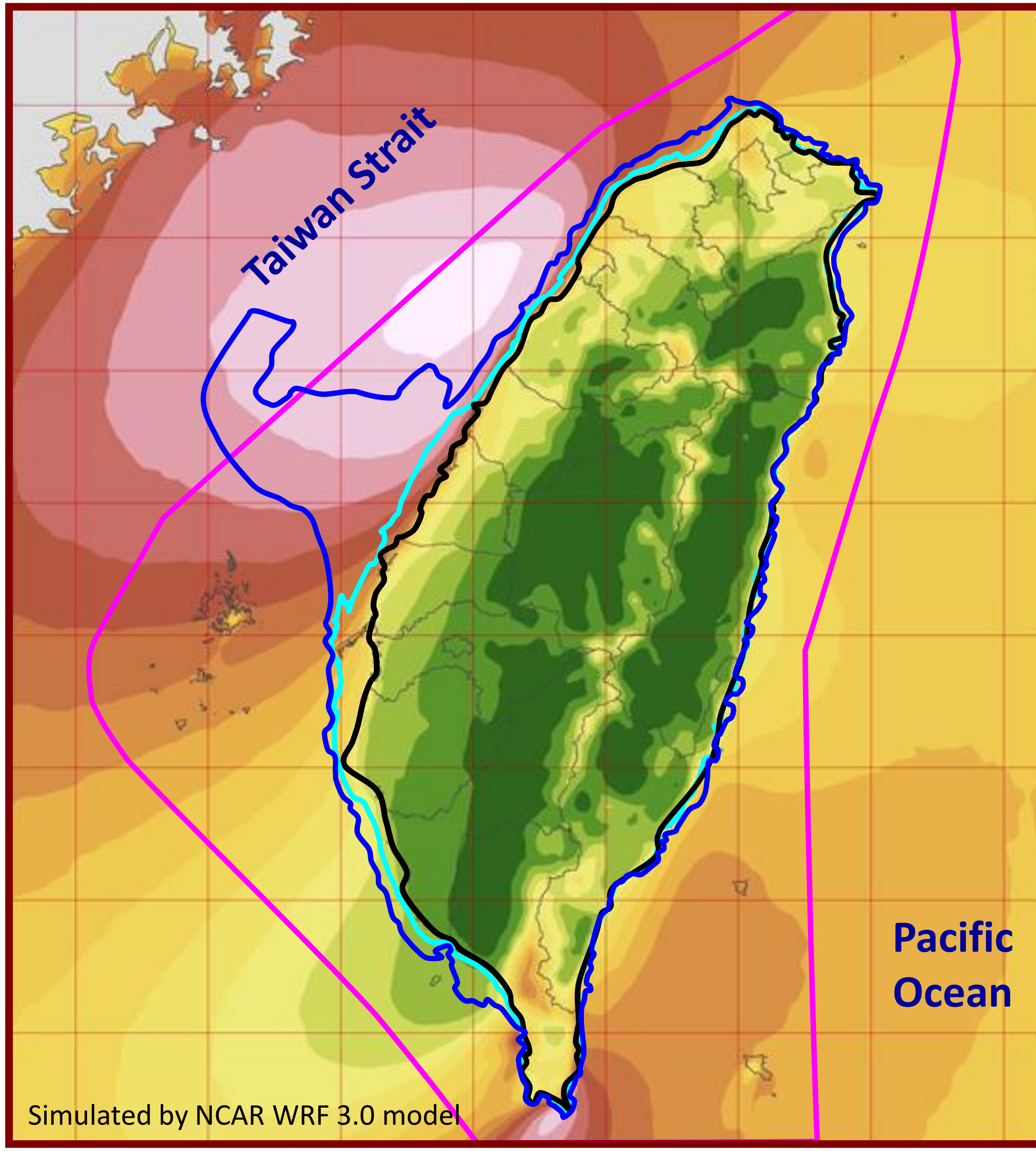
- **Area:** 6,547 km^2
- **Potential:** 48 GW
- **Feasible:** 5 GW

Deeper Water (> 50 m)

- **Potential:** 90 GW
- **Feasible:** 9 GW

Wind Power Density(W/m2)

< 100	400 - 500	800 - 900	1,200 - 1,300
100 - 200	500 - 600	900 - 1,000	1,300 - 1,400
200 - 300	600 - 700	1,000 - 1,100	1,400 - 1,500
300 - 400	700 - 800	1,100 - 1,200	> 1,500



Ref. "Wind Resource Assessment Handbook," ITRI, 2011

Targets of Wind Power Development

- **Short-term Target:** 4 demonstration offshore wind turbines by 2016
- **Mid-term Target:** Offshore 520 MW by 2020
- **Long-term Target:** Offshore 3,000 MW by 2025

	short-term 2016	mid-term 2020	long-term 2025
onshore	671 MW	745 MW	1,200 MW
offshore	Demo. Turbines 16 MW	Demo. Wind Farms & Zones of Potential 520 MW	Zonal Development 3,000 MW

Feed-in Tariff System

Renewable Energy Development Act (REDA, 再生能源發展條例)

- **Taiwan promulgated the Renewable Energy Development Act in July, 2009 to systematically promote renewable energy.**
- **The core strategy of the Act is Feed-in Tariff system.**
- **PPA** (power purchase agreement) **of renewable energy is guaranteed for 20 years.**
- **A Committee is formed to review the formula and tariffs annually.**
- **Tariffs shall not be lower than the average cost of domestic fossil-fueled power.**

Feed-in Tariffs of wind power in Taiwan

- **Onshore**: NT$2.8099 (€7.6₵) / kWh for 20 years
- **Offshore**:
  - **Option #1**: NT$5.7405 (€15.6₵) / kWh for 20 years
  - **Option #2**: NT$7.1085 (€19.3₵) / kWh for the first 10 years
    NT$3.4586 (€9.4₵) / kWh for the next 10 years

Strategies for Offshore Wind

DIP Incentives for Pioneers → **ZAP** Transition Period → **ZD** Self-sustaining Industry

- **[Phase 1] Offshore Demonstration Incentive Program** (示範獎勵辦法)
  - **4 Demonstration Turbines by 2016, 3 Demonstration Wind Farms by 2020**
  - **Government provides subsidy for both equipment & developing processes**
- **[Phase 2] Directions of Zone Application for Planning** (場址作業要點)
  - **36 Zones of Potential revealed for preparation in advance of Zonal Development**
  - **Applicants must acquire EIA approval by 2017 and Preparation Permit by 2019**
- **[Phase 3] Offshore Zonal Development** (區塊開發)
  - **To be announced by 2017 while SEA is currently in progress**
  - **Commercial scale for cost reduction** (similar to Round 3 of UK)

Topics

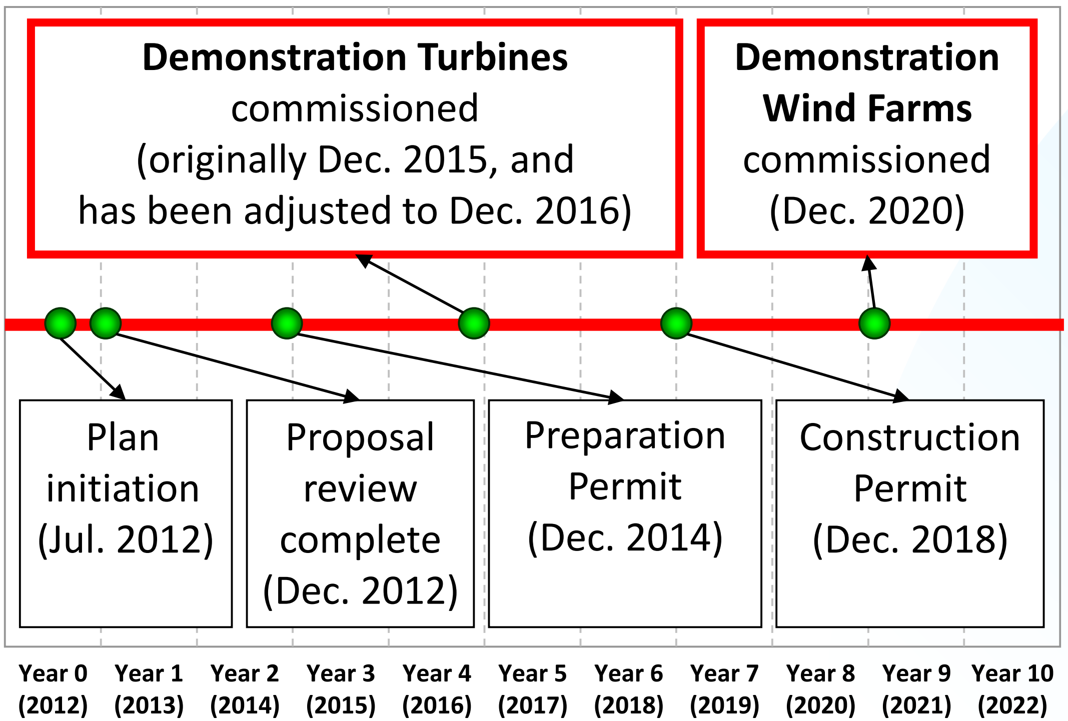
- Targets & Strategies
- **Phases of Promotion**
- Domestic Industry
- Summary

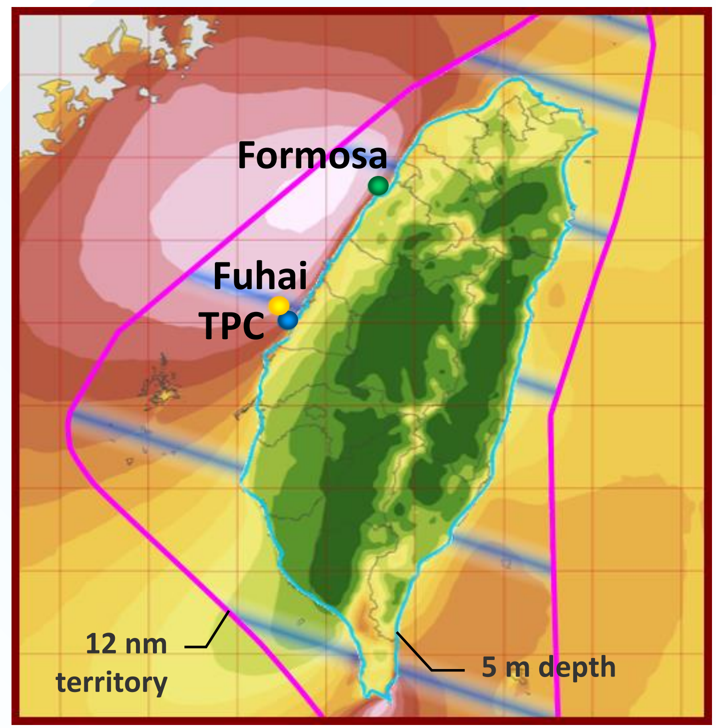
Demonstration Incentive Program

[Phase 1] DIP

Demonstration Projects of Offshore Wind

- **3 Winners** (Fuhai, Formosa & TPC) **officially announced on 9th January 2013**
- **MOEA provides subsidies for both <u>turbines</u> & <u>wind farms</u> to encourage pioneers**
- **To confirm feasibility in terms of administration, technology and finance**





Zone Application for Planning

[Phase 2] ZAP

Siting for Zones of Potential (ZoP, 潛力場址)

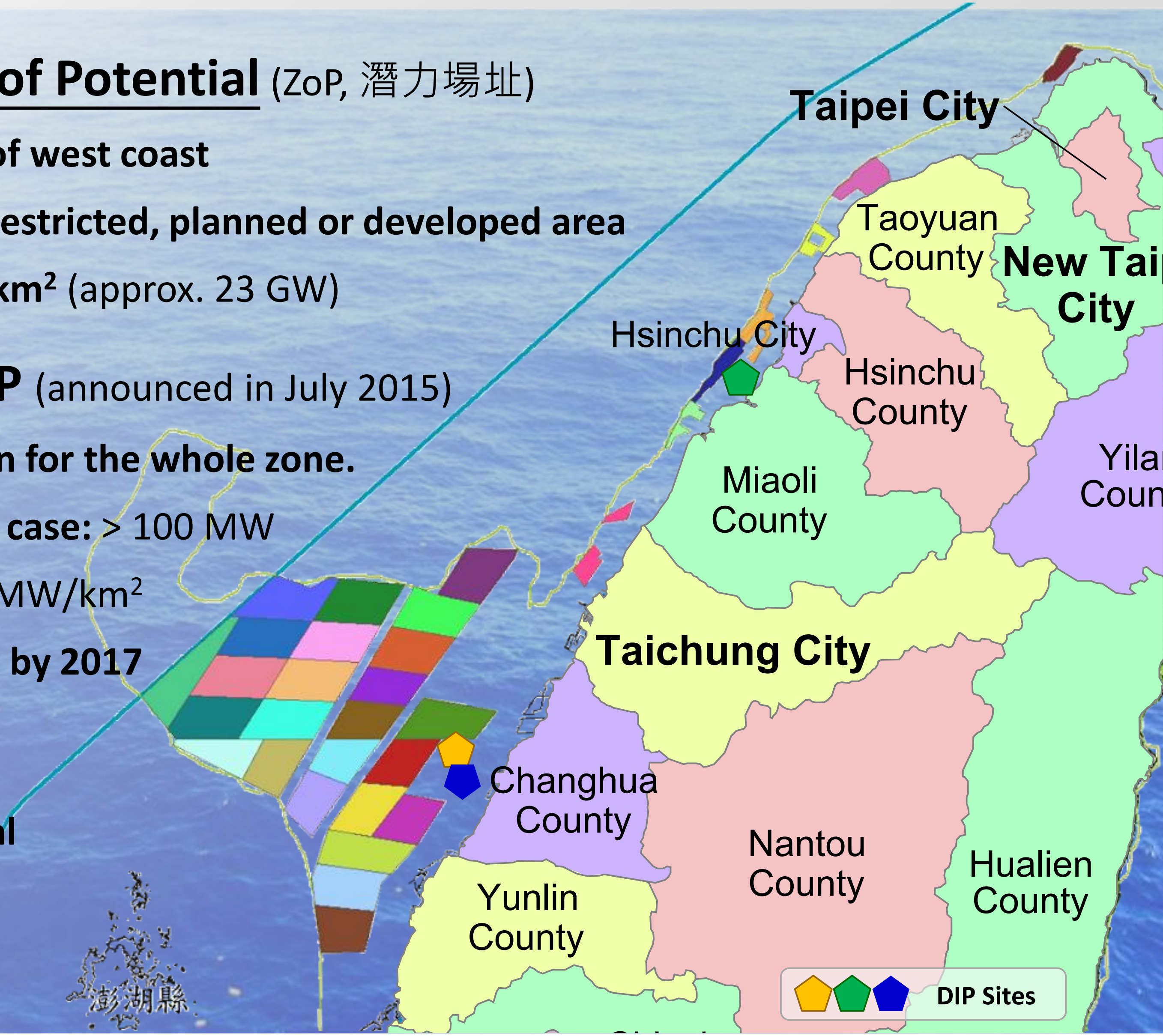
- Within 50 m isobath of west coast
- Excluding protected, restricted, planned or developed area
- 36 ZoP: total 3,084.5 km^2 (approx. 23 GW)

Directions of ZAP (announced in July 2015)

- Applicants should plan for the whole zone.
- Total capacity of each case: > 100 MW
- Capacity density: > 5 MW/km^2
- EIA approval required by 2017

Negotiations

- SEA & inter-ministerial negotiations will be conducted based on 36 ZoP.



Zonal Development

Purpose

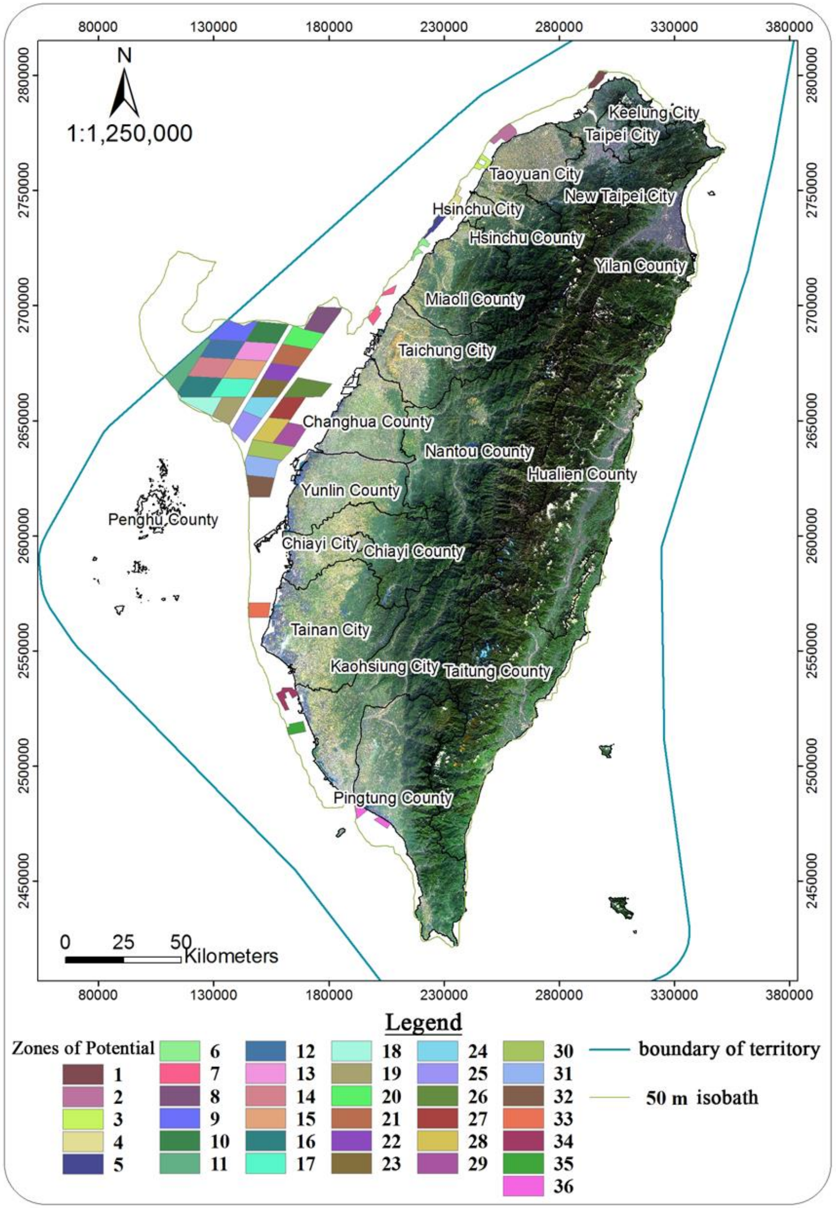
- Marine Spatial Planning
- Optimal Resource Utilization
- Domestic Industry Development

Goal

- To be announced by 2017
- To reach 3 GW target by 2025

Benefit

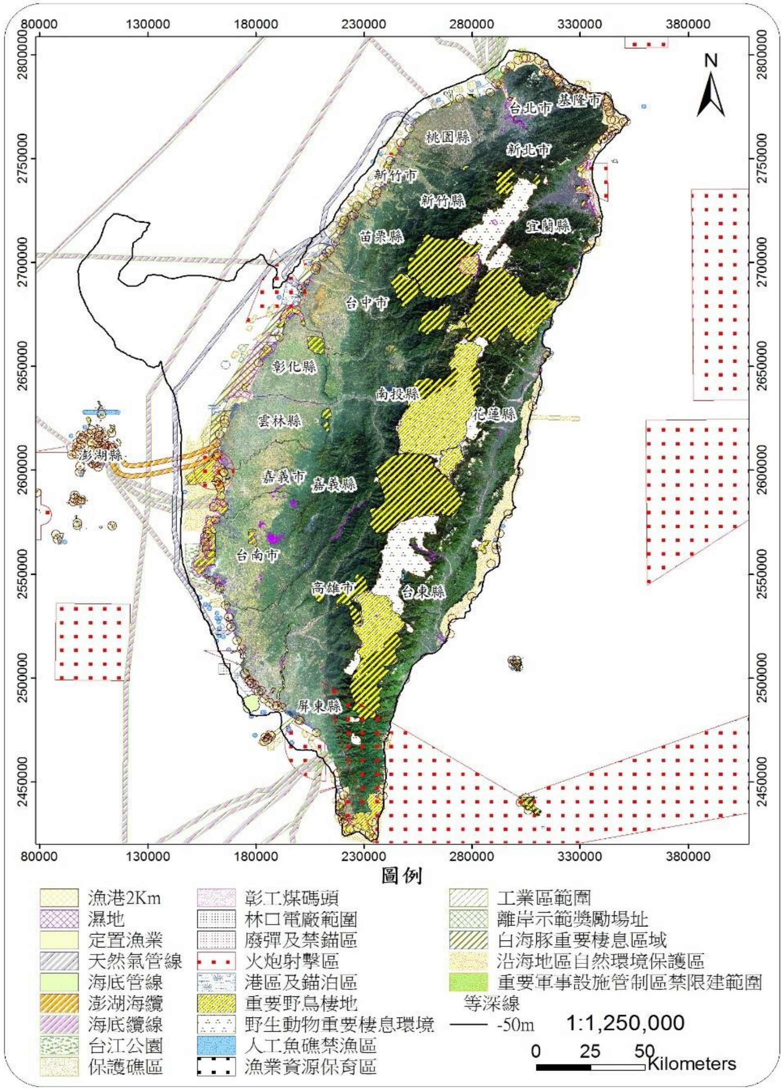
- 11.1 billion kWh/yr of green electricity
- 5.8 million ton/yr of carbon reduction



Strategic Environmental Assessment

34 items of evaluation in 8 categories

- Environmental Assimilative Capacity
- Natural Ecology and Landscape
- Civil Health and Safety
- Utilization of Land Resources
- Water Resource System and Its Usage
- Cultural Heritage
- International Environmental Agreements
- Social Economy



Consultation Meetings

- SEA Report reviewed by EPA on 9th March and 12th July, 2016
- 36 ZoP will be reduced or adjusted based on the results of SEA consultation.

Scheme of Zonal Development (Draft)

[Phase 3] ZD

Pipeline

- **Zones will be released in stages:**
  once every 3 years with review and adjustment
- **Total Capacity Control:**
  to release 500-2,000 MW in each stage
- **Priority of Zones:**
  based on SEA consultation and inter-ministerial negotiations

Criteria

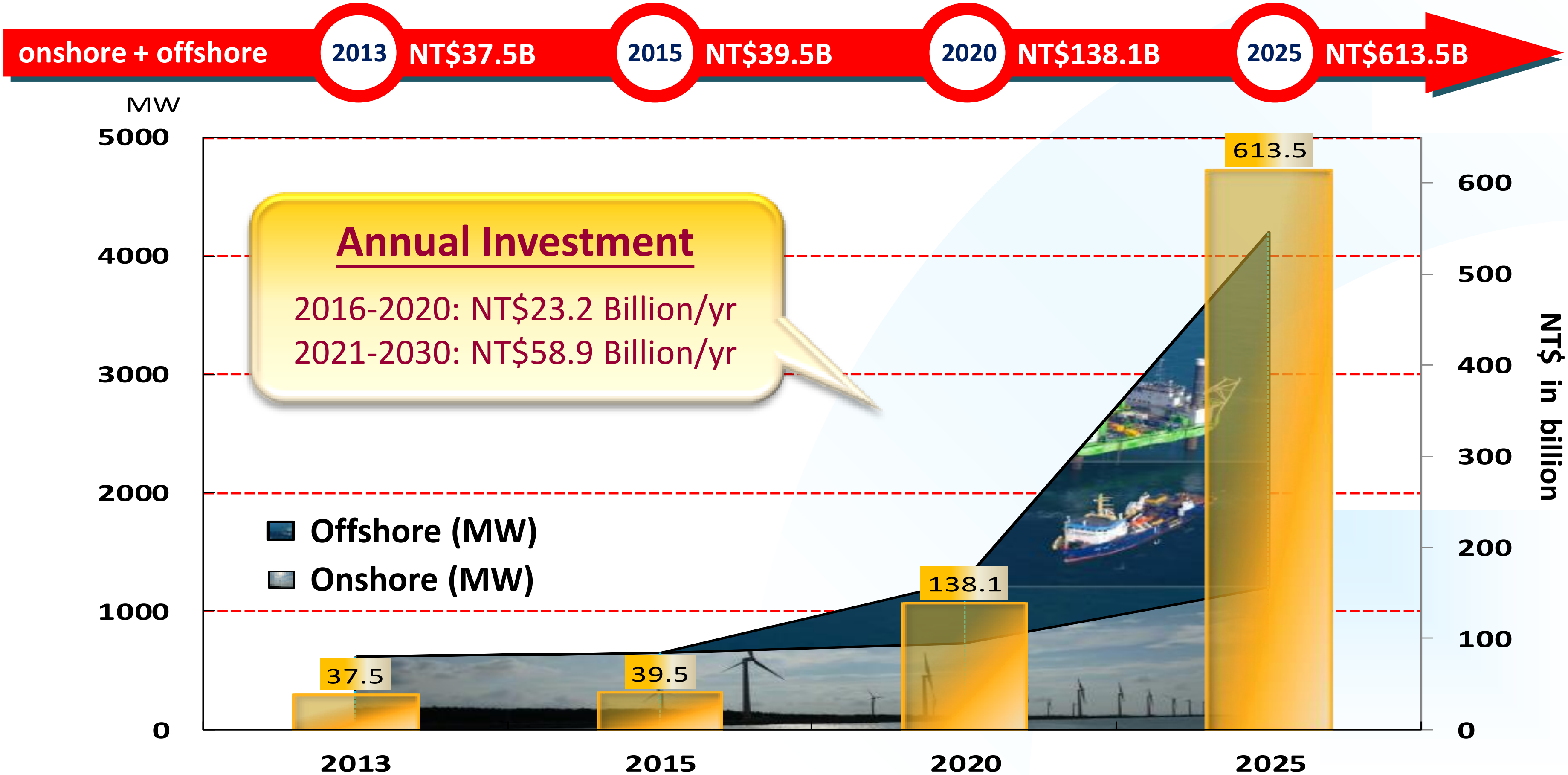
- **Paid-in capital & financial conditions**
- **Team composition & capabilities**
- **Schedule of development**
- **Industrial benefit to the <u>domestic supply chain</u>**

Topics

- Targets & Strategies
- Phases of Promotion
- **Domestic Industry**
- Summary

Domestic Market Estimates

- Offshore 3,000 MW by 2025 → NT$540B (€14B) investment
- Policy → Developers → Service Providers → Manufacturers



Supply Chain of Wind Power in Taiwan

Manufacture

Raw Material

Steel
CSC

Fiber
Formosa Plastics, TaiwanGlass, CHUNG YEH, Drewloong, etc.

Epoxy
Swancor, Eternal Materials , etc.

Components/Sub-system

Electrical Sys.
TECO, TATUNG, Fortune, Shihlin, Chung Hsin, Allis, Delta, etc.

Tower
CSC, Lihkang

Blade
HorizonYacht, China FRP, etc.

Gearbox
FHI

Control
TECO, AIDC, Advantech, etc.

Cast/Forge
YJF Casting, Yeong Guan, Yih Guang, Cheng Sheng, Cheng Feng, Nan Lung, San Eng, Shun Yu, Hongda, etc.

System

Onshore
TECO

Offshore
New Wind Power (TECO/CSC)

Balance of Plant (BoP)

Foundation
CSC, CSBC, Hung Hua, Chau-Hsen, Hwa Chi, MRY, etc.

Cable
TAYA, Walsin, etc.

Service

Planning
TPC, Infravest, TGC, Sinotech, Iy-Hsing, CECI, TMHI, etc.

Construction
Chung Hsin, Fortune, LUXE, Star Energy, Woen Jinn, CSBC, Hwa Chi, AIDC, CSC, Hung Hua, etc.

Maintenance
Solvent, CSBC, KUANG-LEE, Vestech, CSC, etc.

Developer

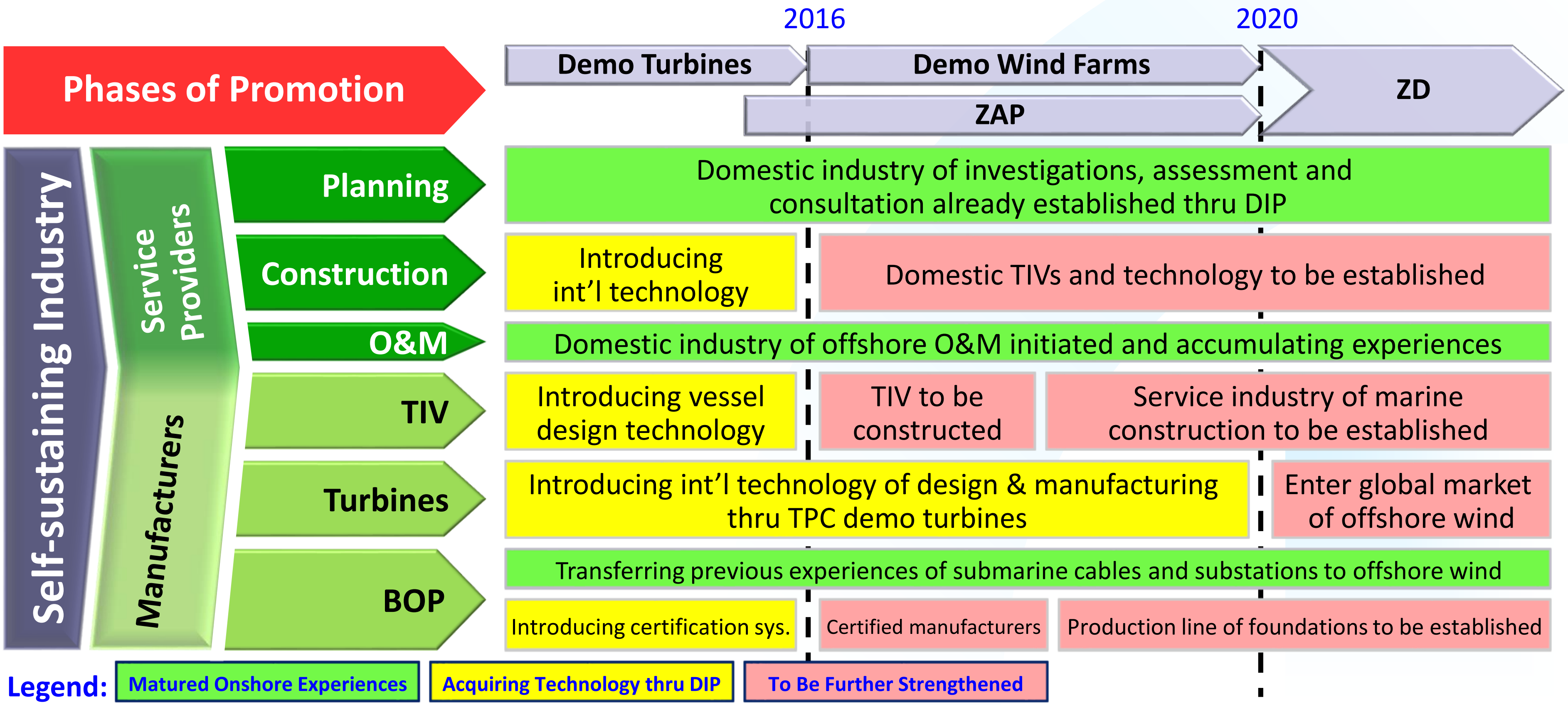
Operation
TPC, Infravest, TGC, Formosa, Fuhai, TCCY, etc.

Matured

Capable

Self-sustaining Industry of Offshore Wind

- Identify the missing links thru DIP
- Match international experts with domestic players
- Develop in-house capabilities



Topics

- Targets & Strategies
- Phases of Promotion
- Domestic Industry
- **Summary**

Summary

Promote Offshore Wind in 3 Phases

- **[Phase 1] DIP** (2012~)**:** Incentives for Pioneers
- **[Phase 2] ZAP** (2015~)**:** "Zones of Potential" for commercial projects
- **[Phase 3] ZD** (2017~)**:** Pipeline for a sustainable domestic market

Taiwan: the Best Entrance into Asian Market of Offshore Wind

- **Resource:** best offshore wind resource in the world
- **Policy:** stable environment and clear targets
- **Supply Chain:** design, manufacturing, construction, O&M
- **Environment:** sound legal framework & high economic freedom
- **Vision:** competitive, innovative, and profitable industry of offshore wind

Thanks for Your Attention

Thousand Wind Turbines Promotion Office

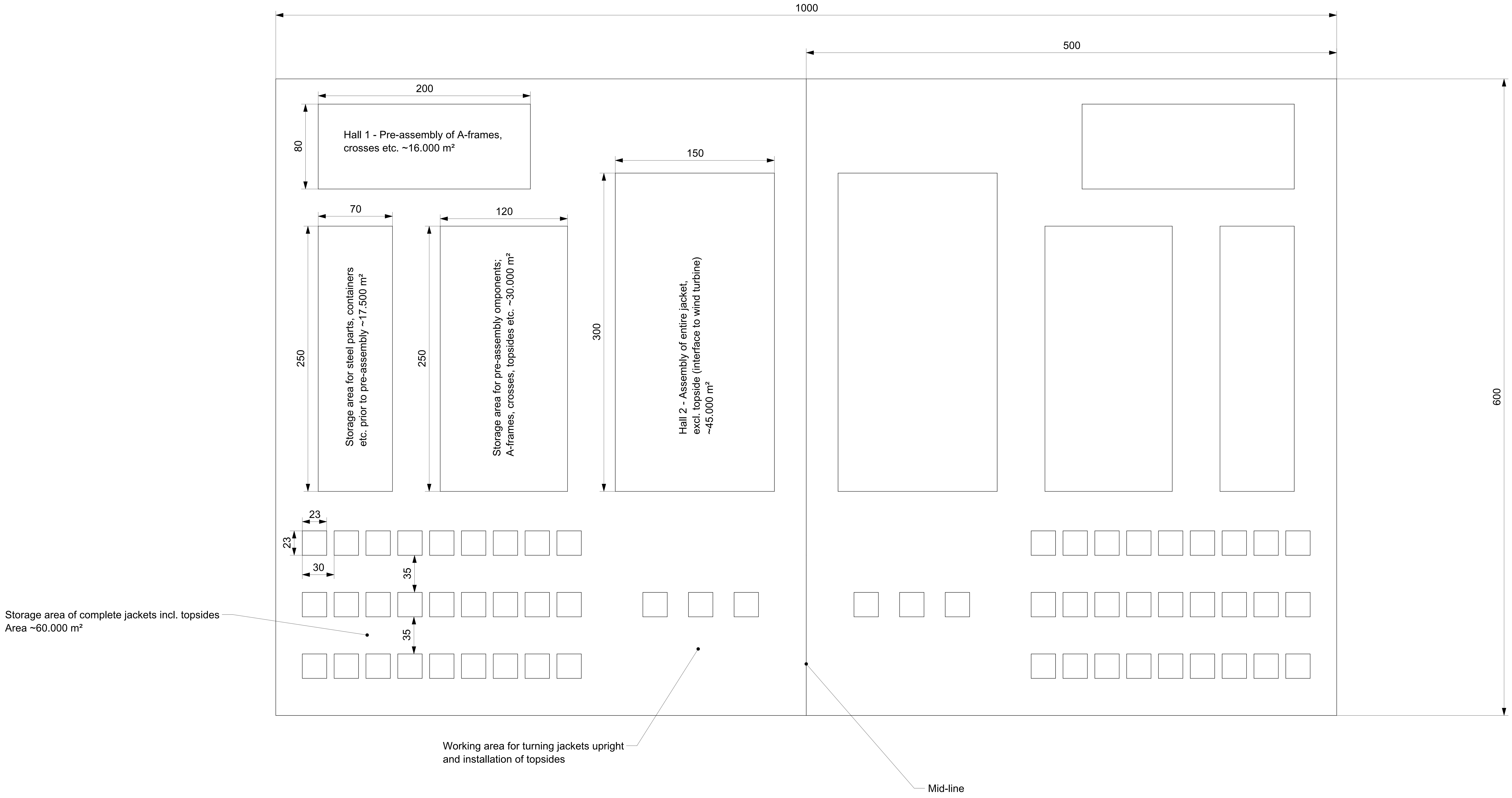
http://www.twtpo.org.tw

APPENDIX B

Generic Foundation Layout

This page is intentionally left blank

Illustration of required area for jacket assembly and storage (same on both sides of mid-line)



Pre-requisites:
- Area required for one project/OEM ~300.000 m² - 600.000 m² required in total for 60 wind turbine jackets
- Storage of 30 jackets per project is included in area requirement assumed
- Process time of one jacket is app. 3 month, hence (most) jackets must be prepared in advance of installation window
- Foot-print of jacket is 23x23 m (center to center of main beams)
- Weight of jacket is app. 660 MT
- Height of jacket is set to ~60-65 m
- Soil capacity for jacket storage must be minimum 40 MT/m²
- Gantry crane or other heavy duty machinery needed for turning jackets upright and install topside
- SPMT needed for jacket movement/transport (depending on location relative to harbour)

ALL DIMENSIONS IN METERS
MT = METRIC TON

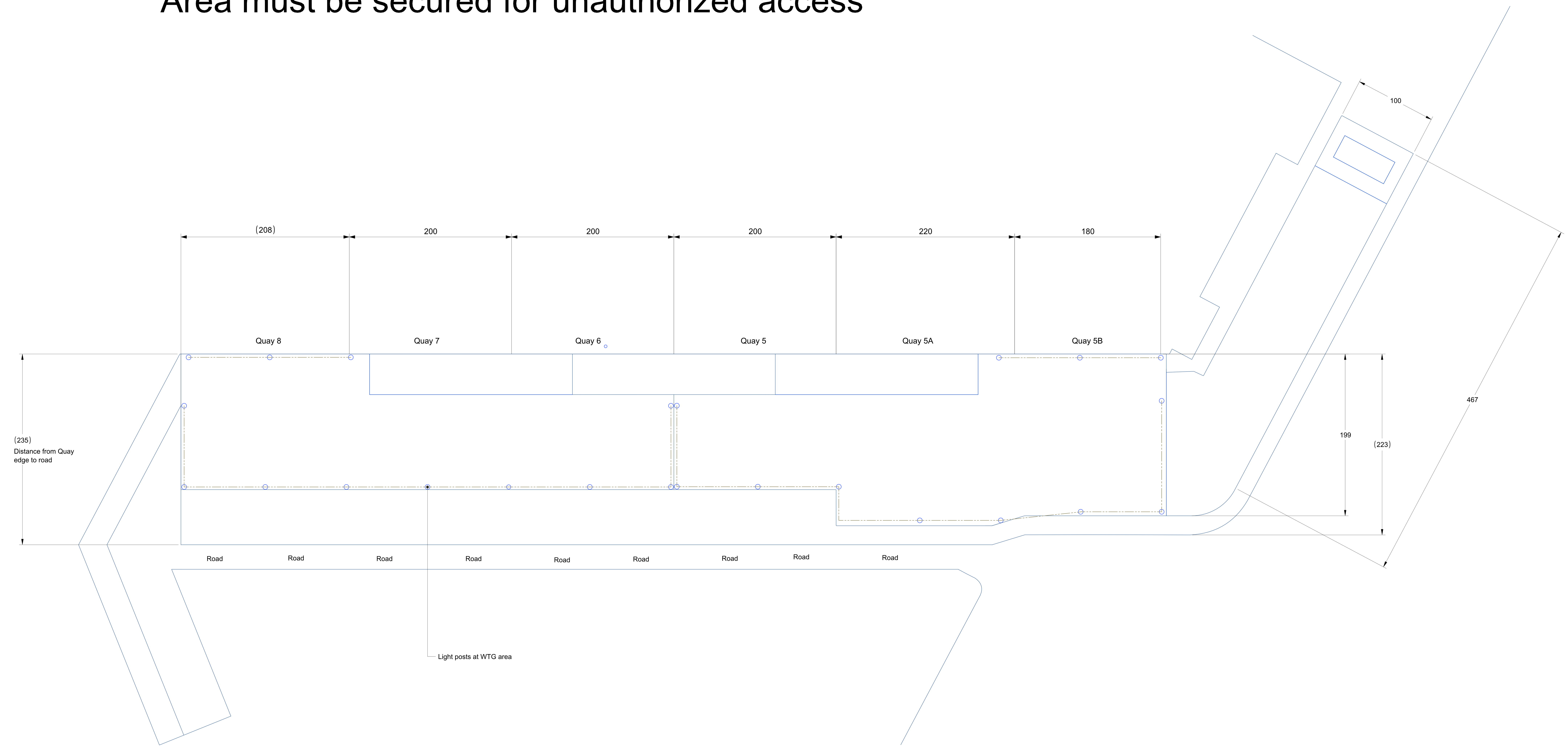
APPENDIX C

Conceptual Baseline Design

This page is left blank intentionally.

Overview of quay area for FINAL design
(incl placement of light posts)

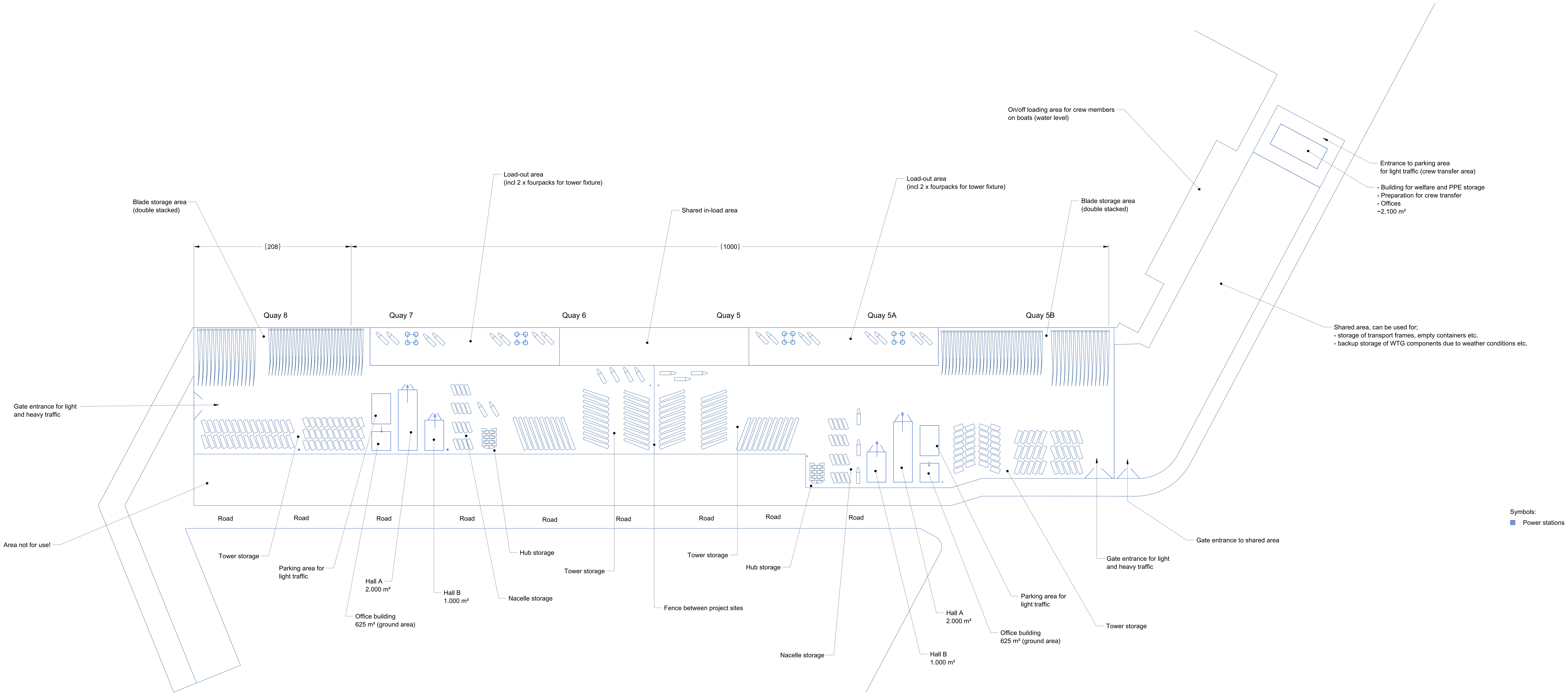
Area must be secured for unauthorized access



All dimensions are in meters

Overview of quay area for FINAL design

Area must be secured for unauthorized access

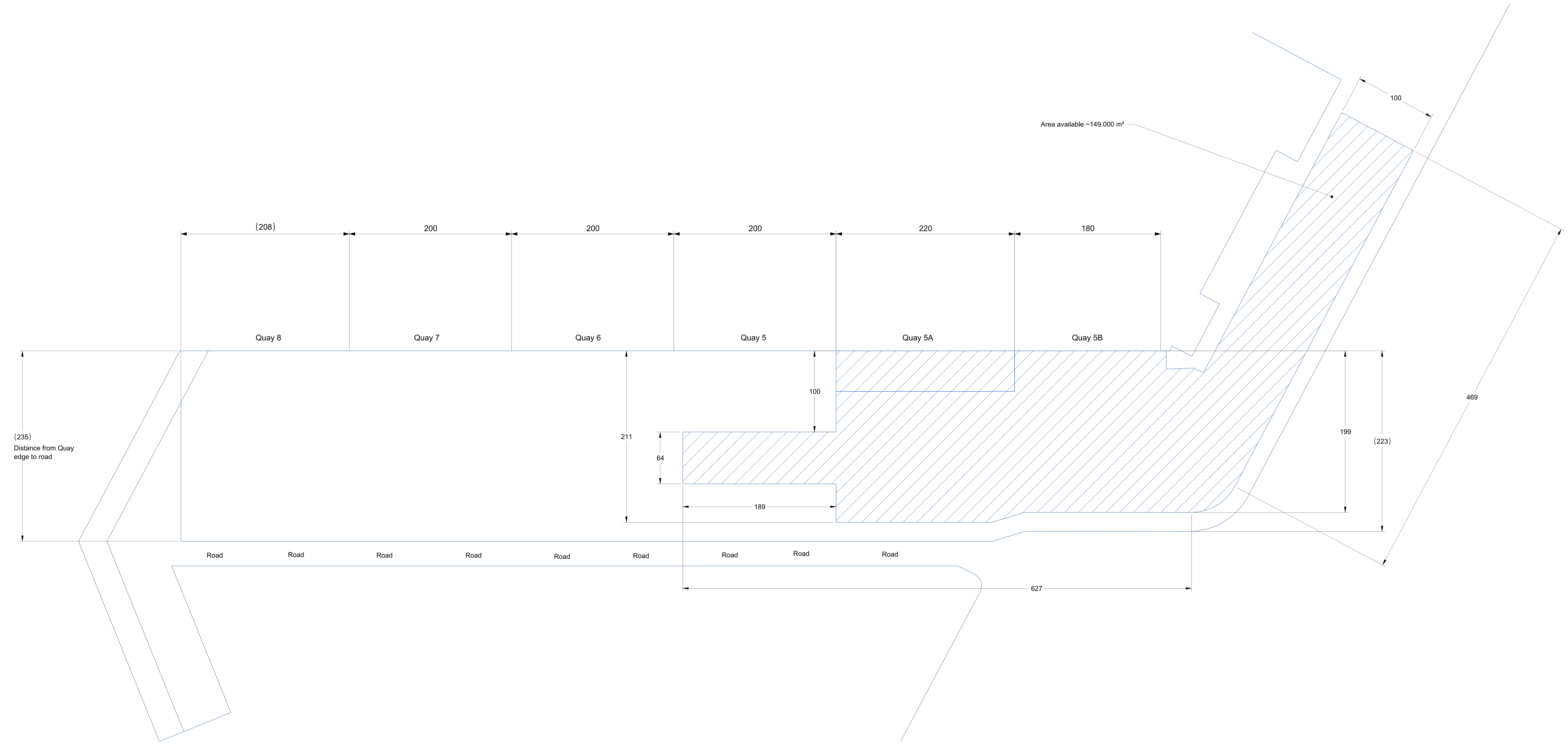


Prerequisites:
- Storage of 30 WTG per site (10 x 7MW and 20 x 4MW sizes used for layout plan)
- Surface conditions for harbour area are described in report
- Blades are double-stacked to minimize storage area. Alternatively some blades can be stored at shared area or remote facility
- Shared in-load, but sites separated by fence
- Area at quay 4C is used as buffer area for storage due to weather conditions or other unforeseen scenarios

All dimensions are in meters

Overview of quay area for Step 1 design

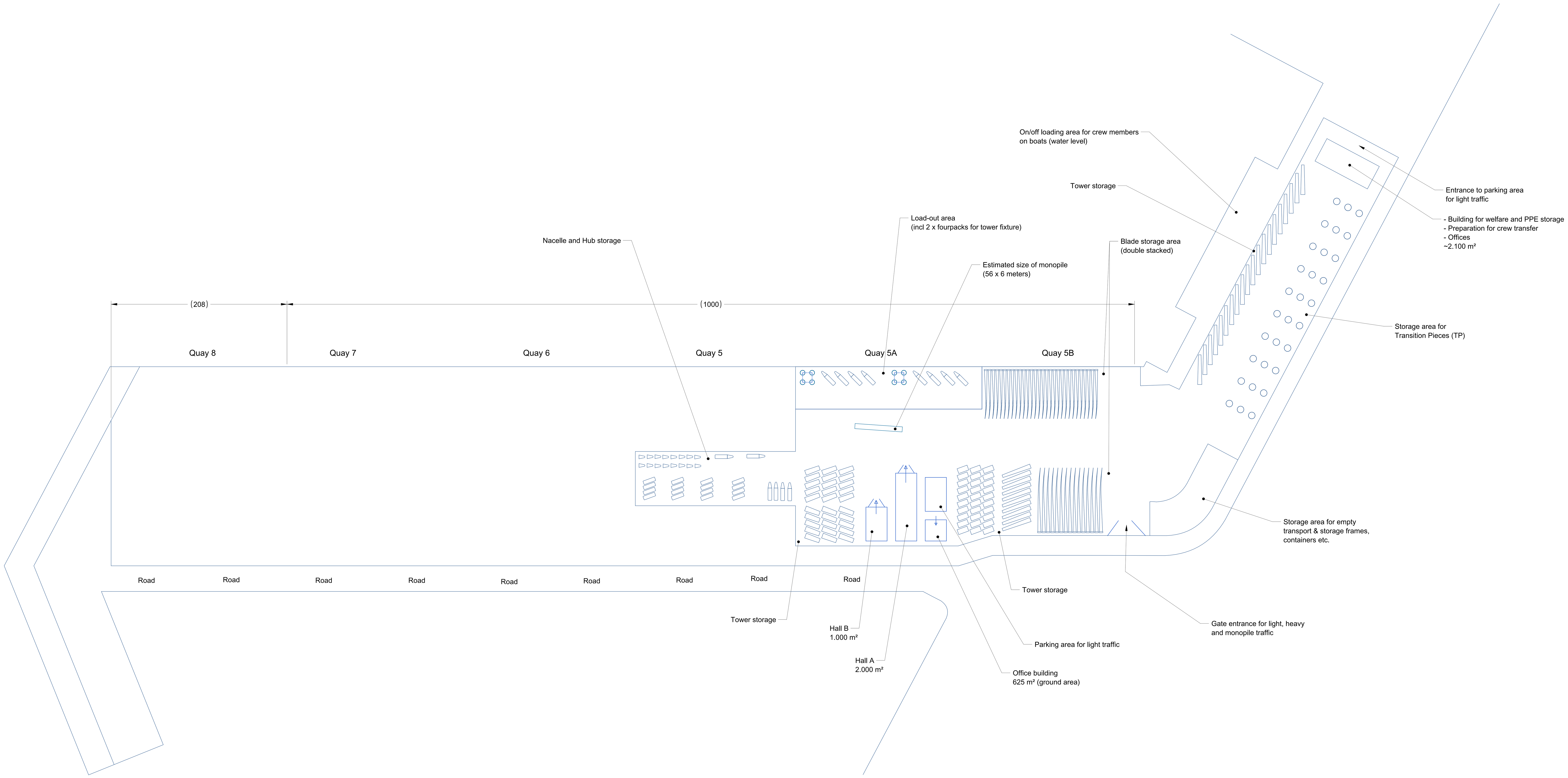
Area must be secured for unauthorized access



All dimensions are in meters

Overview of quay area for Step 1 design

Area must be secured for unauthorized access



Prerequisites:
- 30 Turbines in 2018 (20 x 4MW and 10 x 7MW sizes used for layout plan) are stored in the harbour area along with monopile foundations
- Monopiles to be transported on SPMT's from remote fabrication area
- Blades are double-stacked to minimize storage area. Alternatively have some blades stored at remote facility
- Out-load area also used for in-load (if necessary)
- Monopile foundation consists of monopile and TP. If jackets are needed, some can be stored in 4C, while the remaining must be transported by SPMT's

All dimensions are in meters