Greater Changhua Southwest Offshore Wind Farm in Taiwan

Climate Change Risk Assessment

16 May 2025

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Climate change risks such as physical damage, risk to worker safety and system interruption are plausible to occur to wind energy projects. This report identifies such risks from climate change that may be relevant to the Project. This CCRA was undertaken in alignment with the latest updated Equator Principles IV guidance, released in May 2023, and includes three future Climate Change Scenarios, a high emissions scenario (SSP5-8.5), a middle-of-the-road scenario (SSP2-4.5) and a low-emission scenario consistent with a below 2°C future (SSP1-2.6), as recommended by TCFD guidance of climate change risk assessments. Additionally, a GHG emissions assessment of the estimated annual emissions during the construction and operational phases of the project has been undertaken. This has found that during the operational phase of the project Scope 1 and 2 emissions are not expected to exceed more than 7,112 tonnes CO_2e per year, with annual emissions decreasing over the project life as a result of anticipated grid decarbonisation. During the scheduled construction phase, emissions from fuel combustion are estimated to be approximately 54,488 tonnes CO_2e (only Phase 2b), although these may be allocated as Scope 3 emissions, depending on the level of operational control that the project owner will have over the construction vessels. The assumed and recommended mitigations identified for the offshore and onshore asset design, coupled with recommended management plans and interventions by the Project Company and Project partners has rendered the net classification of these risks as being either medium or low.

It should be noted that implementation of these adaptation measures is assumed at this stage given that parts of the project have not yet been constructed and the risk scoring of medium or low should be read with caution given that it has not yet been confirmed that Project designs will embed these mitigations. The adaptation measures have been based off those which are being embedded in the neighbouring offshore wind projects which are also being developed by Ørsted. The CCRA and the measures identified should be reviewed by the Project Company and the relevant Project partners and taken into account within the design to ensure the resilience of the Project. It is recommended that upon completion, the CCRA is reviewed and risks reevaluated accounting for the measures implemented in the final design.

No fatal flaws in the form of high or extreme risks to the Project have been identified as a result of projected climate change to the 2050s, but a watching brief of risks identified must be maintained throughout the Project lifetime and adaptively managed.

While the management of worker safety is relatively easy to control for, little is known about the interaction of the effects of future climate change on materials or corrosion. Concepts such as the durability or lifespan of assets are not commonly available in this regard. The Project must articulate its overarching maintenance guidance to consider unpredictable, worst case, acute and chronic climate extremes to keep structures and assets in good condition.

1 Introduction

1.1 Overview

Greater Changhua Offshore Wind Farm SW Ltd. (herein referred to as "Project Company") is a special purpose vehicle established by Ørsted Wind Power TW Holdings A/S (Ørsted) to develop an offshore windfarm (OWF) in Taiwan (herein referred to as the "Project" or "Greater Changhua 2"). The Project is located approximately 50km offshore from the coast of Changhua County, Taiwan.

The Project is planned in compliance with the "Offshore Wind Farm Site Application Regulation", stipulated by the Energy Administration[1], Ministry of Economic Affair (EA, MoEA) on 2 July 2015. The regulation gives endorsement to offshore wind energy development for developers to promote nuclear-free homeland by the year of 2025.

In 2022, the National Development Council (NDC) published Taiwan's Pathway to Net-Zero Emissions by 2050. The plan is to decarbonise the electrical sector and targeted 60% renewable energy come 2050[2]. As of 2023, the electricity generation comprised of 42.2% coal-fired, 39.5% liquefied natural gas (LNG)-fired, 6.3% nuclear, 9.5% renewable energy and 2.4% of other types of energy.

As part of the Project's project financing approach, the Project may be required to demonstrate adherence to the Equator Principles (EP). Therefore, Mott MacDonald have been commissioned by Ørsted to undertake a Climate Change Risk Assessment (CCRA), alongside other environmental and social (E&S) services.

The Equator Principles IV (2020)[3] stipulate that a high-level CCRA of a Project's operations be carried out in accordance with the requirements of the Taskforce on Climate-related Financial Disclosures (TCFD). This CCRA aligns with the latest EP4 guidance released in May 2023[4].

A CCRA can cover physical or transitional risks, or both, however this assessment and report only covers physical climate risks. TCFD guideline stipulates that a transition risk assessment should be conducted if scope 1 and 2 emissions from the Project exceeds 100,000 tonnes carbon dioxide equivalent (t CO2e) per year which is not the case for the operational phase of this Project. To verify that the annual scope 1 and scope 2 emissions during the operational phase does not exceed 100,000 t CO2e, a Greenhouse Gas (GHG) emissions assessment has been undertaken.

[1] Formerly known as Bureau of Energy (能源署); renamed the Energy Administration in 26 September 2023.

[2] Lau, Hon Chung and Steve C. Tsai (9 July 2022). A Decarbonization Roadmap for Taiwan and Its Energy Policy Implications. *Sustainability*. Sustainability | A Decarbonization Roadmap for Taiwan and Its Energy Policy Implications (mdpi.com). Retrieved 30 July 2024.

[3] Equator Principles (2020). Available at: The Equator Principles_EP4_July2020 (equator-principles.com)

[4] Equator Principles Guidance Noe on Climate Change Risk Assessment (2023). Available at: Guidance CCRA_May 2023 (equator-principles.com)

1.2 Aims and objective

In keeping with Equator Principles IV (2020), the CCRA aims to assess whether the Project:

- Identifies and addresses current and anticipated physical climate-related risks facing the Project's operation over the 20-25 year operating period (Phase 2a has already been constructed and commenced operations since Q3 2023, Phase 2b is anticipated to begin operations Q3 2025 when all construction activities are due to be complete)[5]
- Incorporates plans and processes appropriate to managing those risks

The time period covered by the assessment considers risks up until the period of 2041 – 2060. As stated above, this is based on the anticipated operating period of 20-25 years following the end of construction activities in 2025.

This physical climate change risk assessment considers both the chronic and acute impacts of climate change and their impacts on the project components, including impacts to physical assets, operations and value chain. The approach to the physical climate change risk assessment broadly follows the Asian Development Bank's (ADB) climate risks management project preparation phase and guidance in their Guidelines for Climate Proofing Investment in the Energy Sector (2013).

The key steps of the assessment included:

- Development of climate change scenarios:
  - An assessment of historical baseline climate and future climate change projections for the Project area (see Section 4)
- Identification of climatic impact to Project components (the consequences of a climate hazard being realised) (see Section 5)
- Qualitative risk assessment for each climate impact through consideration of the likelihood of climate impacts and severity of the impact to the project component (see Section 5)
- A high-level review of potential adaptation and resilience options (see Section 5)

  The risk assessment is based upon information received from the client (i.e. EIA), publicly available data sources and the CCRAs undertaken for the neighbouring developments, Greater Changhua 1 and Greater Changhua 4, also being developed by Ørsted. However, when referring back to the public sources of information used for the previous projects, it was noticed that some data are no longer available or the information has been updated. Previously referenced sources, such as the Taiwan Climate Change Projection Information and Adaptation Knowledge Platform (TCCIP)[6], offers climate projection data only for four climate variables (i.e. average temperature, maximum temperature, minimum temperature and average precipitation), which are not sufficient enough to conduct a comprehensive CCRA.

  Therefore, for the purpose of providing a more robust and consistent CCRA, this report additionally sources climate baseline and projection data from the Copernicus Interactive Climate Atlas and NASA's Sea Level Change Portal's projection tool, which are in alignment with the Intergovernmental Panel on Climate Change (IPCC) (2022) Sixth Assessment Report.[7]

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[5] Greater Changhua Northwest Offshore Wind Farm – Environmental Impact Assessment (EIA) Report.

[6] TCCIP (nat.gov.tw)

[7] AR6 Climate Change 2022: Impacts, Adaptation and Vulnerability — IPCC

Earthquake and tsunami risks are not included in this assessment as they are not climate induced events and there is insufficient evidence to suggest climate change will impact these phenomena in the project location.

1.3 Project background

The Project is being developed on the 14th Zone of Potential in Changhua County according to the Offshore Wind Farm Site Application Regulations announced by the EA MoEA on 2 July 2015[8]. The Project's offshore windfarm area will be approximately 126.3km^2 in size and located 50km offshore from Xianxi Township (線西鄉), Changhua County, on the western coast of Taiwan (see Figure 1.1).

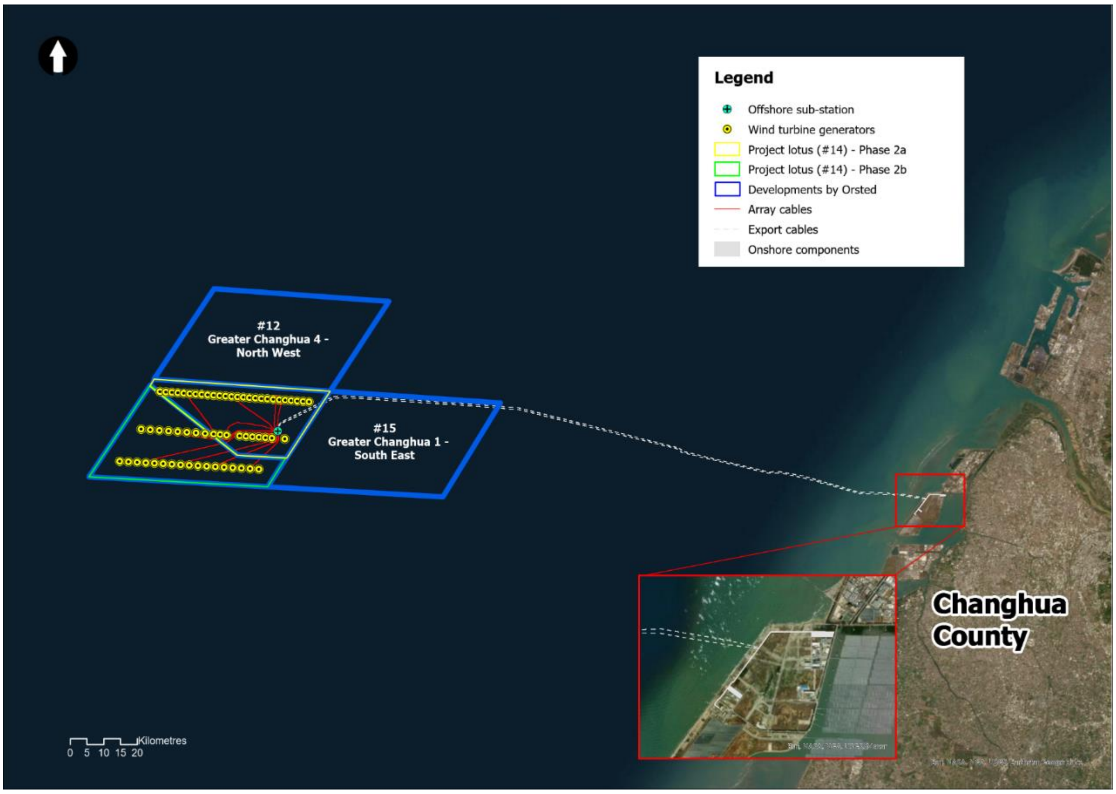
The Project is adjacent to other OWF developments which are also owned by Ørsted. These OWFs are namely:

- East of the Project – Greater Changhua South East, comprising of 75 WTGs, with a capacity of 605.2MW. This OWF development is known as "Greater Changhua 1". Greater Changhua 1 is currently operational, having obtained its electricity business license (EBL) covering all WTGs with the last batch obtained in Q3 2024.
- North of the Project – Greater Changhua North West, comprising of around 42 WTGs, with a capacity of 582.9MW. This OWF development is known as "Greater Changhua 4". Greater Changhua 4 is currently planning construction of its OWF components. The offshore construction is expected to commence in Q1 of 2025.

These are also illustrated in Figure 1.2.

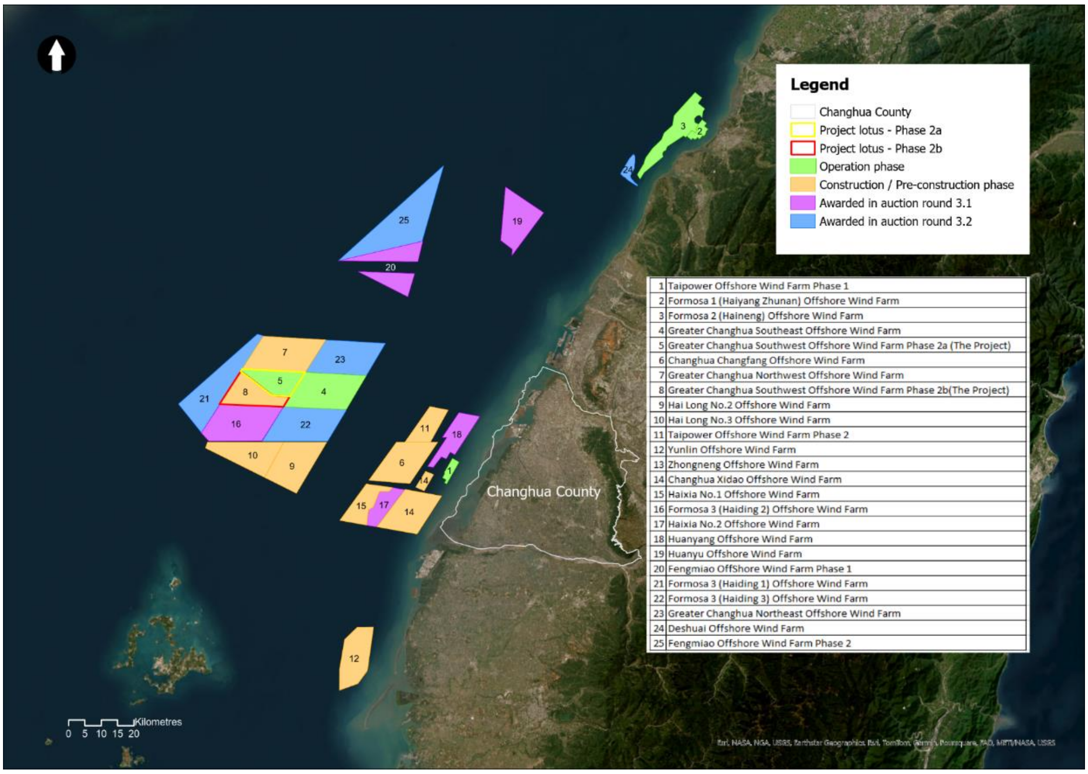
8 Energy Administration, Ministry of Economic Affairs (2 July 2015). Offshore Wind Farm Site Application Regulations (離岸風力發電規劃場址申請作業要點). Retrieved 30 July 2024.

Figure 1.1: Location of Greater Changhua 2 and proximity to Greater Changhua 1 and Greater Changhua 4



Source: Mott MacDonald, 2024

Figure 1.2: Greater Changhua 2 and surrounding windfarms



Source: Mott MacDonald, 2024

As seen in Figure 1.1, the Project comprises of two phases, namely:

- Phase 2a consists of 36 wind turbine generators (WTGs), each of 8MW capacity. All Phase 2a WTGs are in operational phase, having received an updated EBL for all its WTGs on 6 February 2024. The EBL expires on 9 May 2043.
- Phase 2b is currently under planning to commence the construction phase for its OWF components. The offshore construction is expected to commence in Q1 of 2025, alongside Greater Changhua 4. This phase will comprise of 24 WTGs, each of 14MW capacity.

The Project had successfully obtained regulatory approval for its EIA report (i.e.covering both phases) on 23 March 2018.

The planned aggregated capacity for the Project is 632MW (i.e. from a total of 60 WTGs), with Phase 2a generating 294.8MW and Phase 2b aiming to generate 337.1MW. The WTGs will be located at water depths approximately 23.8m to 42.2m below mean sea water level (MSWL). Each phase has its own grid connection point, connecting to two different OnSS then two different Taiwan Power Company (TPC) onshore substations (OnSS).

Other project components include inter-array and export transmission cabling to connect to TPC's electrical grid, as well as various operational support vessels and ancillary facilities.

1.4 Project components

The details of each Phase are presented in Table 1.1 below.

Table 1.1: Summary of Greater Changhua 2 Phases' components and schedule

Aspect	Greater Changhua 2 Phase	
	Phase 2a – operation phase	**Phase 2b – construction phase**
Project components		
Windfarm capacity	294.8MW	337.1MW
Windfarm area	126.3km^2	
Number of WTGs (and capacity)	36 WTGs (8MW each)	24 WTGs (14MW each)
Offshore substation (OSS)	600MW high voltage alternating current (HVAC) offshore substation shared between the two Phases.	
Onshore substation (OnSS)	294.8MW HVAC OnSS, located in Lukang Township, Changhua County.	920MW OnSS shared with Greater Changhua 4, located in Lukang Township, Changhua County.
Transmission	66kV / 230kV / 161kV HVAC	66kV / 230kV / 345kV HVAC
Export cables	Offshore: One (1) 230kV export cable with approximate length of 57km to the landing point Onshore: One (1) 161kV export cable with approximate length of 3.5km from OnSS to grid connection point	Offshore: One (1) 230kV export cable with approximate length of 57km to the landing point Onshore: One (1) 345kV export cable with approximate length of 1.85km from OnSS to grid connection point
Grid connection point	Chang One A (TPC), located in Lukang Township, Changhua County.	ChangKong (TPC), located in Lukang Township, Changhua County.
Project schedule		
Construction commencement	Onshore: Q3 2019 Offshore: Q1 2021	Onshore: Q2 2023 Offshore: Q1 2025
Construction completion	Onshore and offshore: Q2 2023	Onshore: Q2 2025 (targeted) Offshore: Q2 2025 (targeted)
Commercial operation date (COD)	13 September 2023	Targeting Q3 2025

Source: Ørsted and Mott MacDonald

1.5 Implementation schedule

The key milestones for the Project's implementation, with current assumptions for Phase 2b, are summarised in Table 1.2 below. Phase 2a's construction schedule is not shown as it has been operational since 13 September 2023.

Table 1.2: Greater Changhua 2 Phase 2b implementation schedule

Project milestone	**2023**			**2024**				**2025**		
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Phase 2b										
Onshore construction										
Offshore construction										
COD										

Source: Ørsted and Mott MacDonald

2 Policy context and literature review

2.1 Climate change and adaptation policy

In order to improve and reinforce Taiwan's capacity to cope with the growing threat of climate change and reduce its vulnerability, Taiwan has expanded its National Council for Sustainable Development (NCSD), tasked with sustainable development policy, since 2009. A comprehensive Adaptation Strategy to Climate Change for Taiwan has been developed, setting out the following objectives with respect to climate adaptation:

1. Establishing a legal framework and government organizations corresponding to climate change
2. Drafting national policies and decision-making mechanisms that consider climatic issues
3. Establishing a climate-related effective early warning, impact-evaluating and decision-making supporting system, and reinforcing the national and local disaster prevention and systems
4. Selecting no-regret policies and measures that deal with adaptation and mitigation issues simultaneously
5. Enhancing the research and development of climate-change adaptation technology, and cultivating related specialists
6. Raising public awareness on climate change issues and educating the general public to increase knowledge about climate change
7. Setting up a climate-adaptation decision-making and action system that integrates the private and public sectors
8. Devising economic incentive programs for encouraging private and public sectors to practice the climate change adaptation policy voluntarily

Taiwan's National Climate Change Action Guidelines[9] reinforce the nation's endeavours to formulate adaptation strategies to "enhance overarching adaptability, minimise vulnerability and build-up resilience." Importantly, the guidelines capture the need for adaptation strategies to be considered while performing environmental impact assessments (EIAs). Regarding the energy sector in particular, the guidelines specify a high-level policy of improving the adaptability of Taiwan's energy supply system and industries, capturing the following associated goals, strategies and action plans:

Energy Sector Goals

1. Ensure infrastructural safety and stability of energy supply facilities
2. Build an environment that reduces climate risks and strengthens adaptive capacities
3. Elevate businesses' ability of risk management and opportunity exploration, to develop climate-resilient products and services.

[9] Taiwan National Climate Change Action Guidelines (2024). Available at: National Climate Change Action Guidelines-Climate Change Response Policies-Climate Change Affairs｜Climate Change Administration (cca.gov.tw)

In 2018, Taiwan's Environmental Protection Administration and 16 ministries from the Executive Yuan jointly compiled the National Climate Change Adaptation Plan (2018-2022)[10] which goes into more detail with respect to energy sector adaptation strategies and action planning.

Energy Sector Strategies:

1. Strengthen energy industry risk assessment capabilities and establish adjustment guidelines:
   a. Formulate risk assessment criteria
   b. Build risk assessment tools
   c. Establish guidelines for adaptation strategies
2. Build a management mechanism to promote education and training and international cooperation
   a. Construct an adaptive management mechanism
   b. Establish an energy supply and demand monitoring system
   c. Promote education and training promotion and international cooperation
3. Assist the industry to improve the adjustment ability:
   a. Industrial adaptation capacity building and counselling

Energy Sector Adaptation Action Plan

1. Development of risk assessment criteria for climate change shocks in the energy sector
   a. Obtain and record the latest meteorological and disaster potential maps, track and update every year.
   b. Consider the disaster potential, sensitivity and resilience of energy facilities, and review and update the existing flood and strong wind risk assessment criteria.
   c. Consider the disaster potential, sensitivity and resilience of energy facilities, and establish high temperature and slope stability risk assessment criteria.
   d. Integrate and review the results of risk assessment criteria such as flooding, strong wind, high temperature and slope, and establish a composite disaster risk assessment criteria.
2. Establishment of risk assessment tools for energy systems
3. Research and Analysis of Regulations and International Standards Linking Mechanism of Climate Change Adjustment in Energy Industry
4. Energy system and energy industry climate change adaptation monitoring and evaluation system planning and promotion.

Taiwan's executive agency responsible for protecting and conserving the environment, the Environmental Protection Administration (EPA), recommends good international industry practice (GIIP) standards for climate adaptation on projects, such as ISO 31000 Risk Management Guidelines, UNDP's Adaptation Policy Framework and the Taiwan integrated research program on Climate Change Adaptation Technology (TaiCCAT) decision support system.

[10] Adaptation Impact Sectors (2024). Available at: Energy Supply and Industry-Adaptation Impact Sectors-Climate Change Adaptation and Resilience-Climate Change Affairs｜Climate Change Administration (cca.gov.tw)

2.2 TCFD

This CCRA also incorporates the Taskforce on Climate related Financial Disclosures (TCFD) guidance, as the CCRA guidance of the EP4 is developed on the principles of the climate physical risk assessment set out in the TCFD guidance. The TCFD is a voluntary disclosures taskforce principally intended to help lenders assess whether physical (and transition) climate risk is appropriately priced into their valuation of a project or company. The universally accepted definition of physical climate risk is:

- Climate Physical Risks are those risks resulting from climate change, which involve event driven (acute) or longer-term shifts (chronic) in climate patterns. Acute physical risks refer to those that are event-driven, including increased severity of extreme weather events such as cyclones, hurricanes, or floods. Chronic physical risks refer to longer-term shifts in climate patterns (e.g., sustained higher temperatures) that may cause sea level rise or chronic heat waves[11].

2.3 Documented physical risks to wind farms

Due to its geographical location and underlying geological properties, Taiwan regularly encounters natural hazards such as earthquakes, typhoons, mudslides and flash floods. Many of these hazards are, and will be, exacerbated by climate change, while the impacts of, and recovery from, others, such as earthquakes, may become more complex due to interactions with a changing climate.

The expansion of wind energy installed capacity is poised to play a key role in Taiwan's energy mix and ability to deliver on its climate change mitigation targets. Wind energy is, however, susceptible to global climate change impacts from a physical risk perspective. Some changes associated with a changing climate may benefit the wind energy industry while other changes may negatively impact wind energy developments, leading to levelized energy 'gains and losses'[12].

All energy systems are to some extent affected by climate change and changing risks. There are two principal ways in which climate change and intensified disaster risks can affect the wind power sector:

- Wind power generation depends on wind availability and wind speeds. Climate change can affect wind speeds and other variables such as air density, which can have either positive effects (i.e., enhanced energy generation) or negative effects (i.e., disruption to energy generation due to 'shut down' periods associated with extreme conditions or reduced energy generation with lower wind speeds or lower air density) on wind power generation.
- Wind turbine plants could be impacted by more pronounced disaster risks such as typhoons, floods, and storm surge exacerbated by chronic sea level rise (particularly in the case of offshore turbines or low-lying substations).

Changes in wind speed and patterns due to climate change differ significantly from one region to another. Studies suggest changes in global wind speeds could affect regions such as Europe and North America minimally, however it could significantly affect other parts of the world like Asia[13].

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[11] TCFD (2017). Available at: Recommendations | Task Force on Climate-Related Financial Disclosures (fsb-tcfd.org)

[12] Pryor, S.C and Barthelmie, R.J. (2010). Available at: Climate change impacts on wind energy: A review | Request PDF (researchgate.net)

[13] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010). Available at: Climate change disasters and electricity generation.indd (publishing.service.gov.uk)

Climate models are, however, still relatively crude with respect to representing changes in mean wind speeds and extreme wind speeds associated with tropical storms, whereby there are limitations on the ability to identify future changes in their frequency and intensity. Furthermore, drawing firm conclusions in terms of changes in climate extremes such as extreme wind is typically hampered by data quality and availability in observations, the difficulties in separating natural variability from long-term trends and limitations of climate model spatial resolutions.

Most wind turbines shut down at wind speeds above approximately 70-90 km/hour. However, studies suggest the wind power sector might not be negatively impacted by climate change, suggesting a net-gain in higher wind speeds[14].

Mean sea level rise may have implications for offshore and near-shore wind turbines, with the increased risk of flooding or corrosion of turbines. Another aspect of importance to the foundation(s) of offshore wind turbines is wave height, which is significantly dependent on wind speeds[15].

To proactively adapt to changing wind speeds, sea level rise and changing disaster risks, turbines and associated infrastructure that is able to operate in, and which can physically withstand, extreme high wind speeds, rising seas and storms is advisable[16]. The potential effects of climate change and changing disaster risks on wind energy plant / resources and on electricity generation are summarised in Table 2.1.

[14] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010).

[15] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010).

[16] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010).

Table 2.1: Effects of climate change and changing disaster risks on wind energy generation

Change in meteorological variable	Impact on wind energy plant / resources	Impact on electricity generation
Temperature increase	Indirect impact on air density and wind patterns; extreme heat could impact operating conditions and lead to shut down of turbines	Either increased or decreased electricity generation possible
Increase in average precipitation	Increase wear of the turbines – edge erosion	None
Decrease in average precipitation	None	None
Drought	None	None
Glacier melt[17]	None, unless flooding occurs. If flooding occurs risk of damage to equipment	None if no flooding occurs. If flooding occurs, disrupted / decreased electricity generation
Flood	Risk of damage to equipment	Risk of disrupted / decreased electricity generation
Increased frequency and/or strength of storms / cyclones	Risk of damage to equipment and increased periods of shut down	Decreased electricity generation if wind turbines / equipment is damaged, or shut down at excessive wind speeds
Increased wind speed	Better wind conditions	Increased electricity generation, unless a storm occurs (see above)
Decreased wind speed	Worse wind conditions	Decreased electricity generation
Changes in wind patterns	Changes in air density, wind direction, wind variability	Either increased or decreased electricity generation

Adaptation to climate change and changing disaster risks are issues which have not been traditionally or adequately captured in the energy sector thus far. The focus has tended to be on mitigation by reducing emissions from energy systems – ‘transitioning’ – than finding solutions for adapting these transition-enabling technologies to chronic climatic changes and extreme events. Global best practice points to the following high-level mitigating aspects for wind farm projects:

- Enhance resilience to climate change by carefully assessing siting procedures, feasibility studies and EIAs (or similar) for new power plants, which need to take into account existing disaster risks and adaption strategies to climate change
- Design more robust infrastructure based on reasonable worst-case scenarios in terms of the above (and feasibility)
- Establish disaster risk systems, whereby procedures are in place for early warning systems to enable evacuation of staff and to secure electricity infrastructure where possible before an extreme weather event hits
- Long-term insurance schemes for power yields and damage from storms could also be considered

[17] This meteorological variable is location dependent

3 GHG Emissions Assessment

A GHG emissions assessment was undertaken to verify that the estimated annual Scope 1 and 2 emissions of the project during its operational phase are below 100,000 tonnes of carbon dioxide equivalent (CO_2e). In this assessment, emissions is represented for both construction and operations phase (decommissioning is not taken into account), however, whereas emissions for operation phase is provided as an annual basis, emissions for construction phase is provided as a total emission produced throughout construction. It is noted that Phase 2a has already been constructed and currently operational, therefore only the following emissions are accounted for in this assessment:

- Phase 2a: only annual emissions from operational phase
- Phase 2b: both total emissions from construction phase and annual emissions from operational phase

Although Phase 2a has completed construction and currently operational, the activity data on Phase 2a were not yet ready at the time of this report writing. Instead of relying on activity data, emissions was estimated from available project relevant sources.

Mott MacDonald reviewed two documents for this assessment, the Project EIA's section on greenhouse gas reduction[18] and the report on the Project lifecycle assessment[19]. Of the two, the report on lifecycle estimation was not feasible for this assessment as it lacks indicators to estimate operational emissions on an annual basis. Whereas, the EIA provides sufficient assumptions and indicators to be used in this assessment. It is noted that the EIA's estimation is based on an indicative installed capacity of 642.5MW, whereas the actual installed capacity of the Project (Phase 2a and 2b combined) is 632MW. However, as the EIA's indicative capacity is slightly larger than the actual, the EIA's estimation can be considered as a conservative figure and sufficient to be used for this assessment[20].

The specific breakdown and estimation of emissions from each construction phase and operations phase are provided in Section 3.1.1 and Section 3.1.2, respectively. The key assumptions for quantifying activity data and sources for emission factors are summarised in section 3.2.

3.1 Results

3.1.1 Construction Phase

Based on estimation provided by the EIA, emissions from fuel combustion and electricity usage during the project construction phase was estimated to be approximately 102,700 tonnes CO_2e. This figure is an aggregate estimation that would include construction phases for both Phase 2a and 2b (noting that this is not an annual figure but the aggregate emission that would result from the entire construction phase, between Q2 2023 and Q2 2025. It is worth to note that the scale/volume of the Project's overall construction emissions are largely "fixed" (ie amount of total activities/emission) due to the Project's nature. In particular, for installation of WTGs, any program acceleration is proportional and not exponential (ie adding more group of independently working vessels). The annual emission amount is likely to have a limited

[18] Project EIA, Section 7.1.10

[19] Summary report on LCO2 calculation of Greater Changhua Phase 2a offshore wind farm

[20] According to the Greenhouse Gas Protocol guidance, use of conservative assumptions, values and procedures are recommended where there is lack of data. Conservative values and assumptions are those that preferably over-estimate ghg emissions. GHG Protocol Governance and Decision-making Process.pdf

significance since it is subjected to how long the overall construction period is scheduled (eg. whether one or two years). This figure is based on the amount of resources required to construct the specified size of the Project. As mentioned, this figure is for an assumed total capacity of 642.5MW, however, as we are only accounting construction emissions for Phase 2b, an intensity figure was developed from the aggregate figure in order to estimate the amount of construction emissions per MW of capacity installed. Applying this emissions intensity to the actual Project capacity provides the estimated emissions for the Project. Thus, it is estimated for Phase 2b aggregate construction emissions to be 54,779 tonnes CO_2e. Assuming the construction schedule follows the implementation schedule (as outlined in Section 1.5) of approximately 2 years (ie. Q2 2023 – Q2 2025), it is assumed that the annual construction emission will be approximately 27,000 tonnes CO2e. It is noted that this annual emissions is far below 100,000 tonnes.

As construction activities were and is to be undertaken through contractors (ie appointed by the Project) and other sub-contractors (ie. vessel operators), emissions from this activity may be classified as Scope 3 emissions, depending on the contractual arrangements.

Table 3.1: Estimated aggregate GHG emissions from fuel combustion throughout project construction (Breakdown for a total installed capacity of 642.5MW)

Construction area	Component	Emission Source	Diesel/electricity usage	Emissions factor	Emission (tonnes CO2e)
Onshore	Construction of substation and land cable embedment	Dump truck	990,328 L	2.66 g CO2e/L	2,634
		Concrete mixer truck	479,516 L		1,276
	Components/equipment hoisting operations		328,800 L		875
	Electricity consumption at working dock		534,000 kWh	0.495 g CO2e/kWh	264
	Aggregate emissions from onshore construction				**5049**
Offshore	Marine cables	Construction vessels	14,580,000 L	2.66 g CO2e/L	38,783
	Turbine foundation		6,750,000 L		17,955
	Installation of turbine components		8,640,000 L		22,982
	Offshore substation		7,380,000 L		19,630
	Aggregate emissions from offshore construction				**99,350**
Aggregate construction emissions for a 642.5MW offshore windfarm (EIA)					**104,399**

Table 3.2: Intensity figure of construction emissions per MW installed / Construction emissions for Phase 2b

Intensity figure of emissions per capacity installed	**162.5 tCO2e/MW**
Capacity to be installed for Phase 2b	**337.1 MW**
Total estimated construction emissions from Phase 2b	**54,778.75 t CO2e**

GHG emissions during the construction phase of the Phase 2b are expected to result from the operation of a fleet of trucks and vessels that are required to transport and install the various onshore and offshore project components. The largest component of construction emissions is expected to come from the operation of offshore installation vessels, which will be required for the installation of piles and jackets/transition pieces, foundations, WTGs and the offshore substation. Together, offshore installation vessels are estimated to consume a total of 19.6 million litres of marine fuel oil. This will result in approximately 51.87 kT of CO_2e emissions, which is more than half of all direct construction related emissions.

The scope allocation of emissions from fuel combustion during the construction phase of the project is dependent on who has effective operational control of the vessels during the construction period. As based on the current understanding, the Project will be appointing contractors (who employs/own vessels, or even sub-contract to vessel operators) to undertake the construction activity, and in this case the activity would fall under Scope 3 emissions.

3.1.2 Operational Phase

Based on estimation provided by the EIA, annual emissions from fuel combustion and electricity usage during operation phase are estimated to be 7,165 tonnes CO_2e per annum. However, this figure uses an outdated electricity grid emission factor for Taiwan from 2016[21]. Upon applying the latest emission factor from 2022[22], the new estimation is recalculated as 7,112 tonnes CO_2e per annum. Although Phase 2a is currently operational, this figure is an estimation of annual emissions from operations for an assumed period where both Phase 2a and 2b are operational. As such, this figure represents the Project's annual Scope 1 and 2 emissions. It is assumed, as the proportion of renewable energy is expected to increase within Taiwan's grid mix, this electricity grid emission factor is projected to decrease over time, thereby decreasing the emissions associated to electricity consumption over the Project's lifetime. It is noted that thisannual emissions is far below 100,000 tonnes.

Table 3.3: Annual Scope 1 and 2 GHG emissions during project operation

Operations	Emission source	Electricity/diesel usage	Emissions factor	Emission (tonnes CO2e)
Power consumption of operation and maintenance centre	Electricity consumption from grid	440,000 kWh	0.495	218
Power consumption of substation		1,100,000 kWh		545
Turbine maintenance and service	Maintenance vessels	2,400,000 L	2.66	6,384
Total Emissions				7,147

The largest contributor to this annual is from fuel usage from maintenance vessels, from combustion of diesel (6,384 t CO_2e), which would be categorised as Scope 1 emissions. It should be noted that Scope 2 emissions, which account for 762 t CO_2e, and 11% of total Scope 1 and 2 emissions, was recalculated based on the latest available Taiwanese Grid Electricity emissions factor for the year 2022. It is also noted, the Taiwanese government has a plan to

[21] 0.529kgCO2e/kWh, Bureau of Energy, Ministry of Economic Affairs, Project EIA

[22] 0.495kgCO2e/kWh, Bureau of Energy, Ministry of Economic Affairs, Energy Administration, Ministry of Economic Affairs, R.O.C. - 2022 Electricity Carbon Emission Factor (moeaea.gov.tw)

reach zero emissions from electricity generation by 2050. This will necessitate consistent decarbonisation of the energy sector, which will result in a decreasing emissions factor for grid electricity. Assuming a residual grid emissions factor of 0.01 kg CO_2e / kWh in 2050 and a linear reduction from 2022 emissions factor, substantially reduced Scope 2 emissions can be expected from the project over its lifetime, decreasing from 762 t CO_2e in 2025, to just 20 t CO_2e in 2050. This would constitute an approx. 99% reduction in annual Scope 2 emissions and a 11% reduction in annual operational combined Scope 1 and 2 emissions by 2050. Further annual operational emissions reductions from the figures presented in this assessment may occur with the electrification of land and maritime transport, and the use of sustainable fuels, however these are not accounted for in this assessment due to current uncertainty of reduction statistics from such technological advancement.

3.2 Notes, Assumptions and Limitations

The EIA's assumptions to estimate annual Scope 1 and 2 emissions during construction and operations is referenced. These assumptions, as well as notes and limitations on the GHG assessment are detailed as follows:

- Onshore construction is assumed to be associated with the onshore substation, onshore cable works and the assembly and hoisting operations at the docks.
- Offshore construction is assumed to be associated with marine cable construction, wind turbine foundation construction, installation of wind turbine upper components and offshore substation construction.
- Average fuel consumption for construction vehicles (ie. dump trucks, mixer trucks, vessels) were based on a local research report (Lin Zhengxing et al., 2009) and development experiences of other offshore wind farms. Along with estimated number of vehicles required and also considering the estimated number of construction days taken from sample offshore wind farms.
- The Westermost Rough offshore wind farm in the UK was referenced for annual power consumption of the operation and maintenance centre.
- Fuel consumption for operations and maintenance vessels were referenced from crew transfer vessels (CTVs) and service operation vessels (SOVs).

The assumptions for operational days of each vessel for each construction task have been developed with reference to the project construction schedule and similar offshore wind projects located of the same coastal region as the project site. It is assumed that the construction tasks will proceed in a phased manner with overlap between subsequent phases (i.e. foundation installation will not need to wait for pile installation to be fully completed across the entire project to begin)

4 Climate baseline and projections

4.1 Methodology

Although the Project EIA provides historical climate baseline data, this CCRA does not peruse the EIA data. Instead, both historical climate baseline and the future climate projection data are independently sourced from the Copernicus Interactive Climate Atlas (CICA) and NASA's Sea Level Change Portal. This implementation is due to the following reasons:

- The guidance note on CCRA by the EP4 states that the climate risk assessment should be based on a robust analysis of climate data and projection across a range of future GHG emission scenarios, published in the most recent AR5/AR6 IPCC reports.
- Both the CICA and NASA's data are in accordance with the AR6 IPCC report and provides both climate baseline and projection data across different Socioeconomic Pathways. Whereas, the EIA provides historical climate baseline data (sourced from Taiwan's Central Weather Bureau), however does not provide any climate projection data. Even if this baseline data was used, sourcing climate projection data from another source would result in inconsistency due to difference in data modelling used for each source.
- Both CICA and NASA provide an array of climate variables (ie. Temperature, precipitation, wind speed, etc.) and are also recommended data sources by the EP4 guidance note.

4.1.1 Copernicus Interactive Climate Atlas

On the Copernicus Interactive Climate Atlas, a custom polygon was drawn around the Project site in order to extract site-specific (including both onshore and offshore components) climate data for both historical climate baseline data and future projection data. A separate polygon was drawn to only include the sea areas relevant to the Project, for the purpose of extracting sea surface temperature data (Figure 4.1). The boundaries of the domain are approximately framed within the following coordinates:

Both onshore and offshore coverage:

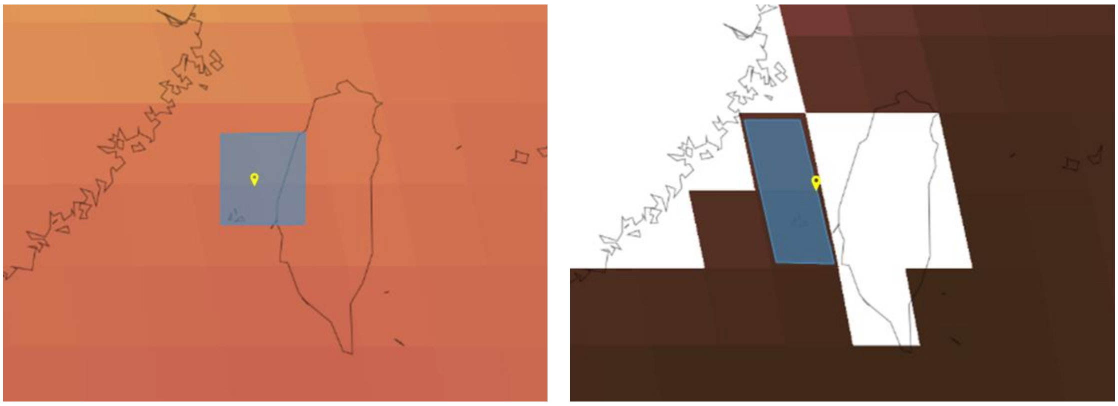
- 24.50, 119.50
- 23.50, 119.50
- 24.50, 120.50
- 23.50, 120.50

Coverage for only sea surface temperature:

- 25.00, 119.00
- 23.00, 119.00
- 25.00, 120.00
- 23.00, 120.00

Area-averaged value was used due to lack of project-specific data on climate projections, and for the purpose of expanding coverage area for both onshore and offshore areas of the project as an average.

Figure 4.1: Defined polygons on Copernicus Interactive Climate Atlas, in relation to the Project site (marked in yellow). Left for analysing both onshore and offshore average climate, and right for analysing only sea surface temperature.



Source: CICA

From within the defined polygons, a subset of six Global Climate Models (GCM) from the latest climate model (CIMP6) were identified for use. The selection of these six models were based on the sole criteria that the data is available for both baseline period and future projection period for each climate variable across all three climate change scenarios. The selection of GCMs was determined by the availability of climate projection data across all three analysed scenarios (SSPs), and the climate variables for which data was accessed. Of the 20+ models, only 6 models provided projection datasets for all three selected scenarios and the range of climate variables reported. Using a different number of models for each climate scenario (e.g. the maximum number available for that scenario) would inhibit the comparison of the scenarios because a different set of GCMs would have been used for each.

The six models used were:

- CMCC_CMCC-ESM2_r1i1p1f1
- CNRM-CERFACS_CNRM-ESM2-1_r1i1p1f2
- CSIRO-ARCCSS_ACCESS-CM2_r1i1p1f1
- INM_INM-CM5-0_r1i1p1f1
- MIROC_MIROC-ES2L_r1i1p1f2
- MPI-M_MPI-ESM1-2-LR_r1i1p1f1

4.1.2 NASA Sea Level Projection Tool

For sea level rise, a location marker was placed on a coordinate of Latitude: 24, Longitude: 120 (which is the approximate location of the Project) on the NASA sea level projection tool in order to extract site-specific data on sea level rise.

Figure 4.2: Defined marker on NASA Sea Level Projection Tool

Source: NASA

4.1.3 Assessed climate variables

In this assessment, the following climate variables are assessed:

- Mean temperature
- Mean of daily maximum temperature
- Maximum of daily maximum temperature
- Sea surface temperature
- Mean of daily accumulated precipitation
- Maximum of 1-day accumulated precipitation
- Maximum of 5-day accumulated precipitation
- Mean wind speed (near surface)
- Average air pressure at mean sea level
- Sea level rise

4.1.4 Historical climate baseline

In alignment with the Intergovernmental Panel on Climate Change (IPCC) (2022) Sixth Assessment Report (AR6), the timeframe of year 1995 – 2014 has been set as the baseline climate reference period. For each climate variable, the historical climate data for the defined timeframe were extracted from the six identified GCMs. From these models, the median value within the timeframe was identified and used as the historical baseline for each of the climate variables (refer to Table 4.1).

4.1.5 Future climate projection

In accordance with the Project's expected lifecycle 20 – 25 years, and alignment with the IPCC AR6 report, the timeframe of year 2041 – 2060 has been set as the future climate projection reference period.

Three future socioeconomic pathways (SSP) were selected for this assessment:

- SSP1-2.6: A world with low emissions (<2°C warmer world). This is the 'Paris Pathway', which is only possible if COP26 pledges are delivered on.
- SSP2-4.5: This is a world with moderate emissions (+2.7°C warmer world). This is similar to the path we are on if we follow through on current policy commitments.
- SSP5-8.5: This is a world with high emissions (>4°C warmer world) premised on a breakdown in international cooperation around climate change and continued fossil-fuel powered development.

For each climate variable and for each SSP, future climate projection data for the defined timeframe were extracted from the same six identified GCMs. From these models, the 10th percentile (P10), the median and the 90th percentile (P90) values were extracted and used as future projection for each of the climate variables and for each SSP (refer to Table 4.1).

4.2 Uncertainty within climate projections

It should be noted that climate projections are not predictions of the future but tools to support us with exploring future scenarios to enable us to be resilient to future climate conditions. Mott MacDonald does not accept any liability for inaccuracy within projections and associated suggested adaptation measures.

It should also be noted that climate change projections are constantly evolving as knowledge and modelling projections improve. A level of uncertainty exists when using projections for the future. The possibility that any single emissions pathway will occur as described in these defined scenarios is inherently uncertain.

Global climate models are averaged over large spatial areas (horizontal resolution of between 50km and 250km[23]) and therefore come with data limitations related to extreme values. They do not adequately include extremes like cyclones, wind or changes in their characteristics. Key driving features such as El Niño-Southern Oscillation (ENSO) are also poorly captured within global climate models.

Sea levels around the world are rising and are projected to continue to rise in the future. Uncertainty exists in predicting future sea level rise within our warming climate (particularly with respect to larger timeframes) due to complexities associated with predicting future temperature increases, thermal expansion of ocean water, ocean circulation dynamics, and glacier and ice sheet mass loss. Despite uncertainty existing within the varying future projections, in order to build resilience, it is vital that we begin to plan and adapt for a changing climate.

Please refer to Appendix A. Climate change limitations and disclaimer, for more details on climate change uncertainties.

[23] CMIP6: Global climate projections - Copernicus Knowledge Base - ECMWF Confluence Wiki

4.3 Climate data

Table 4.1 below summarises the data values for the three future climate projection scenarios outlined in Section 4.1.5 representing low, medium and high emission futures. Historical baseline climate data values are the median values from the 1995-2014 baseline reference period of the six GCMs (modelled baseline). Future projection values are the 10th Percentile (P10), median (P50), and 90th Percentile (P90) values for the future timeframe period 2041-2060 across the 6 GCMS.

Table 4.1: Baseline (1995 – 2014) and climate projections (2041 – 2060)

Climate Variable	Unit		1995-2014 (modelled)			SSP1-2.6			SSP2-4.5			SSP5-8.5		
			P10	Baseline (median)	P90	P10	Median (P50)	P90	P10	Median (P50)	P90	P10	Median (P50)	P90
Mean temp	°C	Absolute	**20.20**	**21.36**	**22.83**	**21.16**	**22.44**	**24.07**	**21.21**	**22.69**	**24.35**	**21.62**	**22.97**	**24.44**
		Change				+0.96	+1.08	+1.24	+1.01	+1.33	+1.52	+1.42	+1.61	+1.61
Mean of daily max temp	°C	Absolute	**21.92**	**22.85**	**24.06**	**22.64**	**24.18**	**25.36**	**22.76**	**24.28**	**25.62**	**23.09**	**24.38**	**25.91**
		Change				+0.72	+1.33	+1.30	+0.84	+1.43	+1.56	+1.17	+1.52	+1.85
Max of daily max temp	°C	Absolute	**27.81**	**30.27**	**31.78**	**28.02**	**31.16**	**32.85**	**28.30**	**31.55**	**33.40**	**28.65**	**31.83**	**33.52**
		Change				+0.21	+0.89	+1.07	+0.49	+1.28	+1.62	+0.84	+1.56	+1.74
Sea surface temperature	°C	Absolute	**23.64**	**24.83**	**25.95**	**24.27**	**26.08**	**26.91**	**24.65**	**26.22**	**27.08**	**24.76**	**26.41**	**27.38**
		Change				+0.63	+1.25	+0.96	+1.01	+1.38	+1.13	+1.12	+1.58	+1.43
Mean of daily accumulated precipitation	mm	Absolute	**3.61**	**5.19**	**7.56**	**3.67**	**5.23**	**8.02**	**3.87**	**5.44**	**7.81**	**4.05**	**5.46**	**8.10**
		Change				+0.06	+0.04	+0.46	+0.26	+0.25	+0.25	+0.44	+0.27	+0.54
Max of 1-day accumulated precipitation	mm	Absolute	**37.71**	**66.50**	**147.05**	**38.13**	**71.70**	**157.59**	**36.39**	**76.49**	**159.14**	**37.77**	**78.63**	**136.59**
		Change				+0.42	+5.19	+10.54	-1.32	+9.98	+12.09	+0.06	+12.13	-10.46
Max of 5-day accumulated precipitation	mm	Absolute	**101.27**	**161.49**	**299.96**	**108.83**	**178.25**	**324.61**	**117.18**	**187.86**	**333.18**	**112.73**	**188.45**	**307.69**
		Change				+7.56	+16.76	+24.65	+15.91	+26.37	+33.22	+11.46	+26.96	+7.73
Mean wind speed *(near surface, may not be site specific[24])*	m/s	Absolute	***2.70***	***4.16***	***5.03***	***2.62***	***4.15***	***4.97***	***2.62***	***4.29***	***4.93***	***2.65***	***4.16***	***5.01***
		Change				-0.08	-0.01	-0.06	-0.08	+0.14	-0.10	-0.05	0.00	-0.02
Average air pressure at MSL	Pa	Absolute	**101196.07**	**101387.50**	**101526.95**	**101185.96**	**101410.91**	**101560.99**	**101189.23**	**101420.13**	**101575.67**	**101184.90**	**101399.02**	**101585.14**
		Change				-10.11	+23.41	+34.04	-6.84	+32.63	+48.72	-11.17	+11.52	+58.19
Sea Level Rise (2060)[25]	m	Change				**+0.01**	**+0.24**	**+0.49**	**+0.04**	**+0.27**	**+0.52**	**+0.08**	**+0.31**	**+0.58**

Source: Copernicus Interactive Climate Atlas, NASA Sea Level Change Portal

[24] Wind speed that matters for WTG would be measured at a height of 100m and may have different results from surface wind speed.

[25] Data for projected sea level rise is taken from the IPCC 6th Assessment Report Sea Level Projections through the Sea Level Projection Tool – NASA Sea Level Change Portal for the coordinates Lat: 24, Long: 120, for the year 2060.

4.4 Discussion on climate variables

This section provides discussions on the baseline and projection data for each climate variables listed in the previous section. Supporting documentation from Taiwan's Central Weather Administration are also referenced for discussion on typhoons.

4.4.1 Temperature

Baseline climate conditions:

- Analysis data (modelled) for the project site area for the reference baseline period of 1995 – 2014 saw a mean temperature of 21.36℃, with a mean maximum daily temperature of 22.85℃, and absolute maximum daily temperatures of 30.27℃. During the same reference period, the sea surface temperature in the offshore area averaged at 24.83℃.[26]

Future projections:

- Overall, all projected median values (P50) and the P90 values for each temperature variable depict an increase across all three scenarios by 2041 – 2060, whereas the P10 values show variability between each scenarios, as compared to the baseline period:
  - For mean temperature, SSP1-2.6 depicts a median increase of +1.08℃ (+0.96℃ to +1.24℃), SSP2-4.5 shows a median increase of +1.33℃ (+1.01℃ to +1.52℃), and SSP5-8.5 respectively shows increase across all percentiles with a median increase of +1.61℃ (+1.42℃ to +1.61℃). Thus, it is moderately likely that the mean temperature will increase throughout the project's lifecycle.
  - For mean maximum daily temperature, SSP1-2.6 depicts a median increase of +1.33℃ (+0.72℃ to +1.30℃), SSP2-4.5 respectively shows a median increase of +1.43℃ (+0.84℃ to +1.56℃), and SSP5-8.5 shows increase across all percentiles with a median increase of +1.52℃ (+1.17℃ to +1.85℃). It is moderately likely that the mean maximum daily temperatures will increase throughout the project's lifecycle.
  - For absolute maximum daily temperature, SSP1-2.6 depicts a median increase of +0.89℃ (+0.21℃ to +1.07℃), SSP2-4.5 shows a median increase of +1.28℃ (-0.49℃ to +1.62℃), and SSP5-8.5 shows a median increase of +1.56℃ (+0.84℃ to +1.74℃). It is slightly likely that the absolute maximum daily temperature will increase throughout the project's lifecycle.
  - For mean sea surface temperature, SSP1-2.6 depicts a median increase of +1.25℃ (+0.63℃ to +0.96℃), SSP2-4.5 shows a median increase of +1.38℃ (+1.01℃ to +1.13℃), and SSP5-8.5 shows a median increase of +1.58℃ (+1.12℃ to +1.43℃). It is slightly likely that the mean sea surface temperature will increase throughout the project's lifecycle.

4.4.2 Precipitation

Baseline climate conditions:

- The analysis-based (modelled) reference baseline climate period (1995 – 2014) saw an average daily accumulated precipitation of 7.02mm and a maximum 1-day accumulated precipitation of 24.31mm, as well as a maximum 5-day accumulated precipitation of

[26] Copernicus Interactive Climate Atlas.

69.41mm. During the same reference period, the region saw an annual average maximum dry period duration of 17.87 consecutive dry days[27].

Future projections:

- Overall, all projected median values (P50) and the P90 values for each precipitation variable depict an increase across all three scenarios by 2041 – 2060, whereas the P10 values show a decrease across all three scenarios, as compared to the baseline period:
  - For average daily accumulated rainfall, the P10 values show a slight increase across all three scenarios (+0.06mm to +0.44mm), the median values for all three future climate scenarios project a small increase in median daily precipitation (+0.04mm to +0.27mm), and the P90 values show a slight increase in daily accumulated precipitation (+0.25mm to +0.54mm) across the three scenarios, showing that there is some probability of increase in average daily accumulated precipitation throughout the project's lifecycle.
  - For maximum 1-day accumulated rainfall, the P10 values show a variation across the three scenarios (-1.32mm to -0.42mm), the median values for all three future climate scenarios project a small increase in 1-day accumulated daily precipitation (+5.19mm to +12.13mm), however the P90 values show a drastic variation in 1-day accumulated precipitation across the three scenarios, where SSP1-2.6 shows an increase by +10.54mm, SSP2-4.5 shows an increase by +12.09mm, whereas SSP5-8.5 shows a decrease by -10.46mm. This show that although there is some probability of increase in maximum 1-day accumulated precipitation throughout the project's lifecycle, there are some uncertainty.
  - For maximum 5-day accumulated precipitation, the P10 values show an increase across all three scenarios (+7.56mm to +11.46mm), the median values for all three future climate scenarios project an increase in 5-day accumulated daily precipitation (+16.76mm to +26.96mm), as well as the P90 values show an increase in 5-day accumulated precipitation across the three scenarios, although the increase is greater for SSP1-2.6 (+24.65mm) and SSP2-4.5 (+33.22mm) scenario, however less substantial for SSP5-8.5 (+7.73mm). This show that there is certain probability of increase in maximum 5-day accumulated precipitation throughout the project's lifecycle.

4.4.3 Wind and typhoons

Baseline Climate Conditions[28]:

- The analysis data (modelled) for the region around the project site from reference baseline period (1995 – 2014) reports a near surface mean wind speed of 4.16m/s, as well as an average air pressure at mean sea level of 1013.9hPa (101387.5Pa).
- Taiwan is located in a region that is often prone to typhoons, where most typhoons are at their strongest stage and deadliest around the moment they make landfall in Taiwan. According to the CWB, between a timeframe of 1991 to 2020, an average of 25.43 typhoons were generated yearly over the North West Pacific. In 2022, there were 25 typhoons generated in the same area, where the government issued warnings for only three and where only typhoon HINNAMNOR caused some damage to Taiwan. Most typhoons occur between July and October (Figure 4.4).[29]

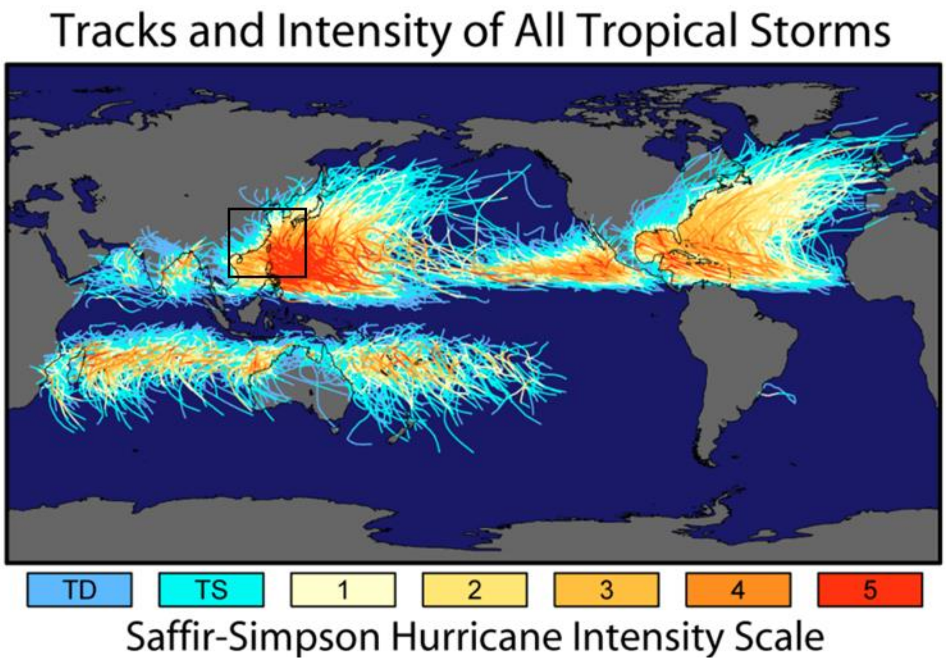
[27] Maximum of consecutive days when daily accumulated precipitation amount is below 1mm.

[28] Please refer to Section 2.3 for commentary on typhoon impacts on wind farms.

[29] Publish_20230914153735.pdf (cwa.gov.tw)

- A climatological analysis of typhoon occurrences in the North West Pacific (Taiwan included) throughout the past four decades (from 1977 - 2016), revealed that the recent years of 2013 - 2016 recorded the maximum average frequency of 7 super typhoons per year.[30]
- Both 2023 and this year 2024 (to date of this report) each saw 3 typhoons with a typhoon category of 4, causing substantial impact on Taiwan, which is the most number of super typhoons encountered per year since 2018.[31]
- For this year (2024) statistics from the Central Emergency Operation Center, it shows that typhoons GAEMI and KRATHONS caused a total of 14 deaths, more than a thousand injuries and more than a million households were cut from electricity in Taiwan.[32,33]

Figure 4.3: Track of tropical cyclones showing strengths along individual tracks. Taiwan marked within black square.



Source: Historic Tropical Cyclone Tracks (nasa.gov)

30 Typhoon strength rising in the past four decades - ScienceDirect
31 Recent typhoons in Taiwan
32 rdc28.cwa.gov.tw/TDB/public/typhoon_detail?typhoon_id=202403
33 rdc28.cwa.gov.tw/TDB/public/typhoon_detail?typhoon_id=202418

Figure 4.4: Monthly distribution of typhoons throughout 2022 and average for 1991 – 2020.

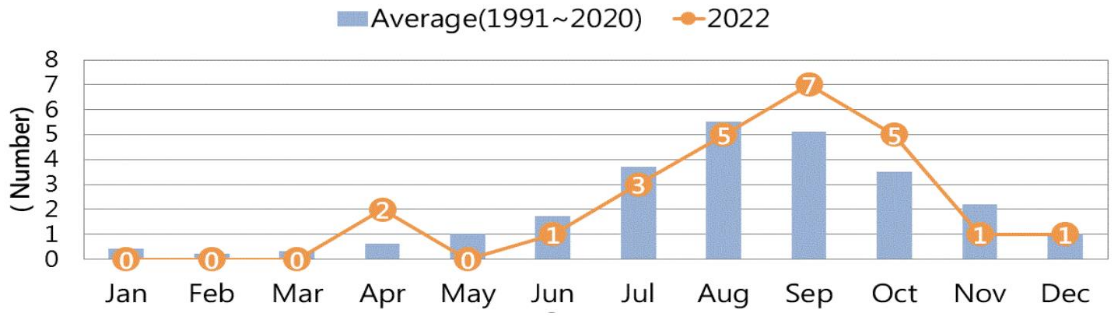


FIG. 4. Tracks of 25 named TCs over the western North Pacific in 2022 (upper left) and 3 for which warnings were issued (upper right). Monthly number of named TC formation for 2022 and monthly average as calculate over 1991-2020 (lower).

Source: CWB

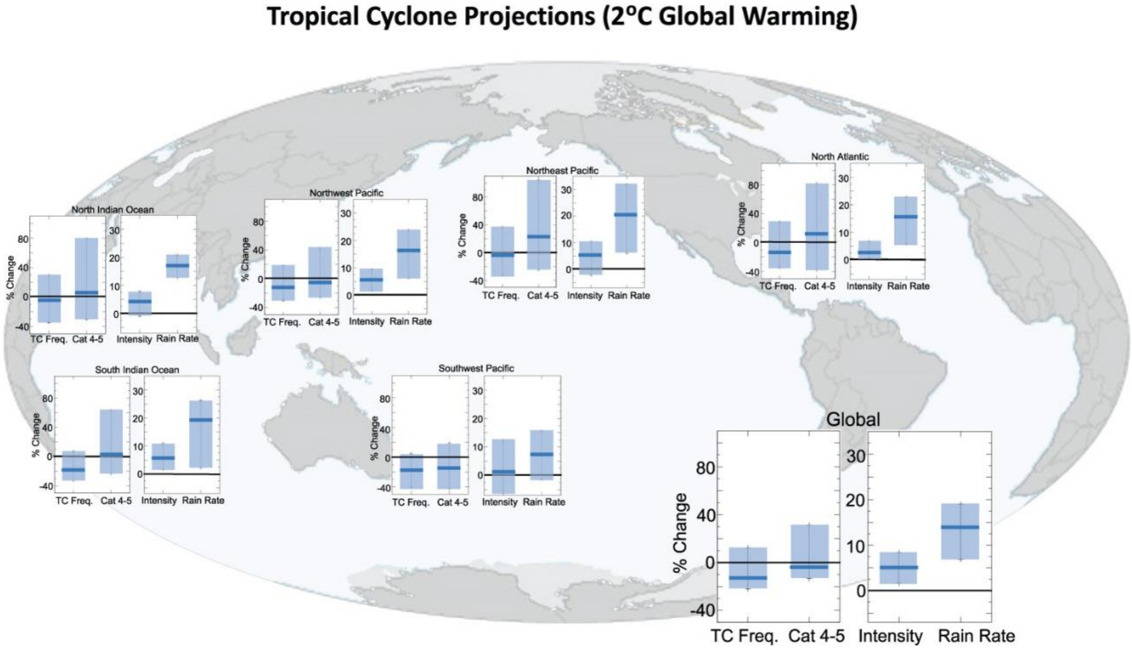
Future projections:

- The three projection scenarios for near surface mean wind speed in the project region (but not project site specifically) show very little change in the median value (+/- 0.1 m/s) across all three scenarios. P10 to P 90 values show some decrease (although not significant) across the three scenarios and show a range of between -0.08m/s to -0.05m/s for change in wind speeds. The impact of climate change on future wind speeds are uncertain, but projection data points to little change, however weighing very slightly more towards a decrease in mean wind speed. It should be noted that projection for wind speed at turbine height was not available, however based on the above information, it is assumed that the wind speed at turbine height will show little to no change.
- All three projection scenarios for average air pressure at MSL show fluctuation in change between each scenarios and percentiles, although all P10 values show a decrease (-201.54Pa to -198.27Pa) while all P50 and P90 values show an increase (P50: +11.52Pa to +32.63Pa, P90: +173.49Pa to +197.64Pa). Change weighs slightly more towards an increase of average air pressure throughout the project lifecycle, however, the change is not substantial (<0.1% change).
- According to NOAA, although the average number of typhoons generated each year is projected to decrease or remain the same, climate models show that proportion of intense typhoons with a typhoon category of 4[34] and above is projected to increase further due to warming of the surface ocean (Correspondingly, climate model studies project a reduction in the proportion of weak typhoons). This is likely to bring a greater proportion of storms having more intense wind speeds, higher storm surges, and more extreme precipitation.[35]

[34] Typhoons with a category of 4 observe wind speeds of at least 209 km/h. This is strong enough to uproot trees and topple power poles. Tropical Cyclone Classification | National Oceanic and Atmospheric Administration (noaa.gov)

[35] Summary of a series on "Critical Issues in Climate Change Science" prepared for the COP26 climate conference held in Glasgow, 2021. Climate change is probably increasing the intensity of tropical cyclones | NOAA Climate.gov

Figure 4.5: Typhoon projections under a 2℃ global warming scenario



Source: Climate.gov

4.4.4 Sea Level Rise

Projections for the seas adjacent to the project site location (Longitude: 24, Latitude: 120) depict future sea level rise to range between +0.01m (P10 value of SSP1-2.6) and +0.58m (P90 value of SSP5-8.5), within median increase of +0.24m, +0.27m and +0.31m for SSP1-2.6, SSP2-4.5 and SSP5-8.5 respectively by 2060 relative to a 1995-2014 baseline.[36] Sea level rise may influence flood events in the plains surrounding the site, either through inundation or increased ground water levels, thus impacting components located on low elevation grounds or limit access to the site.

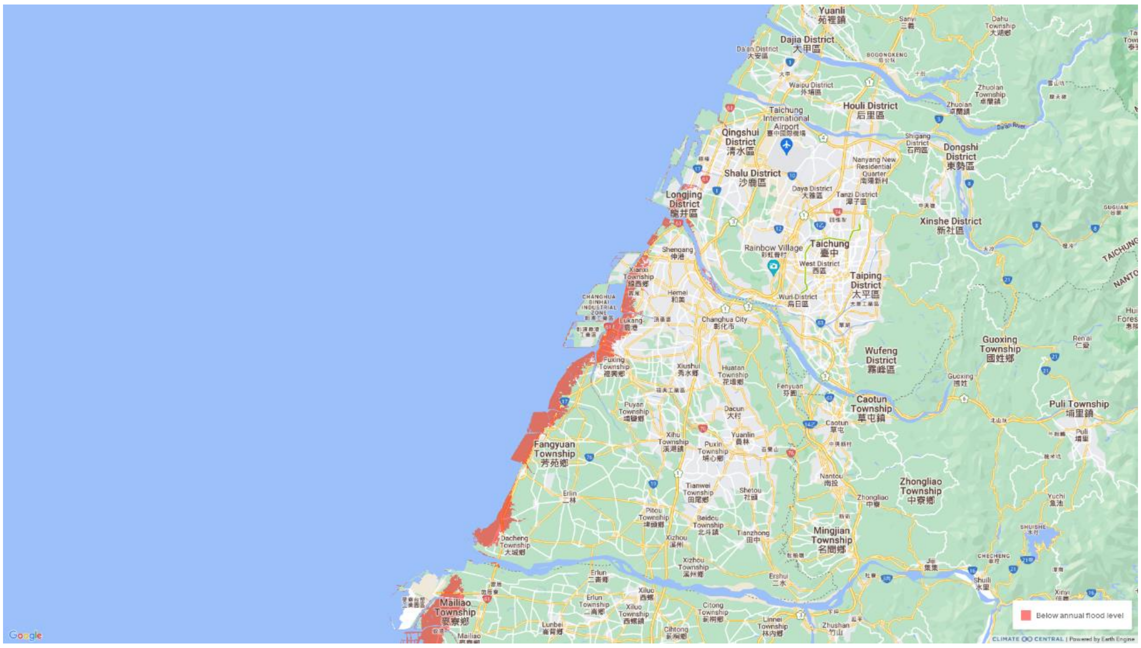
Climate Central allows a high-level screening of flood risk as a result of sea-level rise by decadal year for a range of scenarios[37]. The results of the analysis for the Project landing infrastructure location by 2050 for land below the annual flood level is shown in Figure 4.6.[38] This screening suggests that onshore infrastructure is likely to be affected by sea level rise by 2050, and this should be carefully considered in the final choice of infrastructure location and design requirements.

[36] Sea Level Projection Tool – NASA Sea Level Change Portal

[37] Climate Central (2021). Available at: Maps & Tools | Surging Seas: Sea level rise analysis by Climate Central

[38] Parameters used to determine future sea level rise via Climate Central: Year: 2060; Project Type: Sea level rise + annual flood; Pollution pathway: unchecked pollution; and Luck: bad.

Figure 4.6: Land projected to be below annual flood level in 2060



Source: Climate Central

4.4.5 Lightning

There is insufficient lightning data near the site to accurately map the baseline or to accurately predict the lightning hazards that would be expected under a climate change scenario. There is a consensus that an increase in mean temperature will lead to an increase in convective activity. Research suggests that for every 1.0°C rise in global temperature, lightning strikes in the contiguous United States are estimated to increase by 12% ± 5% and about 50% over this century[39].

Furthermore, separate research conducted in 2008 also suggests that there is a positive relationship between temperature and lightning, with lightning increasing anywhere from 10% to 100% for every one degree of surface warming[40]. It is understood that the above research is predominantly concerned with an increase in the frequency of lightning activity.

Accepting that not all storm events may be electrical by nature, there are empirical relationships which suggest that if the number of thunderstorm days (Keruanic level) doubles, so does the number of flashes per square kilometre[41]. This would suggest that it could be expected that the number of lightning events in Taiwan might increase as we move through the century.

With regard to whether the intensity of lightning might increase as a result of climate change the understanding is less clear. The magnitude of the current discharge, the rate of rise of the current and the number of discharges collectively determine whether a flashover occurs. It is clear that there will be an increase in the number of storms and therefore, the frequency of

[39] D. M. Romps et al., "Projected increase in lightning strikes in the United States due to global warming", Science, vol. 346, issue 1162, pp. 851-854, 14 November 2014 (DOI: 10.1126/science.1259100)

[40] C. Price, "Thunderstorms, Lightning and Climate Change", Lightning: Principles, Instruments and Applications, ed. H.D. Betz, U. Schumann and P. Laroche, Springer Publications, pp. 521-536, 2009

[41] Electric Power Research Institute (EPRI), "Handbook for Improving Overhead Transmission Line Lightning Performance", December

lightning. However, the changes in intensity (heat and electrical power) are not known. The intensity of a lightning strike in terms of the associated heat and electrical power are so large that any increase or decrease is not likely to affect the impact of a lightning strike.

4.5 Other climate variability

4.5.1 ENSO

Taiwan is susceptible to climate variability and extreme weather events, in part due to the influence of the El Niño–Southern Oscillation (ENSO), and in part due to anthropogenic climate change. Taiwan's most significant ENSO related impacts are due to flooding during the wet season and typhoons.

ENSO is the strongest and most consequential year-to-year climate fluctuation on the planet[42]. ENSO events have global impacts, however the effects are different depending on the region and the time of year (Figure 4.7). During El-Niño events, which usually peak during the northern-hemisphere winter, precipitation over Taiwan tends to be lower during September – November, while wetter conditions are experienced during northern-hemisphere spring[43].

Recent studies have reported that anthropogenic climate change has resulted in an enhancement in the frequency of the central Pacific El-Niño[44], and this trend is projected to continue under a warming climate[45]. Another paper found that the central Pacific ENSO has become more influential in determining spring rainfall compared to the Pacific Decadal Oscillation (PDO), with warmer SSTs in the central Pacific resulting in increased Spring precipitation even when the PDO phase would normally cause the opposite signal[46].

Climate change is expected to interact with ENSO. The result is more variable precipitation patterns, and more extreme ENSO conditions. Furthermore, the uncertainty associated with future climate is compounded by the fact that climate change is occurring on top of existing inter-annual variability in climate caused by ENSO.

However, while Climate model simulations suggest that central Pacific ENSO variability may increase under greenhouse forcing, instrumental records of tropical Pacific sea surface temperatures (SSTs) are too short to provide robust constraints on recent trends in ENSO variability[47,48]. As such, while studies suggest that anthropogenic warming may result in more frequent central Pacific El-Niño events delivering more Spring precipitation to Taiwan, there is still substantial uncertainty around this trend.

[42] Geng et al, (2022). Available at: Emergence of changing Central-Pacific and Eastern-Pacific El Niño-Southern Oscillation in a warming climate | Nature Communications

[43] Lu et al. (2005). Available at: 2005.pdf (cwb.gov.tw)

[44] Liu et al. (2017). Available at: Recent enhancement of central Pacific El Niño variability relative to last eight centuries | Nature Communications

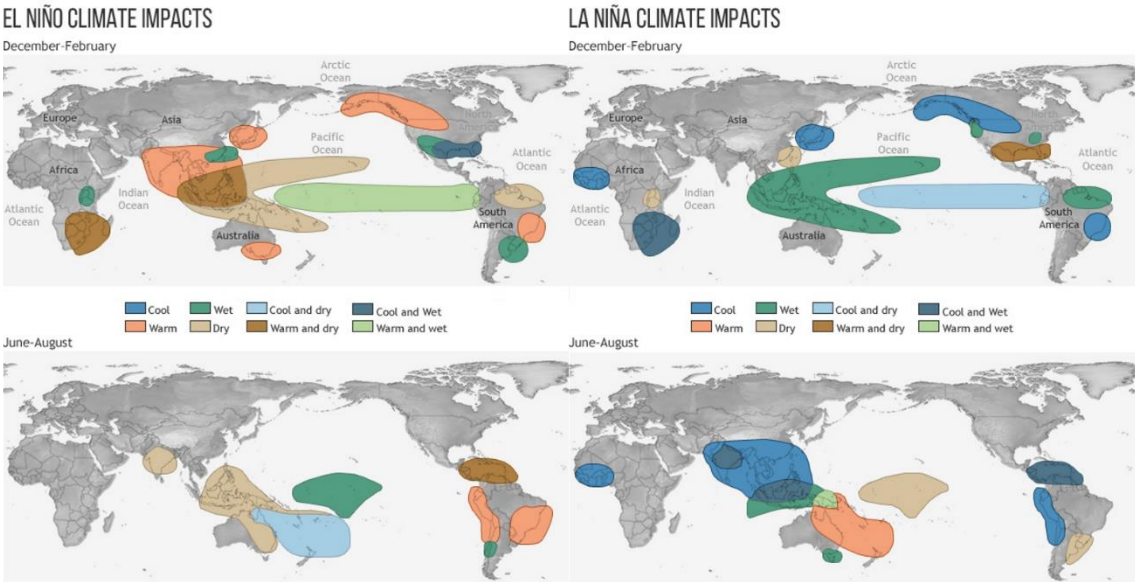
[45] Shin et al. (2022). Available at: More frequent central Pacific El Niño and stronger eastern pacific El Niño in a warmer climate | npj Climate and Atmospheric Science (nature.com)

[46] Kao et al. (2018). Available at: Increasing influence of central Pacific El Niño on the inter-decadal variation of spring rainfall in northern Taiwan and southern China since 1980 - Kao - 2018 - Atmospheric Science Letters - Wiley Online Library

[47] Liu et al. (2017).

[48] Chen et al. (2008). Available at: chen.li.shih2008.pdf (hawaii.edu)

Figure 4.7: Inter-annual ENSO climate impacts during different seasons



5 Physical Climate Change Risk Assessment

5.1 Analysis method

Mott MacDonald produced a Risk Register to collate potential climate hazards and impacts on different projects components using technical expertise, the climate data listed above and information collated during a literature review.

Each impact identified for a project component was assessed for:

1. **Likelihood of occurrence** within the assets lifecycle (using the descriptors in Table 5.1). Likelihood is defined as is the chance of a specific outcome occurring.
2. **Consequence of occurrence** on the asset based on damage to infrastructure, impact on operations and health & safety consequence (using descriptors in Table 5.2). Consequence is defined as the impact(s) that may occur given a projected change in climate, without considering adaptation.
3. Likelihood and consequence were then combined together to determine overall **risk rating** (using the matrix in Table 5.3). Risk is defined as the potential for adverse consequences which is determined by considering the likelihood of a climate hazard occurring and its associated impact on receptors / assets.
4. Dependent on their overall risk rating (i.e. low, medium, high etc.) each risk has differing levels of **acceptability/tolerability**. Acceptability/tolerability is defined as the value judgement of whether a risk is viewed as manageable or not.

5.1.1 Likelihood

The likelihood of impacts to the infrastructure is rated based on a uniform scale below. This has been determined based on an evaluation of current and projected (future) climate data, using a representation of the likelihood of impacts. The current climate impact is based on an estimated impact return period, using the information we have collected.

Table 5.1: Likelihood descriptors (for likelihood of occurrence within the assets lifecycle)

Level	Likelihood	Quantitative	Qualitative
5	Almost certain	> 85%	Expected to occur frequently during time of activity or project
4	Likely	> 55% - 85%	Expected to occur occasionally during time of activity or project
3	Possible	> 30% - 55%	More likely not to occur than occur during time of activity or project
2	Unlikely	> 5% - 30%	Unlikely to occur than occur during time of activity or project
1	Rare	0% - ⩽ 5%	Not expected to occur during the time of activity or project

5.1.2 Consequences

The potential consequences of the climate impact is rated based on a uniform scale below. This has been determined based on a combination of expert judgement and review of available evidence and literature.

Table 5.2: Consequence descriptors

Level	1	2	3	4	5
Consequence Descriptor	**Insignificant**	**Minor**	**Moderate**	**Severe**	**Extreme**
Damage to infrastructure	Minor superficial impact. No material infrastructure damage.	No permanent damage. Some minor restoration work required. Early renewal of infrastructure required 10-20% of the time. Need for new / modified equipment.	Damage recoverable by maintenance and minor repair. Early renewal of infrastructure required 20-50% of the time.	Extensive infrastructure damage requiring major repair. Early renewal of infrastructure required 50-90% of the time.	Significant permanent damage and/or complete loss of the infrastructure and the infrastructure service. Loss of infrastructure support and translocation of service to other sites. Early renewal of infrastructure required >90% of the time.
Impact on operations	An event, the impact of which can be absorbed as part of normal activity. little change to operations	An event the impact of which can be absorbed but some additional maintenance effort is required. Short period of operational shut down of several hours to a day required. Limited and isolated impact on operations. Localised infrastructure service disruption.	An event, the impact of which can be absorbed but much broader maintenance effort is required. Moderate period of operational shut down of several days or weeks is required. Ongoing changes to some operations required. Limited infrastructure damage and loss of service.	Major event which can be absorbed, but substantial maintenance effort is required. Major loss of infrastructure service. Significant period of operational shut down of several weeks or months is required. Major and permanent changes required to operations.	Severe event which requires extensive maintenance effort but can be survived. Operations are fundamentally compromised and / or cannot be delivered.
Health & safety	Illness, first aid or injury not requiring medical treatment	Illness or minor injuries requiring medical treatment	Single recoverable lost-time injury or illness, alternate / restricted duties injury, or short-term occupational illness.	1-10 major injuries requiring hospitalisation and numerous days lost, or medium-term operational illness.	Any fatalities, permanent disabilities / chronic illness, and / or 10 + major injuries

5.1.3 Risk

The risk to the assets of the Project is scored using the risk matrix below, which categorises the level of risk as low, medium, high, or extreme as defined in Table 5.4.

Table 5.3: Overall risk rating matrix

	Consequence				
	1	2	3	4	5
Likelihood	Insignificant	Minor	Moderate	Severe	Extreme
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Low	High

Table 5.4: Risk definitions & associated acceptability/tolerance levels

Rating	Acceptability/ tolerance level	Consequence on the Project
Low	Acceptable	A low level of vulnerability to specific climate risk(s). Remedial action of adaptation may be required.
Medium	Tolerable	A moderate level of vulnerability to specific climate risk(s). Mitigation action or adaptation could improve resilience, although an appropriate level of resilience is provided.
High	Potentially intolerable / Tolerable	A high level of vulnerability to specific climate risk(s). Mitigation action or adaptation is recommended.
Extreme	Intolerable	An extreme level of vulnerability to specific climate risk(s). Mitigation action or adaptation is highly recommended.

5.2 Physical Climate Change Risk Assessment

The physical climate change risk assessment carried out for the Project is presented in Table 5.6 and has been undertaken in line with the methodology presented in Section 5.1. It summarises the potential impacts to the Project due to climate hazards affecting vulnerabilities of Project components and applies a risk rating to each potential impact.

The design climatic conditions of the WTG model was referenced for this assessment, however it should be noted that other detailed information on the Project design and requests for information were not available at the time of writing as some of the documentation (ie. Technical Due Diligence, etc.) are pending finalization. Additional information will be made available as the Project progresses. As such, this assessment referred to other documents that were prepared for other offshore wind projects adjacent to the area (Greater Changhua 1 and Greater Changhua 4), which are also developed by Ørsted.

It is noted that Phase 2a of shares the same WTG technology as Greater Changhua 1 (8MW turbines) and Phase 2b of the Project shares the same WTG technology as Greater Changhua 4 (14MW turbines). Mott MacDonald undertook CCRAs for both Greater Changhua 1 and 4 that includes detail on measures taken into account with the WTG designs in relation to climate change. As such, the CCRAs from both offshore wind farms have been used to form the basis of this assessment.

In summary, the CCRA has identified a total of 17 risks of which 3 are identified to be of a low rating and the remaining 14 are of a medium rating. The medium risks are summarised in Table 5.5 with more detail presented in Table 5.6.

Table 5.5: Summary of medium rated risks identified

Hazard - Climatology	Project component	Impact type	Consequence/impact	Risk
Temperature - Increase in extreme temperatures[49]	Wind Turbine Generators	Damage to Infrastructure	Fatigue and degradation of turbines as a result of extreme heat leading to increased maintenance requirements	Medium
	Substations (both offshore and onshore)	Damage to Infrastructure	Increased temperatures may result in exceedance of design conditions for electrical equipment resulting in failure of equipment, requiring maintenance and replacement.	Medium
	Substations (both offshore and onshore)	Power Transmission	Increased temperatures may result in de-rated component capacity at substations and transformers. This results in a lower capacity of the system to transmit energy.	Medium
	Substation (onshore)	Working Conditions	Changes to ground moisture and ground temperature influence efficiency of substation earthing & lightning protection which could pose a safety risk on-site.	Medium
	O&M (both offshore and onshore)	Working Conditions	Extreme heat impacts on workers leading to heat exhaustion, or reductions in outside work time for repair and maintenance activities.	Medium
Precipitation - Increase in extreme precipitation events	Wind Turbine Generators	Damage to Infrastructure	Extreme precipitation could cause enhanced erosion of leading edges. Additionally there is a risk of water ingress into the nacelle, causing damage to electrical boards and wiring and corrosion of key components.	Medium
	O&M (both offshore and onshore)	Working Conditions	Extreme precipitation may result in elevated risks to the health and safety of workers on site resulting from poor visibility, wet clothing, slip hazards and erosion to access roads etc	Medium
Typhoon - Increased proportion of super typhoons	Wind Turbine Generators	Damage to Infrastructure	Typhoons with a category of 4 and above are always accompanied by strong winds that can cause damage to turbine blades or to the tower.	Medium
	O&M (both offshore and onshore)	Working Conditions	Typhoons with a category of 4 and above are always accompanied by strong winds that can impact access to sites leading to delays in maintenance.	Medium
	Substations (both offshore and onshore)	Damage to Infrastructure	Typhoons with a category of 4 and above are always accompanied by strong winds that can cause damage to buildings and infrastructure.	Medium
	Onshore cables and grid connection	Damage to Infrastructure	Typhoons with a category of 4 and above are always accompanied by strong winds that can cause damage to transmission lines and poles.	Medium
Flooding - Rise in sea level and	Substation (onshore)	Damage to Infrastructure	The onshore substation is located directly adjacent to the coast, and therefore	Medium

[49] Condition for high temperatures (technical): WTGs typically observe degeneration between 25 - 30℃, unless the WTG has a special design to help reduce the temperature inside the nacelle. This design condition was not identified, and therefore we define the condition of high temperatures as a temperature above 30. (working condition): According to OSHA.gov, temperatures above 25℃ could bring high-risk of heat-related illness with strenuous work for unacclimatized workers, and strenuous work would be possibly unsafe for acclimatized workers.

Hazard - Climatology	**Project component**	**Impact type**	**Consequence/impact**	**Risk**
increase precipitation			susceptible to flooding during events that combine sea level rise, high tide, storm surge and extreme precipitation.	
	Cables & Grid Connections	Damage to Infrastructure	Damage to underground cables - water intrusion into cable ducts	Medium
	Operation & Maintenance	Reduced Access	Flooding in the harbour and coastal areas might restrict access to the site for O&M activities.	Medium

Table 5.6: Physical Climate Change Risk Assessment of the Project

Projection Scenario: SSP5-8.5 / Timeframe: 2041-2060 (excl. Construction)

Hazard - Climatology	Project component	Impact type	Risk description		Risk rating with BAU controls			Acceptance level	Potential proposed adaptation actions
			Consequence/impact	Current BAU risk controls	L/hood	Consequence	Risk		
Temperature - Increase in extreme temperatures	Wind Turbine Generators	Damage to Infrastructure	Fatigue and degradation of turbines as a result of extreme heat leading to increased maintenance requirements	Turbines typically have sensors measuring temperatures, and other variables, at different time intervals. This real time measurement data is combined with historical data and wind farm system understanding to optimise power output, scheduled and corrective maintenance, detecting and diagnosing installation and warranty issues, amongst others. Targeted monitoring and replacement of components with expected life times shorter than the remaining wind-farm lifetime. Where data shows the turbine has been operating / or is at risk of operating outside of specified parameters, targeted pre-emptive and/or remedial maintenance and servicing will be actioned. The turbine specification for the Project notes that the High Temperature Ride Through (HTRT) enables reduced operation up to the design temperature.	L3 Possible	S3 Moderate	Medium	Tolerable	Review assumed allowances within the design and take these into account for O&M manual if not already implemented. Turbines are understood to operate effectively under local temperature conditions including fluctuations from 'normal' range. Sustained heatwave conditions may require more regular checking of equipment performance and more regular maintenance.
Temperature - Increase in extreme temperatures	Wind Turbine Generators	Power Generation	Lower energy yield as a result of increased air temperatures. The air temperature has an indirect impact on wind turbine loads. Increasing air temperatures (T) lead to decreasing air densities (ρ). Rotor thrust (FT) is not only proportional to the square of the wind speed (v) but also to the air density: FT ~ ρv2	While it is not quantified how much impact this would have to the air density. It is assumed that the EYA has factored in uncertainty range for future energy generation, which account for the uncertainty in site environment.	L2 Unlikely	S2 Minor	Low	Acceptable	Ensure that the estimated yield used have taken uncertainty into account.
Temperature - Increase in extreme temperatures	Substations (both offshore and onshore)	Power Transmission	Increased temperatures may result in de-rated component capacity at substations and transformers. This results in a lower capacity of the system to transmit energy.	It is assumed that designs will account for functionality in high temperatures.	L3 Possible	S2 Minor	Medium	Tolerable	Ensure that systems are rated appropriately for future increases in temperature and that appropriate ventilation and/or A/C equipment is included to maintain temperatures within operating ranges.
Temperature - Increase in extreme temperatures	Substations (both offshore and onshore)	Damage to Infrastructure	Increased temperatures may result in exceedance of design conditions for electrical equipment resulting in failure of equipment, requiring maintenance and replacement.	It is assumed that designs will account for functionality in high temperatures.	L3 Possible	S3 Moderate	Medium	Tolerable	Ensure that systems are rated appropriately for future increases in temperature and that appropriate ventilation and/or A/C equipment is included to maintain temperatures within operating ranges.
Temperature - Increase in extreme temperatures	Substation (onshore)	Working Conditions	Changes to ground moisture and ground temperature influence efficiency of substation earthing & lightning protection which could pose a safety risk on-site.	It is assumed that the annual substation O&M check will include the typical grounding resistance check and should the parameters become out of the range, rectification will be implemented.	L3 Possible	S2 Minor	Medium	Acceptable	Ensure that earthing and lightning protection equipment takes into account and is designed to operate for a range of plausible temperatures and ground moisture conditions.

Projection Scenario: SSP5-8.5 / Timeframe: 2041-2060 (excl. Construction)

Hazard - Climatology	Project component	Impact type	Risk description		Risk rating with BAU controls			Acceptance level	Potential proposed adaptation actions
			Consequence/impact	Current BAU risk controls	L/hood	Consequence	Risk		
Temperature - Increase in extreme temperatures	O&M (both offshore and onshore)	Working Conditions	Extreme heat impacts on workers leading to heat exhaustion, or reductions in outside work time for repair and maintenance activities.	BAU mitigation measures to minimise heat exposure and reduce the risk of potential heat stress, include: – Implementing portable air conditioning to provide localised cooling for technicians – Installing centrifugal fans in the nacelle to improve air flow and exchange hot air with cooler air from outside – Adequate work and rest patterns – Employing light workwear and PPE suitable for work in tropical climates – Adapting shifts to work at cooler times of day (for example, night work) – First aid kits are extended with tools in case of heat stroke incidents – Special care is taken to ensure that technicians are hydrated It is assumed that all contractors will be required to provide health & safety plans for their respective scope of works and teams deployed to site.	L3 Possible	S2 Minor	Medium	Acceptable	
Temperature - Increase in extreme temperatures	O&M (both offshore and onshore)	Damage to Infrastructure	Extreme high temperatures can cause loss of information through communication networks or reduced quality of service, leading to sub-optimal operation or in the worst case damage to WTGs	It is assumed that communications and data services with the WTGs will be designed to be resilient in a wide range of operating conditions, including in high temperatures.	L2 Unlikely	S2 Minor	Low	Acceptable	Ensure that hardened back-up communication and data systems exist to maintain control of critical functions even in extreme circumstances
Precipitation - Increase in extreme precipitation events	Wind Turbine Generators	Damage to Infrastructure	Extreme precipitation could cause enhanced erosion of leading edges. Additionally there is a risk of water ingress into the nacelle, causing damage to electrical boards and wiring and corrosion of key components.	It is assumed that the selected blade design is appropriate for regional climatic conditions and the turbine model has incorporated water-proofing measures suited to the rainy climate of the tropics.	L3 Possible	S3 Moderate	Medium	Tolerable	Ensure that the project conduct regular monitoring to check for anomalies in electrical components and operations. Leading edge protection should be checked/monitored at least on an annual basis.
Precipitation - Increase in extreme precipitation events	O&M (both offshore and onshore)	Working Conditions	Extreme precipitation may result in elevated risks to the health and safety of workers on site resulting from poor visibility, wet clothing, slip hazards and erosion to access roads etc	It is assumed that the health & safety plan takes into account extreme weather events and appropriate working conditions. It is also assumed that WTG operations will come to a stop during extreme weather events.	L2 Unlikely	S3 Moderate	Medium	Tolerable	Ensure that the project incorporate H&S procedures for extreme weather events, including cessation of work where necessary and select locations for evacuation/shelter of workers. It is recommended that the weather forecast be checked regularly throughout the project lifecycle, to proactively plan work around extreme weather events to avoid any accidents and casualties.
Wind - Wind speed variability	Wind Turbine Generators	Power Generation	Changes in wind patterns impact on power output within operating range.	Cut in wind speed had been defined/included within the turbine specifications.	L2 Unlikely	S1 Insignificant	Low	Acceptable	
Typhoon - Increased proportion of super typhoons	Wind Turbine Generators	Damage to Infrastructure	Studies show that there is possibility that although the number of typhoon is projected to stay the same, the proportion of typhoons with a typhoon category of 4 and above is likely to increase (wind speeds of >58m/s). Typhoons with a category of 4 and above are always accompanied by strong winds that can cause damage to turbine blades or to the tower. If a significant typhoon event damages the WTG, this may affect generation operations and an increased budget for replacement of components and maintenance.	The current BAU is performed and approved according to international design standard requirements, which factors extreme wind speed in the design. Greater Changhua 2 Phase 2b is reported to use a newer version of the design standard, which has an even more stringent extreme wind speed design requirement.	L3 Possible	S3 Moderate	Medium	Tolerable	Recommend to consider if the WTG is to conduct a typhoon resistance structural analysis based on the finite element method (FEM). Recommend additional monitoring of WTGs during and after extreme wind events.

Projection Scenario: SSP5-8.5 / Timeframe: 2041-2060 (excl. Construction)

Hazard - Climatology	Project component	Impact type	Risk description		Risk rating with BAU controls			Acceptance level	Potential proposed adaptation actions
			Consequence/impact	Current BAU risk controls	L/hood	Consequence	Risk		
Typhoon - Increased proportion of super typhoons	O&M (both offshore and onshore)	Working Conditions	Studies show that there is possibility that although the number of typhoon is projected to stay the same, the proportion of typhoons with a typhoon category of 4 and above is likely to increase. Typhoons with a category of 4 and above are always accompanied by strong winds that can impact access to sites leading to delays in maintenance. Strong winds can accompany flying debris, which would be a health & safety risk for operations & maintenance workers Delays in maintenance activities due to reduced access to sites.	It is assumed that appropriate actions regarding working conditions during an extreme wind event are implemented within health & safety plans. Health & safety risks are significantly reduced if appropriate plans are in place to manage climatic extremes such as high wind events. Danger to life is a residual risk if workers need to tend to an emergency in stormy and windy conditions.	L3 Possible	S3 Moderate	Medium	Tolerable	Ensure that the project incorporate H&S procedures for extreme weather events, including cessation of work where necessary and select locations for evacuation/shelter of workers. It is recommended that the weather forecast be checked regularly throughout the project lifecycle, to proactively plan work around extreme weather events to avoid any accidents and casualties.
Typhoon - Increased proportion of super typhoons	Substations (both offshore and onshore)	Damage to Infrastructure	Studies show that there is possibility that although the number of typhoon is projected to stay the same, the proportion of typhoons with a typhoon category of 4 and above is likely to increase. Typhoons with a category of 4 and above are always accompanied by strong winds that can cause damage to buildings and infrastructure. If a significant typhoon event damages the substations, this may affect power transmission operations and an increased budget for maintenance of the housing.	It is assumed that infrastructure will be built to appropriate design codes to withstand force of extreme wind gusts.	L3 Possible	S3 Moderate	Medium	Tolerable	Review assumed allowances within the design and take extreme winds into account if not already implemented. Maintenance guide should specify regular monitoring of potential wind-related damage, wear and tear.
Typhoon - Increased proportion of super typhoons	Onshore cables and grid connection	Damage to Infrastructure	Studies show that there is possibility that although the number of typhoon is projected to stay the same, the proportion of typhoons with a typhoon category of 4 and above is likely to increase. Typhoons with a category of 4 and above are always accompanied by strong winds that can cause damage to transmission lines and poles. If a significant typhoon event damages the wider electrical grid and causes a power outage, this may effect ability to restart WTGs or function of safety feature of the WTG.	It is assumed that infrastructure will be built to appropriate design codes to withstand force of extreme wind gusts. WTG also have back up power system to handle the grid outage.	L3 Possible	S3 Moderate	Medium	Tolerable	Review assumed allowances within the design and take extreme winds into account if not already implemented. Maintenance guide should specify regular monitoring of potential wind-related damage, wear and tear.
Flooding - Rise in sea level and increase precipitation	Substation (onshore)	Damage to Infrastructure	The onshore substation is located directly adjacent to the coast, and therefore susceptible to flooding during events that combine sea level rise, high tide, storm surge and extreme precipitation.	Drainage design/plan of the site and components are currently unknown, however, it is assumed that adequate drainage measures will be incorporated for vulnerable components. Elevation of any buildings/substations are unknown at this stage, however, it is assumed that the relative elevation of vital components will be considered.	L2 Unlikely	S3 Moderate	Medium	Tolerable	It is recommended that necessary designs to mitigate flooding around the substation to be incorporated, such as but not limited to; constructing a flood wall around the substation, elevating the ground levels of the foundation of the substation, sufficient drainage around the substation, portable temporary flood barriers at the entrance of the substation building, etc.
Flooding - Rise in sea level and increase precipitation	Cables & Grid Connections	Damage to Infrastructure	Damage to underground cables - water intrusion into cable ducts	The cable design is currently unknown at this stage, however, it is assumed that underground cables will implement water-proofing, as seen with similar projects.	L2 Unlikely	S3 Moderate	Medium	Tolerable	It is recommended for cable junctions to be well sealed and protected to prevent water ingress and for underground cable routes to avoid flow paths and low lying areas where water may pool.

Projection Scenario: SSP5-8.5 / Timeframe: 2041-2060 (excl. Construction)

Hazard - Climatology	Project component	Impact type	Risk description		Risk rating with BAU controls			Acceptance level	Potential proposed adaptation actions
			Consequence/impact	Current BAU risk controls	L/hood	Consequence	Risk		
Flooding - Rise in sea level and increase precipitation	Operation & Maintenance	Reduced Access	Flooding in the harbor and coastal areas might restrict access to the site for O&M activities.	Flood design measures for local access roads are unknown.	L2 Unlikely	S3 Moderate	Medium	Tolerable	It is recommended that access route be designed with enhanced drainage or elevated to improve resilience against flooding removing access to the project site.

6 Conclusion

The risk of physical damage, risks to worker safety and system interruptions with respect to wind energy projects is present irrespective of climate change. The physical CCRA presented in Section 4.2 identifies Project and asset risks that may be magnified by climate change. The assumed and recommended mitigations identified for the offshore and onshore asset design, coupled with recommended management plans and interventions by the Project Company and Project partners has rendered the net classification of these risks as being either medium or low.

The measures have been based off those which are being embedded in the neighbouring project which is also being developed by Ørsted. The CCRA and the measures identified should be reviewed by the Project Company and the relevant Project partners and taken into account within the design to ensure the resilience of the Project. The CCRA should then be reviewed and scored appropriately in line with the measures implemented taken into account.

No fatal flaws in the form of high or extreme risks to the Project have been identified as a result of projected climate change to the 2050s, but a watching brief of risks identified must be maintained throughout the Project lifetime and adaptively managed.

While the management of worker safety is relatively easy to control for, little is known about the interaction of the effects of future climate change on materials or corrosion. Concepts such as the durability or lifespan of assets are not commonly available in this regard. The Project must articulate its overarching maintenance guidance to consider unpredictable, worst case, acute and chronic climate extremes to keep structures and assets in good condition.

The GHG emissions assessment found that estimated annual Scope 1 and 2 emissions during project operations would be approximately 7,112 tonnes, where Scope 2 is 762 t CO_2e based on the latest emission factor for electricity grid consumption. Scope 2 is expected to fall to approximately 20 tonnes in 2050 based on Taiwan’s plan for electricity grid decarbonisation reducing Scope 2 emissions. Total GHG emissions from fuel combustion during Phase 2b construction are estimated to be approximately 54,488 tonnes CO2e during the anticipated construction period. However, these are likely to be allocated as Scope 3 emissions subject to the level of operational control that the project owner has over the vessels. Emissions from purchased electricity are expected to be immaterial during construction.

Appendices

A. Climate change limitations and disclaimer

The assessments in this report are based on freely available information available from third parties for purposes such as this report, being observational data from local weather stations, a number of readily available climate change projections and informed by a selected range of existing climate change research and literature at the time of writing this assessment. The following limitations and disclaimer should be noted:

- Climate change projections: climate projections are not predictions or forecasts but simulations of potential scenarios of future climate under a range of hypothetical emissions scenarios and assumptions. The results, therefore, from the experiments performed by climate models cannot be treated as exact or factual, but projection options. They represent internally consistent representations of how the climate may evolve in response to a range of potential forcing scenarios and their reliability varies between climate variables. Scenarios exclude outlying “surprise” or “disaster” scenarios in the literature and any scenario necessarily includes subjective elements and is open to various interpretations. Generally global projections are more certain than regional, and temperature projections more certain than those for precipitation. Further, the degree of uncertainty associated with all climate change projections increases for projections further into the future.
- Validation of information: Mott MacDonald has not independently verified the observational or projection data and does not accept responsibility or liability for any inaccuracies or shortcomings in this information. Should these information sources be modified by these third parties we assume no responsibility for any of the resulting inaccuracies in any of our reports. Issued reports are relevant to the project information provided and are not intended to address changes in project configuration or modifications which occur over time. The data is obtained to provide a general ‘sense check’ on the published literature on existing observational and climate projections for the region.
- We have not undertaken any climate modelling and rely solely on freely available data on climate projections in this region. Accordingly, any further research, analysis or decision-making should take account of the nature of the data sources and climate projections and should consider the range of literature, additional observational data, evidence and research available - and any recent developments in these.

Detailed information on the Project design and other requests for information were not available at the time of writing as the Project is at an early stage (pre final investment decision). Additional information will be made available as the Project progresses. Two CCRAs were undertaken for the neighbouring Ørsted Group development, Greater Changhua 1 in 2020 and Greater Changhua 4 in 2023, and includes detail on the measures taken into account within the design in relation to climate change. Given the two other wind farms and this Project are being developed by the same developer, and the proximity of the sites to one another (as shown in Figure 1.1), the CCRAs for Greater Changhua 1 and 2 have been used to form the basis of this assessment. It is therefore assumed that the same allowances for climate change and embedded resilience measures to reduce vulnerability has been applied to the Project. As such, these embedded measures have been taken into account when conducting the assessment, and risk ratings have been scored on this basis.