Project Trinity: Greater Changhua Northwest (NW) Offshore Wind Farm in Taiwan

Climate Change Risk Assessment

February 2024

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Mott MacDonald
5F, No.92 Sec 2
Dunhua S. Road
Da'an District
Taipei City 10668
Taiwan

T +886 (0)2 8978 8978
mottmac.com

Ørsted Wind Power TW
Holding A/S, Kraftværksvej
53, DK-7000 Fredericia
Denmark, (36 03 57 81)

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Executive summary

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 climate change risk assessment (CCRA) in the report identifies Project and asset risks that may be magnified by climate change. The CCRA was undertaken in alignment with the latest updated Equator Principles IV guidance, released in May 2023, and includes two future Climate Change Scenarios, a high emissions scenario, SSP5-8.5, and a 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 the project Scope 1 and 2 emissions are not expected to exceed more than 2,288 tonnes CO_2e per year, with annual emissions decreasing over the project life as a result of anticipated grid decarbonisation. During the scheduled 1-year construction phase, emissions from fuel combustion are estimated to be approximately 193,526 tonnes CO_2e, although these are expected to 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 these measures are assumed at this stage given the lack of available information and the scoring of medium or low should be read with caution given it has not yet been confirmed that Project designs will embed these mitigations. 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.

1 Introduction

1.1 Overview

The Greater Changhua Offshore Windfarm Northwest Ltd. (herein referred to as “Project Company”) is a special purpose vehicle established by Ørsted to develop the proposed Greater Changhua Offshore Northwest Wind Farm (herein referred to as the “Project”). The Project is located approximately 50km offshore the area of Xianxi Township, Changhua County, Taiwan.

The Project is planned in compliance with the “Offshore Wind Farm Site Application Regulation”, stipulated by the Bureau of Energy, Ministry of Economic Affair 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.[1] As of 2021[2], the electricity generation comprised of 81.5% fossil fuels, 9.6% nuclear, 6% renewable energy and 2.9% of other types of energy. By 2025, Taiwan has set an ambitious commitment for their electricity sector to be 20% renewable energy, 30% coal, and 50% gas. The most targeted renewable energy is solar photovoltaic (Solar PV) and wind power.

Mott MacDonald have been commissioned by Ørsted to undertake this Climate Change Risk Assessment (CRRA), alongside other environmental and social impact assessment services.

The Project’s sources of financing require adherence to the Equator Principles IV (2020)[3], which stipulate that a high-level CCRA of the 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].

The CCRA can cover physical or transitional risks, or both, however this assessment and report only covers physical climate risks. TCFD guidelines stipulate that a transition risk assessment should be conducted if scope 1 and 2 emissions from the Project will exceed 100,000 tonnes carbon dioxide equivalent (CO_2e) per year which is highly unlikely for this Project. A Greenhouse Gas (GHG) emissions assessment has been undertaken to verify that annual scope 1 and 2 emissions during the operational phase of the project will not exceed 100,000 tonnes. It is also noted that the Project appears in line with Taiwan’s national transition pathway. In 2020, the Bureau of Energy in the Ministry of Economic Affairs (BOEMOEA) set targets to achieve 5.7 Gigawatts (GW) of offshore wind capacity by 2025. Consequently, transitional risks have been scoped out of this CCRA.

1.2 Aims and objectives

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

[1] Lau, Hon Chung and Tsai, Steve C. 2022. *A decarbonization Roadmap for Taiwan and Its Energy Policy Implications*. MDPI.

[2] Retrieved from 110 年發電概況 - 能源統計 - 經濟部能源局(Bureau of Energy, Ministry of Economic Affairs, R.O.C.)全球資訊網 (moeaboe.gov.tw)

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

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

- Identifies and addresses current and anticipated physical climate-related risks facing the Project's operation over the 20-25 year operating period (anticipated to begin in 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 2050. 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 the current baseline climate (see Section 3.1)
  - An assessment of future climate change projections for Taiwan (see Section 3.2)
- Identification of climatic vulnerability of Project components (the consequences of a climate hazard being realised) (see Section 4.2)
- Qualitative risk assessment for each vulnerability through consideration of the likelihood of climate impacts and severity of the impact to the project component (see Section 4.2)
- A high-level review of potential adaptation and resilience options (see Section 4.2)

The risk assessment is based upon information received from the client, publicly available data sources and the CCRA undertaken for the neighbouring development, Greater Changhua Offshore Wind Farm South East (CHW01), also being developed by Ørsted. No additional modelling has been conducted as part of this high-level review.

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 impacts these phenomena in the project location.

1.3 Project background

The west coast of Taiwan is considered to have abundant natural wind power resource given the strong south westerly airstream during summer and the northeast monsoon winds during winter[6]. These seasonal winds and the gently sloped undersea continental shelf contribute to the suitability of the area for offshore wind.

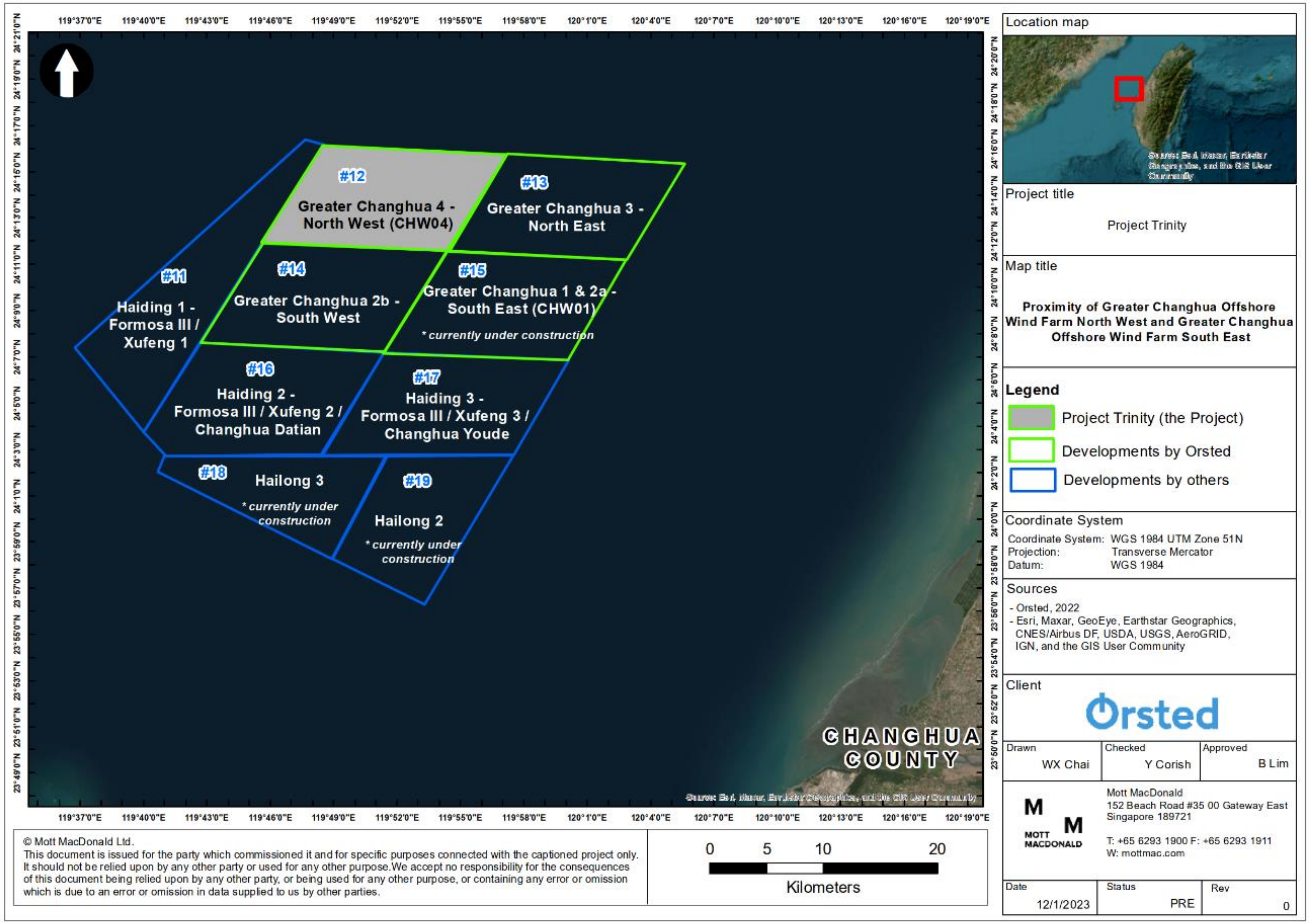
The Project is a world-class offshore wind asset located approximately 50km off the coast of Changhua County in Taiwan (as shown in Figure 1.1). The total area of the Project is approximately 117km^2 and it benefits from a mean wind speed of approximately 11.6 meters per second (m/s). The Project is expected to consist of 54 to 74 wind turbine generators (WTGs), each with a capacity of 8 to 11 Megawatts (MW). There is a grid capacity of up to 598MW. The WTGs will be connected to one offshore substation (OSS) via 33 or 66 Kilovolt (kV) inter-array cable strings, and subsequently to the Changkong grid connection point owned by Taiwan Power Company (TPC) through two export cables.

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

[6] Greater Changhua Northwest Offshore Wind Farm – EIA Report.

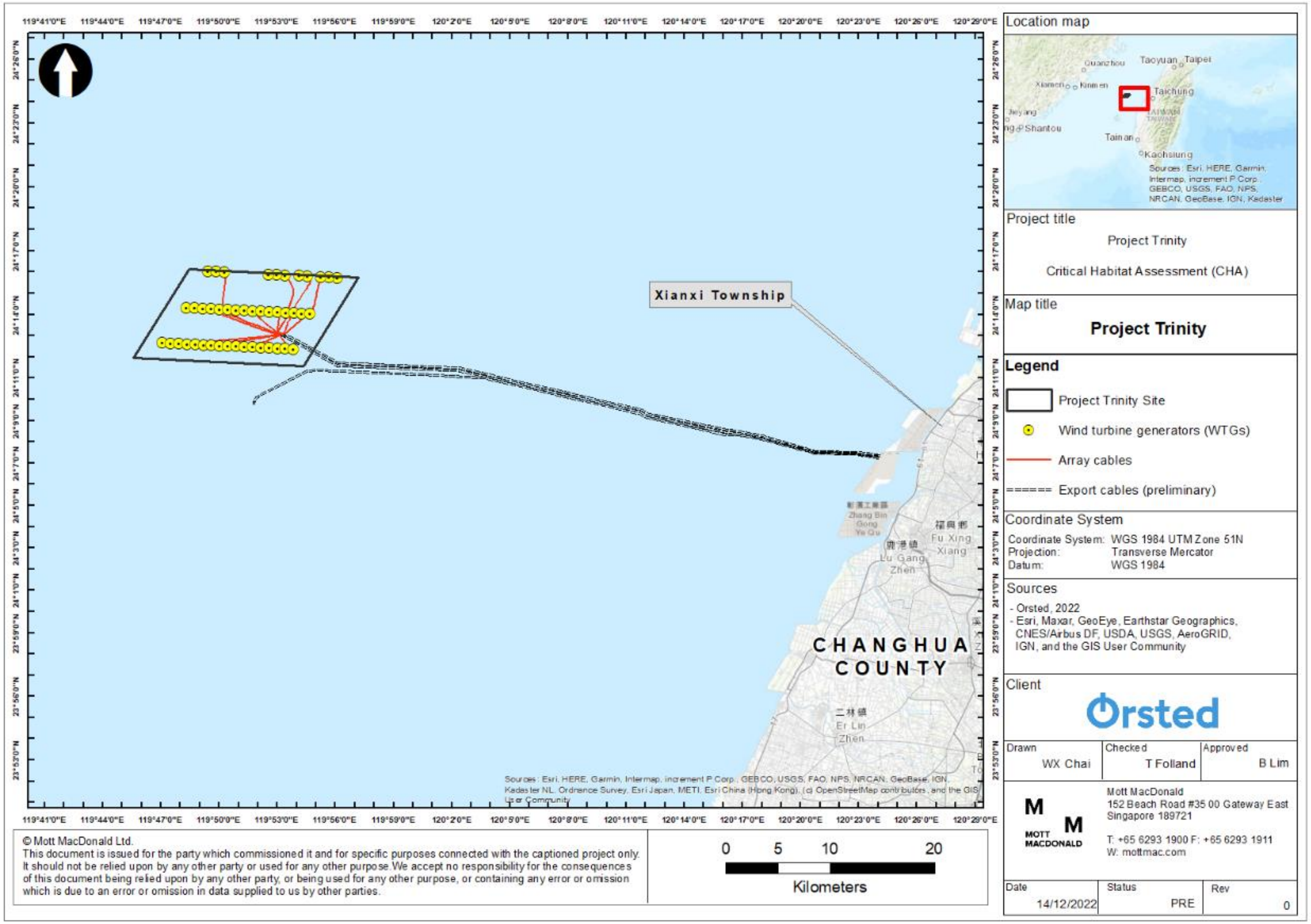
As noted above, this Project (CHW04) is adjacent to the Greater Changhua Offshore Wind Farm South East (CHW01) which is also being developed by Ørsted. A CCRA was developed for the Greater Changhua Offshore Wind Farm South East in 2020 and has been used a reference for this Project given the proximity of the sites to one another and that they are both being developed by Ørsted. Figure 1-1 shows the locations of these two sites. CHW04 is serial number #12 on the map, and #15 on the map represents the CHW01 project. Figure 1-2 shows the Project location relative to Changhua County.

Figure 1-1: Proximity of Greater Changhua Offshore Wind Farm North West and Greater Changhua Offshore Wind Farm South East



Source: Mott MacDonald, 2023

Figure 1-2: Project Location



Source: Mott MacDonald, 2023

1.4 Document structure

The CCRA is structured as follows:

- Chapter 1 outlines the aims and objectives of the CCRA and Project background.
- Chapter 2 provides the policy context and background literature review for the physical risk assessment.
- Chapter 3 sets out the current and future climate baseline.
- Chapter 4 is the is the physical climate change risks assessment considering the effects of the acute and chronic impacts of climate change on the Project infrastructure and operation.
- Chapter 5 contains the results of the GHG assessment for estimated Scope 1 & 2 emissions during the operational phase of the project.
- Chapter 6 provides the overall conclusions and recommendations from the CCRA.

2 Policy Context and Literature Review

2.1 Climate change 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[7] 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.

[7] Taiwan Adaptation Platform (2017). Available at: National Climate Change Action Guidelines (legislated in February, 2017) | Database of Taiwan Climate Change Adaptation Information and results (epa.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)[8] 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. Based on a review of appropriate climate change risk assessment frameworks for Taiwan, the ADB's Climate Change Risk Management Framework (CCRMF) for projects at concept, preparation or implementation phase is considered appropriate.

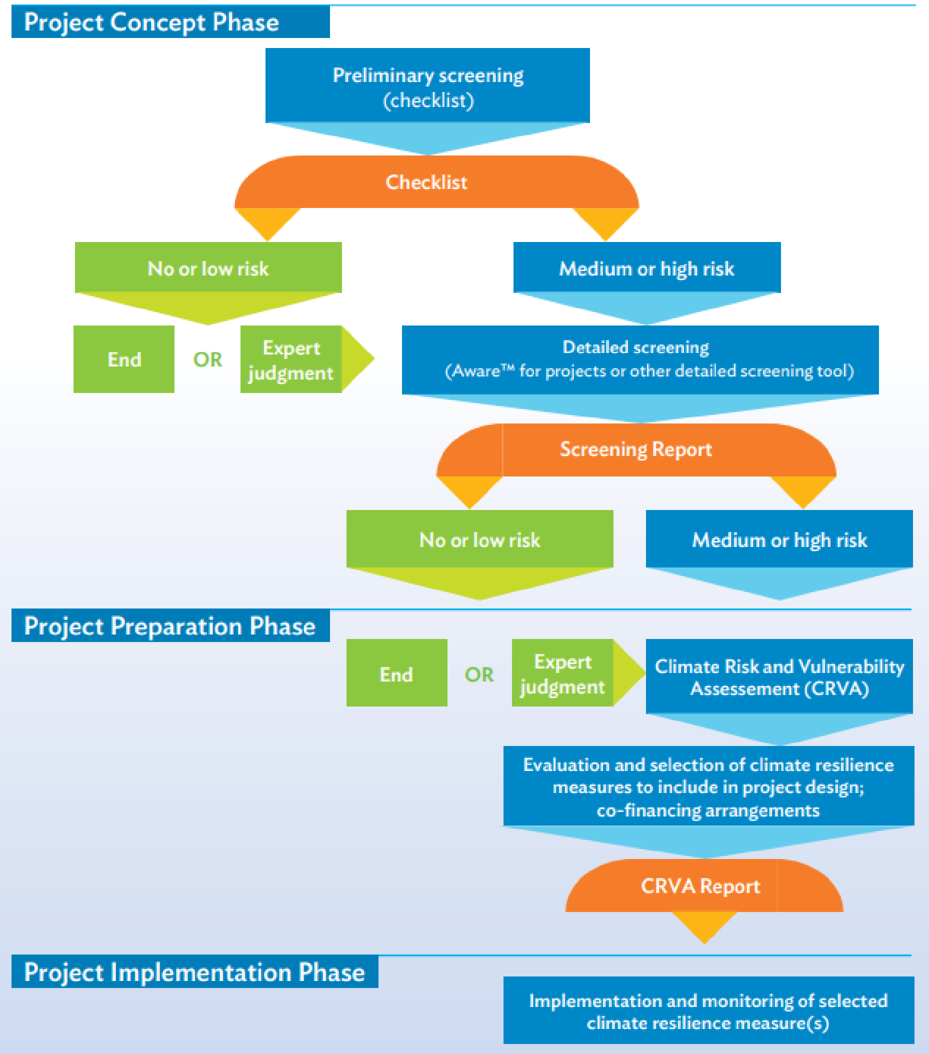
The CCRMF itself is high level and allows for expert judgement when it comes to assessment at project preparation (this) stage – ranging from a simple desktop analysis to a complex assessment based on custom climate projections to enable a more detailed assessment. It proposes the identification of climate change risks to project performance in the early stages of

[8] Taiwan Adaptation Platform (2018). Available at: Framework | Database of Taiwan Climate Change Adaptation Information and results (epa.gov.tw)

project development and incorporates adaptation measures in the design of projects at risk. The framework comprises the following steps (see Figure 2-1):

1. Context-sensitive climate risk screening at the concept development stage to identify projects that may be at medium or high risk
2. Climate change risk and vulnerability assessment during preparation of projects at risk
3. Technical and economic evaluation of adaptation options
4. Identification of adaptation options in project design
5. Monitoring and reporting of the level of risk and climate-proofing measures

Figure 2-1: ADB flow chart for climate risk management of investment projects



Source: Asian Development Bank[9]

2.2 TCFD

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:

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[9] ADB (2014). Available at: Climate Risk Management in ADB Projects | Asian Development Bank

- 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[10].

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 deliver on their 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'[11].

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 pattern 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[12].

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.

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[10] TCFD (2017). Available at: E06 - Climate related risks and opportunities.pdf (tcfdhub.org)

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

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

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[13].

A range of climatic changes can affect wind energy generation, such as changes in wind speed and direction, air density, land cover / sea ice cover changes, icing, changes in sea levels, sea temperature, salinity content and wave heights. 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[14].

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[15]. 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.

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[16]	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

Source: Adapted by Mott MacDonald[17]

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

[13] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010).
[14] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010).
[15] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010).
[16] This meteorological variable is location dependent
[17] Strengthening Climate Resilience, Urban, F and Mitchell, T. (2010).

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

3 Climate Baseline

3.1 Current baseline

3.1.1 Overview

To understand the impacts of climate change, a baseline set of climate conditions or scenarios must be established. Climate scenarios including baseline conditions are based on observed or modelling climate conditions averaged over a 20-30 year time period. For this assessment, the current baseline climate is for the average for the period between 1981 and 2010 unless stated otherwise.

The Project is located approximately 50km offshore, adjacent and connected to the central plain of the west coast of Taiwan and has a subtropical monsoon climate[18]. The rainy season or typhoon season is from April to September, peaking in August. The summer temperatures in the area are high and there is little rainfall during the winter months.

Climate change has already been observed in Taiwan. The Taiwan Climate Change Science Report 2017 - The Physical Science Basis[19] reports observed climate change including:

- The average temperature has increased as has the number of warm days whereas the number of cold days has decreased
- Seasonality has been changing over the past 50 years:
  - Longer summers (by an average 28 more 'summer' days/year)
  - Shorter winters (by an average 30 fewer 'winter' days/year)
- No apparent change in precipitation patterns over the past century, however, there has been an increase in heavy rain days and no rain days, and an enlarged discrepancy of rainfall between the wet and dry season is observed
- Mean sea level rise has been occurring at 3.4mm/annum

This section provides an overview of Taiwan's current climate and presents observed changes in climate to inform the identification and assessment of climate change risks and potential adaptation options.

3.1.2 Onshore

Baseline climate data is available for the Project from the Taiwan Central Weather Bureau (CWB) and the Taiwan Climate Change Projection Information and Adaptation Knowledge Platform (TCCIP). The source data is based on weather stations but is also available on a 5km grid for Taiwan. The weather stations have long data records and good data availability. The stations used for this assessment are as follows with Wuqi station being the closest at 6km from the landing site[20]:

- Chiayi
- Dongjidao
- Penghu
- Taichung

[18] Greater Changhua Northwest Offshore Wind Farm – EIA Report.

[19] Taiwan Adaptation Platform. Available at: Climate change impacts | Database of Taiwan Climate Change Adaptation Information and results (epa.gov.tw)

[20] Greater Changhua Northwest Offshore Wind Farm – EIA Report.

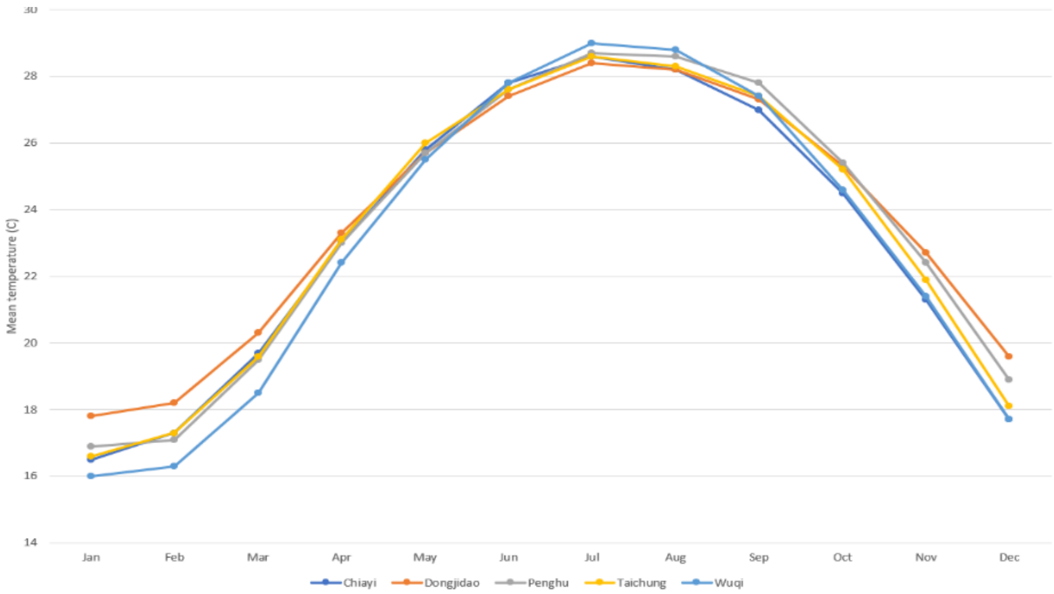
- Wuqi

3.1.2.1 Temperature

Monthly average temperatures (Figure 3-1) west of Taiwan range from 16°C to 20°C in winter months (December to March) to 27°C to 30°C in summer months (June to September). There is minimal difference between the mean temperatures recorded at the weather stations on the mainland compared with those on the islands to the west of the mainland. Average maximum daily temperatures (Figure 3-2) vary more from 30.6°C at Dongjidao in August to 33°C at Taichung and Wuqi. These differences are likely to reflect urban heat effects at Taichung and Wuqi. At Taichung stations, on average the majority of days during May to October have a temperature exceeding 30°C.

Over the last 30 years (1991-2021), temperatures in Taiwan have been increasing by 0.3°C per decade, which is 0.09°C higher than the global average of 0.21°C per decade[21]. According to the latest CWB annual climate report, the mean temperature recorded in 2021 in Taiwan was 1.22° higher than the average since 1880, making 2021 the seventh warmest year on record.

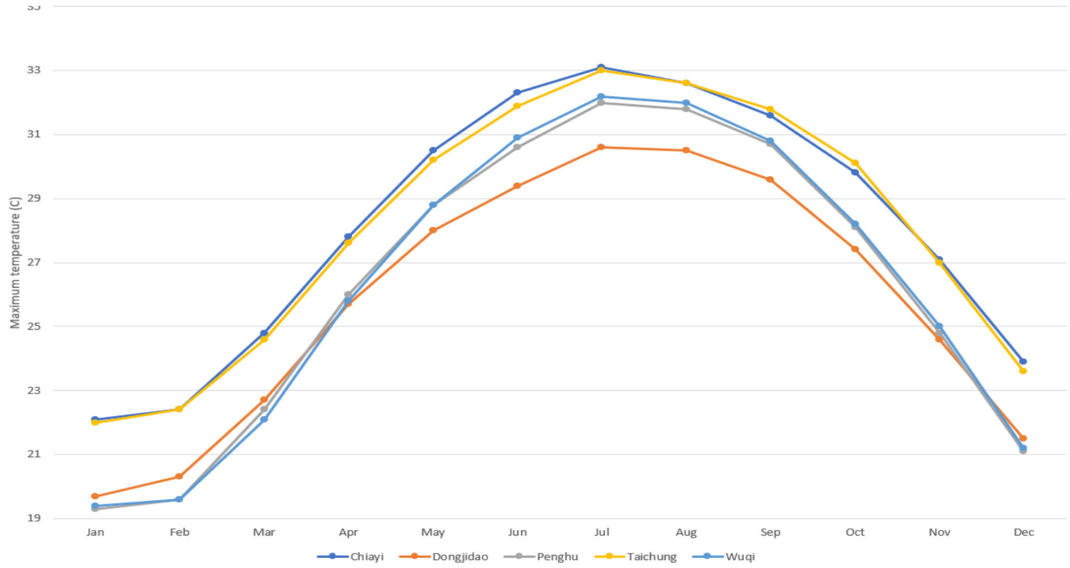
Figure 3-1: Monthly average temperatures (1981-2010)



Source: CWB and TCCIP

[21] CWB (2022). Available at: Publish_20220628113633.pdf (cwb.gov.tw)

Figure 3-2: Monthly average maximum temperatures (1981 – 2010)



Source: CWB and TCCIP

3.1.2.2 Precipitation

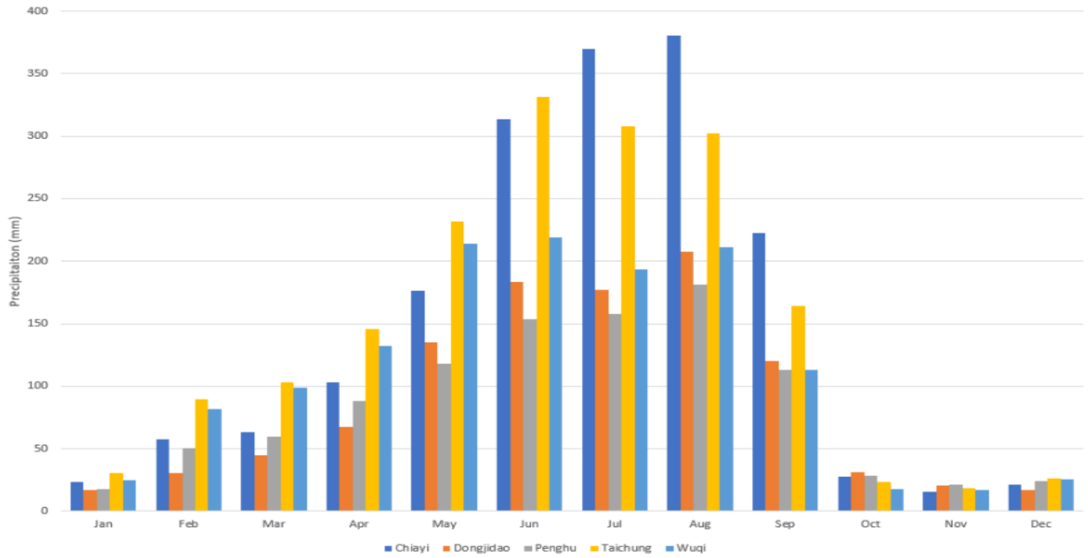
Taiwan receives abundant precipitation, totalling approximately 2,590mm annually, distributed in a marked seasonal pattern. In general, rainfall is heavier on the east side of the island and in the mountains than toward the west. However, its distribution depends on the seasonal monsoon (wet-dry) wind patterns.

Taiwan is also affected by tropical cyclones (typhoons) from late summer to early fall that are among the strongest in the world. Taiwan’s typhoons can inflict considerable damage to infrastructure and cause severe flooding[22].

Highest monthly rainfall totals (Figure 3-3) occur during the summer months with less precipitation in the winter months (November to January). In the summer months there is also more variability in precipitation totals between the weather stations that have been considered. In general, Taichung and Chaiyi have higher amounts of rainfall compared with the island stations and Wuqi.

[22] Available at: https://www.britannica.com/place/Taiwan/Climate

Figure 3-3: Monthly average precipitation (1981-2010)



Source: CWB and TCCIP

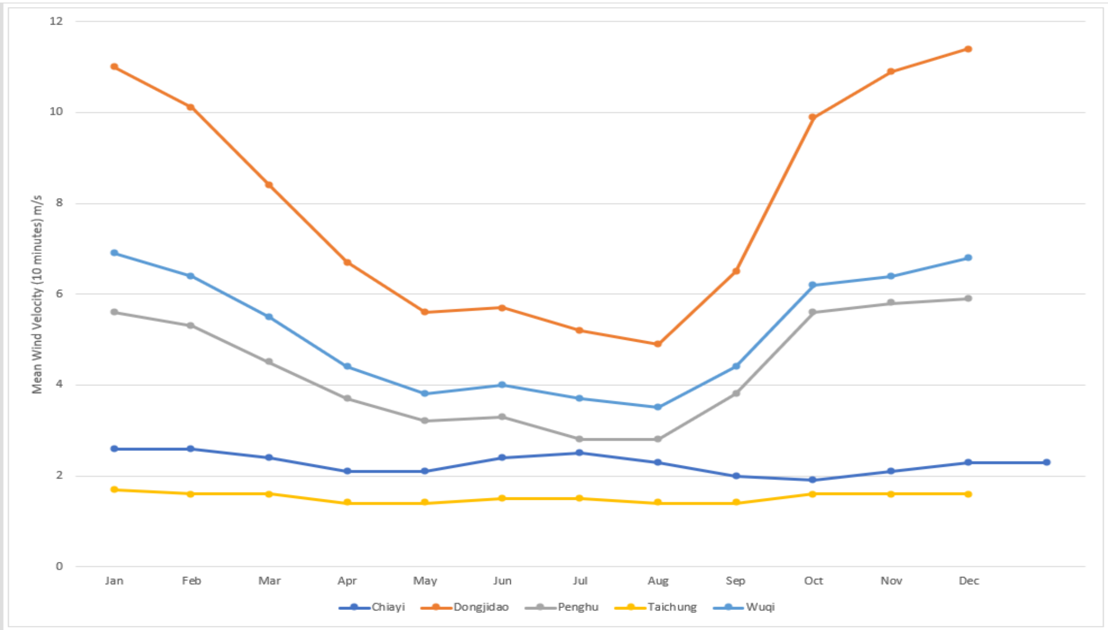
3.1.2.3 Wind

Average wind speeds (Figure 3-4) are higher in the winter months for the offshore and coastal weather stations of Dongjidao, Penghu and Wuqi. Less variability is seen in the monthly average wind data for Taichung and Chaiyi for the baseline period.

The wind direction distribution in the Project area is defined by two predominant seasons:

- Winter: defined by strong winds from north-north-east (NNE) directions
- Summer: milder winds from south-south-west (SSW) directions

Figure 3-4: Monthly average wind speed (1981-2010)



Source: CWB and TCCIP

3.1.3 Offshore

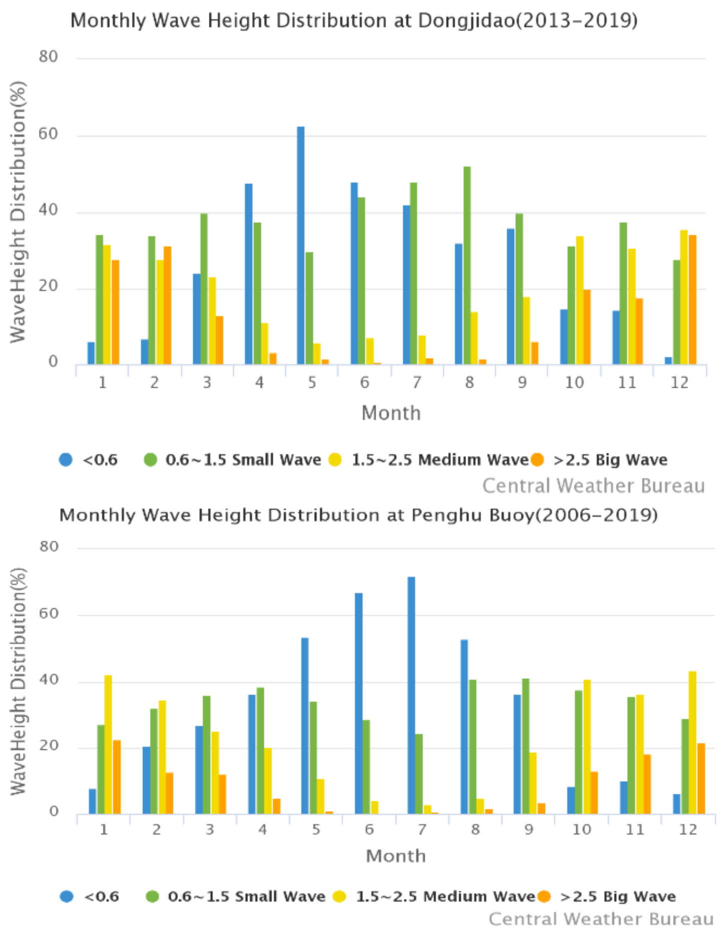
3.1.3.1 Sea surface temperature

Sea surface temperatures at Taichung Port are highest in July and August, with a monthly mean of 28.8 - 29°C, however the record monthly maximum temperature of 36.9°C was recorded in June 2022. This is based on observed data over the baseline period 2003 to 2022[23].

3.1.3.2 Waves

Monthly wave height distributions (Figure 3-5) are available for Dongjidao and Pengu for the baseline period 2013 to 2019 and 2006 to 2019 respectively from the CWB. The data shows that the large waves, greater than 2.5m in height, occur most often in the winter months coinciding with the strong NNE winds.

Figure 3-5: Monthly wave height distribution at Donjidoa (2013-2019) and Penghu (2006-2019)



Source: CWB

Further detail on the spatial variation of significant wave height is provided in the Met Ocean report, undertaken for the neighbouring Greater Changhua Offshore Wind Farm South East[24]. Maximum significant wave heights at the offshore Project site range from 1.56m for the 50th

[23] CWB (2022). Available at: Sea Surface Temperature Statistics | Central Weather Bureau (cwb.gov.tw)

[24] DHI (2018). CHW01 Local Metocean Hindcast Study – Greater Changhua Offshore Wind Farm, Taiwan.

percentile to 5.1m for the 99th percentile. These wave heights have been calculated based on hydrodynamic modelling calibrated to observed data.

Waves driven by a NNE wind direction will impact the coast at the location of the onshore Project sites.

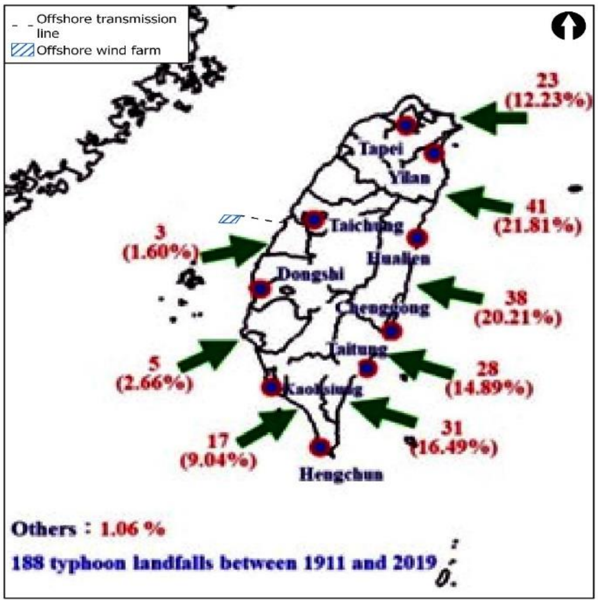
3.1.4 Typhoons

According to Taiwan's CWB a total of 371 typhoons between 1911 and 2021 have made landfall on Taiwan or have passed offshore without landfall on Taiwan but caused impacts on land[25]. The peak frequency for typhoons is in the summer months of August and September, and in 2021 there were 8 typhoons in the Western North Pacific across the two months.. Typhoons have occurred in April and December but are far less likely in the winter months.

Figure 3-6 shows the direction of typhoons impacting Taiwan between 1911 and 2019 (data regarding tracks for 2020 and 2021 were not available). The majority impact the east coast of Taiwan away from the Project site. Only 1.6% have made landfall in the Project area, however, the impacts of typhoons in terms of intense precipitation, strong winds, extreme water levels and waves can be widespread. Furthermore, the damage and threat to human life from typhoons has been increasing due to a combination of population growth and climate change[26].

Figure 3-7 captures the most severe cyclone tracks (ranging from categories 3-5) recorded for Taiwan and the Taiwan Strait. Specific data including maximum wind speeds is captured in Table 3-3.

Figure 3-6: Statistics for typhoon landfalls on Taiwan's coast 1911-2019 (CWB)

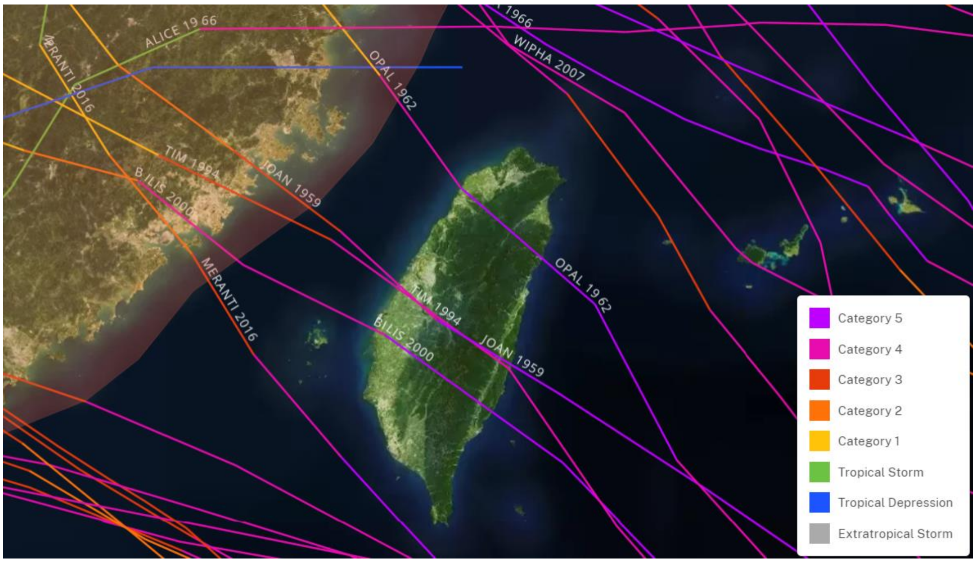


Source: CWB

[25] CWB (2022). Available at: Publish_20220628113633.pdf (cwb.gov.tw)

[26] Yu et al. (2019) Available at: https://doi.org/10.3390/atmos10060346

Figure 3-7: Historic major (category 3-5) cyclone tracks over Taiwan and Taiwan Strait



Source: National Oceanic and Atmospheric Administration (NOAA)

Table 3-1: Major cyclone event data for Taiwan and the Taiwan Strait

Cyclone	Year	Category (at/near site)	Max Wind Speed Recorded /kts
Joan	1959	5	170
Opal	1962	4	145
Tim	1994	4	125
Bilis	2000	4	145

Source: NOAA

There is uncertainty in trend regarding In Taiwan there is evidence that the average number of typhoons annually has increased between 1961 and 2009, with a more pronounced trend after 1980 (Figure 3-8). This is potentially caused by the northward shift of the typhoon tracks over the Western North Pacific[27]. Since 2009 the trend has shown a small decrease. The yellow line in Figure 3-9 reflects a 9-year running mean. Furthermore, the Penghu station, has recorded a decreasing trend in wind speeds for typhoon days (i.e., on the days on which typhoons traversed the site)[28]. It is also noted by the CWB that the number of typhoons which make landfall in Taiwan has been less than the average over the last eight years (before 2021)[29].

In 2021, it was reported that 22 typhons were generated over the West Northern Pacific in 2021 which is less than the average of 25.4[30]. Only one typhoon, Typhoon Chanthu, made landfall in September 2021. This is in the context that the number of typhoons which have made landfall in Taiwan has been less than the average over the last eight years.

[27] TCCIP (2011). Available at: TCCIP (nat.gov.tw)

[28] TCCIP (2011). Available at: TCCIP (nat.gov.tw)

[29] CWB (2022). Available at: Publish_20220628113633.pdf (cwb.gov.tw)

[30] CWB (2022). Available at: Publish_20220628113633.pdf (cwb.gov.tw)

Figure 3-8: Annual number of typhoons affecting Taiwan from 1961 to 2009

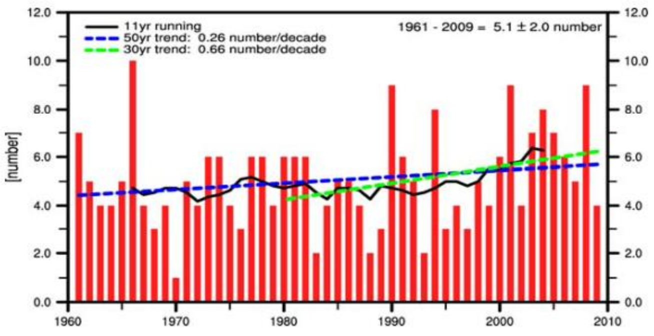
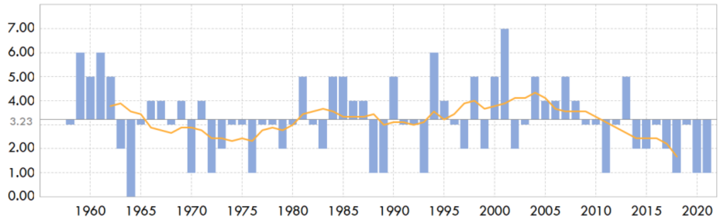


Figure 3-9 Annual number of typhoons making landfall over Taiwan 1960-2021.



Source:CWB.

3.1.5 Water Levels

The extreme water levels during a typhoon event are comprised of a number of different factors, which can be largely split into two categories: (i) the still water level (SWL) and (ii) wave conditions. During a typhoon event, flood risk will be largely dictated by the SWL but also a combination of wave conditions and intense rainfall. Both wave conditions and high intensity rainfall have the potential to exacerbate the flooding caused by high SWLs or cause flooding independently.

SWL is comprised of a combination of:

- Astronomical tide, not impacted by climate
- Surge due to low pressure, wind speed and direction, storm track and typhoon intensity
- Sea-level rise as a result of climate change

Monthly averaged water level statistics are available for Taichung from the CWB for the period 2000 to 2021. The highest high-water level (HHWL) at Taichung peaks in September, coinciding with the peak typhoon intensity and is 3.34m relative to the Taiwan Vertical Datum of 2001 (TWVD2001) mean sea-level[31].

Extreme water level estimates for the offshore Project site are not available. However, in 2018, a Metocean study was undertaken by the Danish Hydraulic Institute (DHI) for the neighbouring Ørsted offshore windfarm site (CHW01) situated adjacent to the Project[32]. Extreme still water levels are derived based on observed data and a statistical distribution fitted to calculate extreme events up to the 1 in 500 year event (0.2% annual exceedance). It is reported that extreme water levels vary by up to 0.5m across the offshore site. Maximum extreme water levels are shown in Table 3-2.

[31] CWB (2022). Available from Tide Statistics | Central Weather Bureau (cwb.gov.tw)

[32] DHI (2018). CHW01 Local Metocean Hindcast Study – Greater Changhua Offshore Wind Farm, Taiwan.

Table 3-2: Extreme water levels at CHW01

Return period (years)	Extreme high-water level derived by Met Ocean Study (m above mean sea level)
1	2.7
10	2.9
50	3.2
100	3.3
500	3.5

Source: DHI

Extreme water levels are not provided for the coastal locations, these levels could potentially be higher than the offshore values due to the shoaling effects of shallower water. The extreme water levels at the coast are important to understand the risk of coastal flooding to the onshore substation and other onshore infrastructure.

3.1.6 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[33]. ENSO events have global impacts, however the effects are different depending on the region and the time of year (Figure 3-10). 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[34].

Recent studies have reported that anthropogenic climate change has resulted in an enhancement in the frequency of the central Pacific El-Niño[35], and this trend is projected to continue under a warming climate[36]. 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[37].

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

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

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

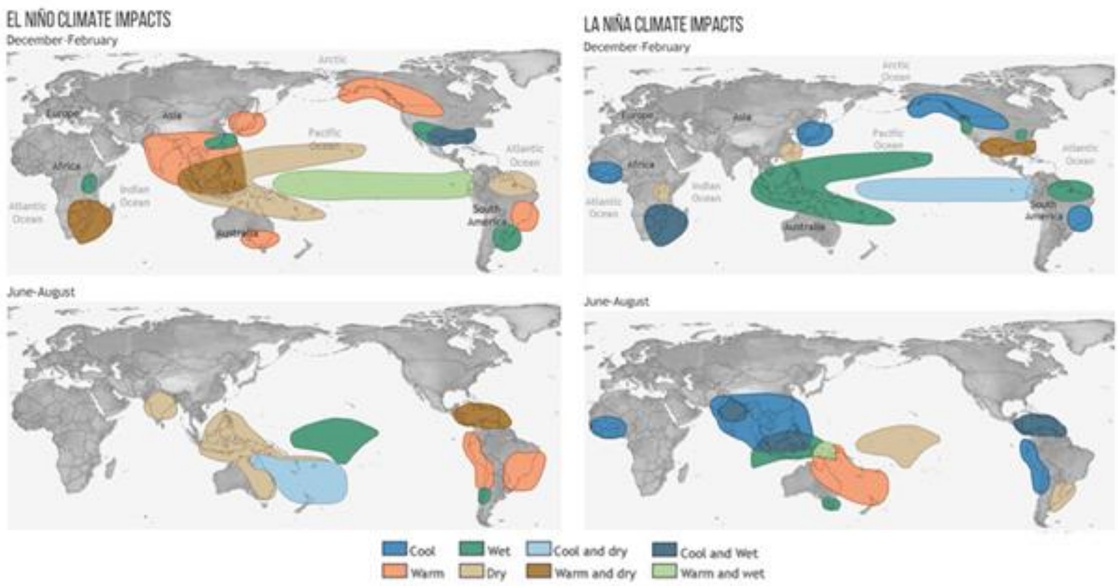
[35] Liu et al. (2017). Available at: Recent enhancement of central Pacific El Niño variability relative to last eight centuries | Nature Communications

[36] 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)

[37] 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

variability[38,39]. 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.

Figure 3-10: Inter-annual ENSO climate impacts



Source: The Globe Platform[40]

3.2 Future baseline

3.2.1 Overview

Climate change is a risk multiplier which threatens the longevity and success of this Project through chronic long-term variations to present climate conditions and changes to the severity and frequency of acute extreme events. An understanding of risks to this Project is required to ensure the investment is resilient. This section provides an overview of the projected future climate change for Taiwan to inform the identification and assessment of climate change risks and potential adaptation options.

3.2.2 Climate Projections

The World Bank Climate Change Knowledge Portal (WBCCKP) has been used to obtain the future temperature and precipitation baseline. The latest Coupled Model Intercomparison Project Phase 6 (CMIP6) projection data is available and has been used to develop the future baseline. CMIP6 uses Shared Socio-Economic Pathways (SSP) which considers how various socio-economic factors (global society, demographics and economic) might change over the next century and affect future climate change[41]. These SSPs are used to determine emissions and radiative forcing, used for the basis of the climate models. There are five SSPs of which this study will investigate two; the highest SSP (SSP5 – 8.5) has been selected based on a precautionary approach, and a second scenario aligned with keeping global temperature

[38] Liu et al. (2017).

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

[40] The Globe Platform. Available at: Science of ENSO - El Niño - GLOBE.gov

[41] Carbon Brief. Available at: Explainer: How 'Shared Socioeconomic Pathways' explore future climate change - Carbon Brief

increases below <2°C (SSP1 – 2.6) has been selected as recommended by TCFD and EP4 guidance. The narrative for the two scenarios is presented in Table 3-3[42]. Under SSP5 – 8.5, the average global temperature is projected to be around 2.4°C warmer by the mid-term (2041-2060) and 4.4°C warmer in the long-term (2081-2100), while under SSP1 – 2.6, the respective mid-century and end of century temperature increases are projected to be 1.7°C and 1.8°C, respectively[43].

Table 3-3: Shared Socio-Economic Pathways Narratives

SSP	Narrative
SSP1 – 2.6: Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation)	The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.
SSP5 – 8.5: Fossil-fuelled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation)	This world places increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

Source: Riahi et al (2017)

The WBCCKP temperature and precipitation projections used are probabilistic and a baseline of 1995-2014 is used. The 50th percentile, the central estimate representing ‘as likely as not’ probability of change, has been selected. The projections on the WBCCKP are provided as a change in the selected variable for a given month as compared to the month in the historical baseline. Annual and/or seasonal projections were not able to be obtained.

The time period covered within the assessment considers risks up until 2050 and the WBCCKP timescale of 2040-2059 has therefore been selected for the future climate baseline period. This is based on the 20-25 year operational period which is due to commence in 2025 following the completion of construction activities.

WBCCKP projection data on temperature and precipitation has been supplemented with other sources as detailed in the sections below. Additional sources of information and data has been obtained for other variables to demonstrate projected changes for the future, including sea level rise and typhoons.

It should be noted that TCCIP projection data has been reviewed, however given this is based on the previous Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) information and the Representative Concentration Pathways (RCP) scenarios have been replaced with the SSPS from CMIP6, it is not presented in this report.

Please note the following assumptions and limitations:

[42] Riahi et al. (2017). Available at: The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview - ScienceDirect

[43] IPCC (2021). Available at: Summary for Policymakers (ipcc.ch)

- While Regional Climate Models (RCMs) and TCCIP are considered in this study, this is only to verify that they fall within the range of the GCMs. Furthermore, whilst the results from climate change experiments performed with RCMs appear to provide more precision, they do not provide more accuracy especially with regard to changes in key variables. It is more important to capture the full range of future climate change in Taiwan using the latest ensembles of GCM climate change experiments.
- Climate modelling and downscaling of the climate models to a site-specific detail is beyond the scope of this Project. Reliance has been made solely on freely available data on climate projections in this region, which in several cases is limited.
- All climate scenarios are plausible. Due to uncertainty around the decarbonisation pathway that society will take taken, the impacts of climate change are investigated through defined scenarios.
- In addition, the impact of anthropogenic forcing is understood better for some climate variables (e.g. temperature) than for others, and therefore ranges will be identified highlighting where there is confidence and where there is uncertainty.
- GCMs are averaged over a large spatial area and therefore come with data limitations related to extreme values. They do not adequately resolve extremes like hurricanes, wind or changes in their characteristics. Key driving features such as ENSO are also poorly captured.
- See Appendix A for our disclaimer and climate modelling limitations.

3.2.2.1 Temperature

Globally, surface temperatures are projected to increase until at least the mid-century under all of the SSP scenarios. The changes in global surface temperatures are outlined in Table 3-4 for the mid-term (2041-2060) which has been selected as the closest time period to that which is being considered for this Project[44]. All five of the SSPs are included to demonstrate changes associated with the various emissions scenarios.

Table 3-4: Projected changes in global surface temperatures for 2041-2060

SSP	Best estimate (°C)	Very likely range (°C)
SSP1-1.9	1.6	1.2 to 2.0
SSP1-2.6	1.7	1.3 to 2.2
SSP2-4.5	2.0	1.6 to 2.5
SSP3-7.0	2.1	1.7 to 2.6
SSP5-8.5	2.4	1.9 to 3.0

Source: IPCC

The maximum and minimum temperature projections obtained for Taiwan for the two projections in 2040-2059 are shown in Table 3-5. Overall, both maximum and minimum temperatures are projected to increase in Taiwan over the selected time period as shown in Figure 3-11 and Figure 3-12 respectively.

Maximum temperatures are projected to increase by between 0.87°C to 1.18°C under SSP1-2.6 and 1.43°C to 1.74°C under SSP5-8.5 across the year with the lowest projected increases occurring in October and June and highest increases projected to occur in February and March, respectively. Minimum temperatures will also increase across the year with the lowest and highest projected increases of 0.83°C and 1.12°C occurring in the same months for SSP1-2.6, with increases of 1.45°C and 1.72°C under SSP5-8.5 occurring in June and January

[44] IPCC (2021). Available at: Summary for Policymakers (ipcc.ch)

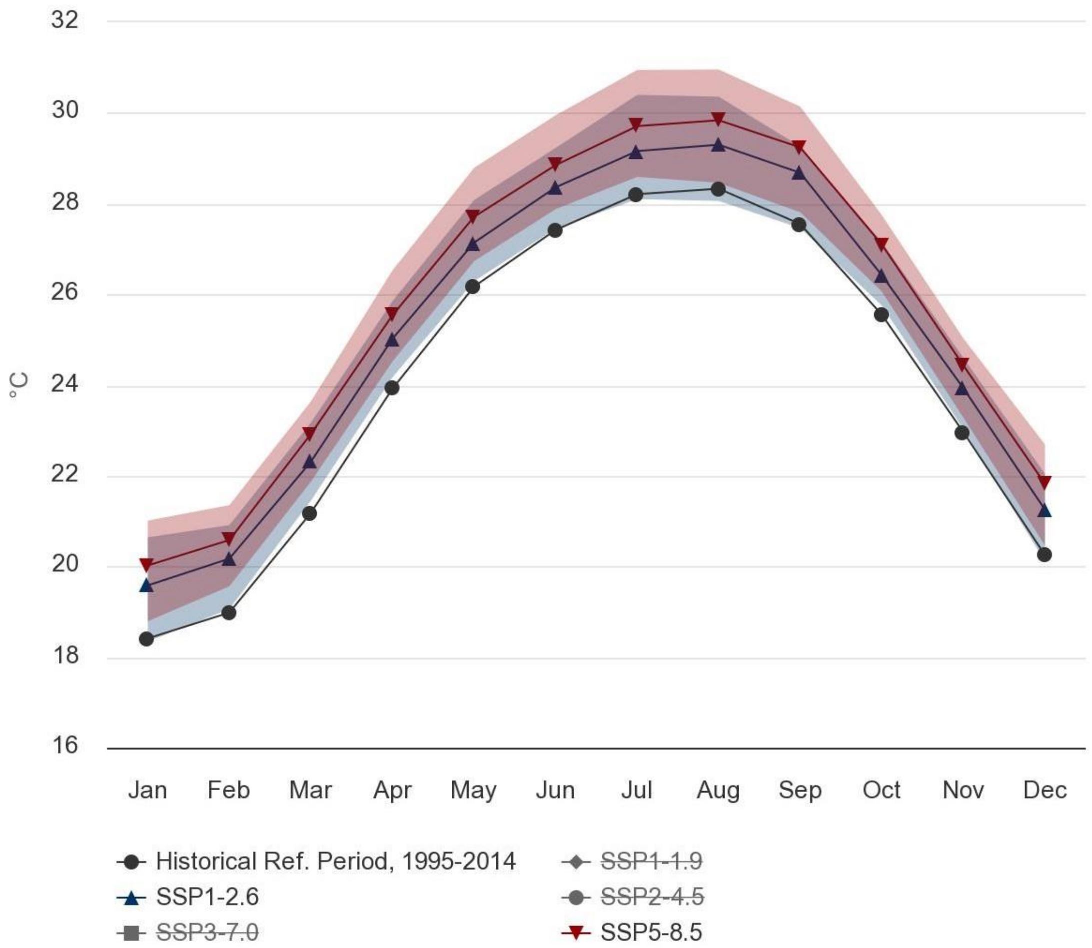
respectively,. Historically, the months with the highest maximum and minimum temperatures are June to September which are projected to see increases of 0.94-1.13°C (SSP1-2.6) and 1.43-1.69°C (SSP5-8.5) for maximum temperatures, and between 0.84-0.97°C (SSP1-2.6) and 1.45-1.64°C (SSP5-8.5) for minimum temperatures. Across the year, increases in minimum and maximum temperatures in 2040-59 are expected to be approximately 0.5-0.6°C higher under the SSP5-8.5 than under the SSP1-2.6 scenario.

Table 3-5: Projected changes in maximum and minimum temperature for 2040-2059, Taiwan, (50th percentile), against 1995-2014 reference period

Month	Max.Temp. ref. period	Max. Temp. Anomaly		Min.Temp. ref. period	Min. Temp. Anomaly	
		SSP1-2.6	SSP5-8.5		SSP1-2.6	SSP5-8.5
January	18.41°C	**1.16°C**	**1.61°C**	12.13	**1°C**	**1.73°C**
February	18.98°C	**1.18°C**	**1.59°C**	12.51	**1.12°C**	**1.69°C**
March	21.18°C	**1.12°C**	**1.74°C**	14.69	**1.08°C**	**1.52°C**
April	23.92°C	**1.1°C**	**1.62°C**	17.41	**0.99°C**	**1.68°C**
May	26.17°C	**0.97°C**	**1.54°C**	20.05	**0.87°C**	**1.54°C**
June	27.42°C	**0.94°C**	**1.43°C**	21.63	**0.85°C**	**1.45°C**
July	28.21°C	**0.95°C**	**1.50°C**	22.37	**0.89°C**	**1.46°C**
August	28.33°C	**0.97°C**	**1.51°C**	22.41	**0.84°C**	**1.49°C**
September	27.55°C	**1.13°C**	**1.69°C**	21.6	**0.97°C**	**1.64°C**
October	25.55°C	**0.87°C**	**1.55°C**	19.54	**0.83°C**	**1.58°C**
November	22.96°C	**0.97°C**	**1.47°C**	17.01	**0.9°C**	**1.53°C**
December	20.25°C	**1°C**	**1.57°C**	14.25	**0.9°C**	**1.51°C**

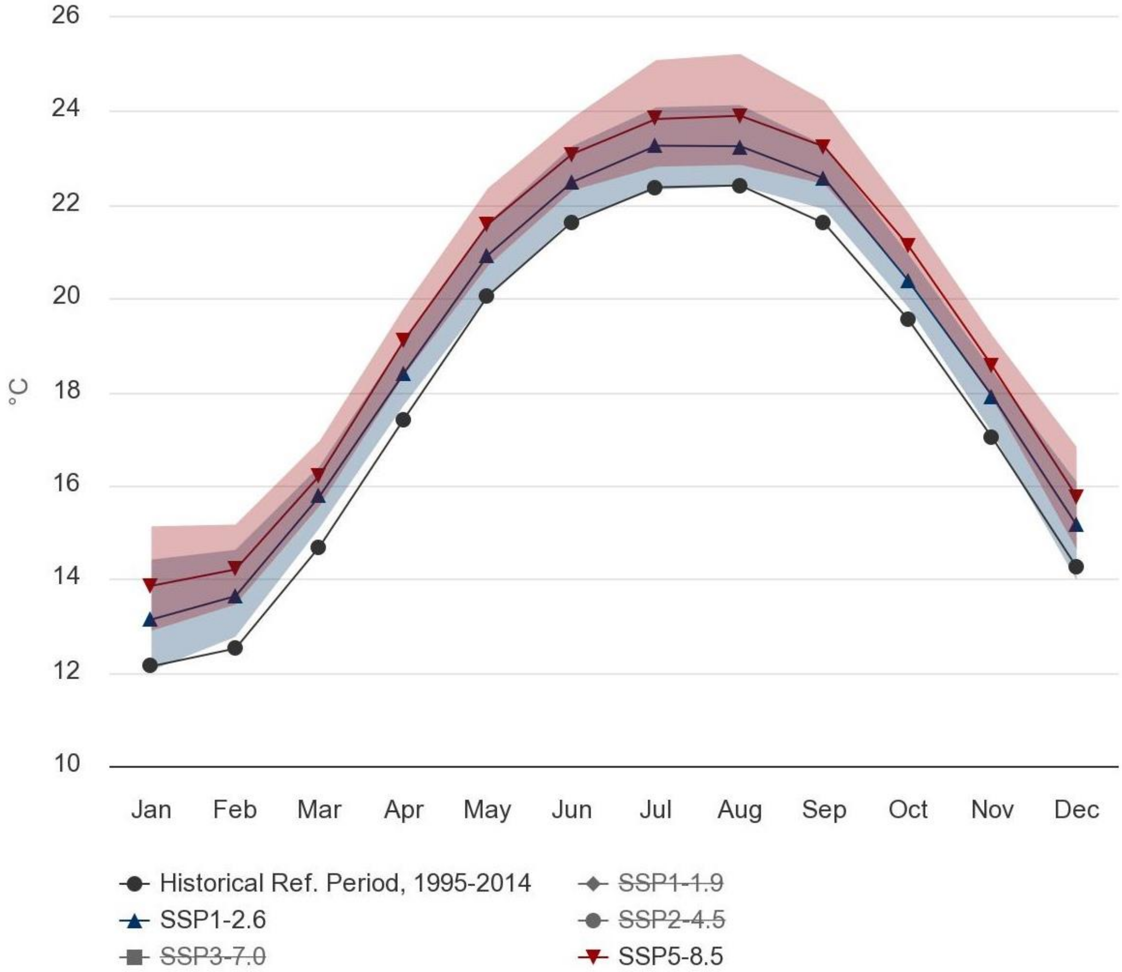
Source: WBCCKP

Figure 3-11: Projected changes in maximum temperature for 2040-2059, Taiwan, SSP1-2.6 and SSP5-8.5, 1995-2014 reference period (10th, 50th and 90th percentile)



Source: WBCCKP

Figure 3-12: Projected changes in minimum temperature for 2040-2059, Taiwan, SSP1-2.6 and SSP5-8.5, 1995-2014 reference period (10th, 50th and 90th percentile)



Source: WBCCKP

Extreme temperatures are also projected to increase over the lifetime of the Project continuing the observed trend. High-temperature days and the annual number of extremely hot days have increased at all six stations analysed in the Taiwan Climate Change Science Study over the last 100 years[45].

The IPCC identified as part of the Sixth Assessment Report (AR6) with high confidence that marine heatwaves have become more frequent over the 20th century and are projected to increase globally over the 21st century[46]. Sea surface temperatures are expected to increase over the Project's design life, and although the marine impacts of this are less well understood, high SSTs (above >26°C) are known to provide the conditions for the formation and sustenance of tropical storms, which may affect the project location.

3.2.2.2 Precipitation

The projections for precipitation for 2040-2059 are presented in Table 3-6. The projections at the 50th percentile alongside the 10th and the 90th percentile are included to demonstrate a

[45] TCCIP (2011). Available at: TCCIP (nat.gov.tw)

[46] IPCC (2021). Available at: Regional_Fact_Sheet_Ocean (ipcc.ch)

range as also illustrated in Figure 3-13. Overall, the projections for precipitation show both increases and decreases across the year.

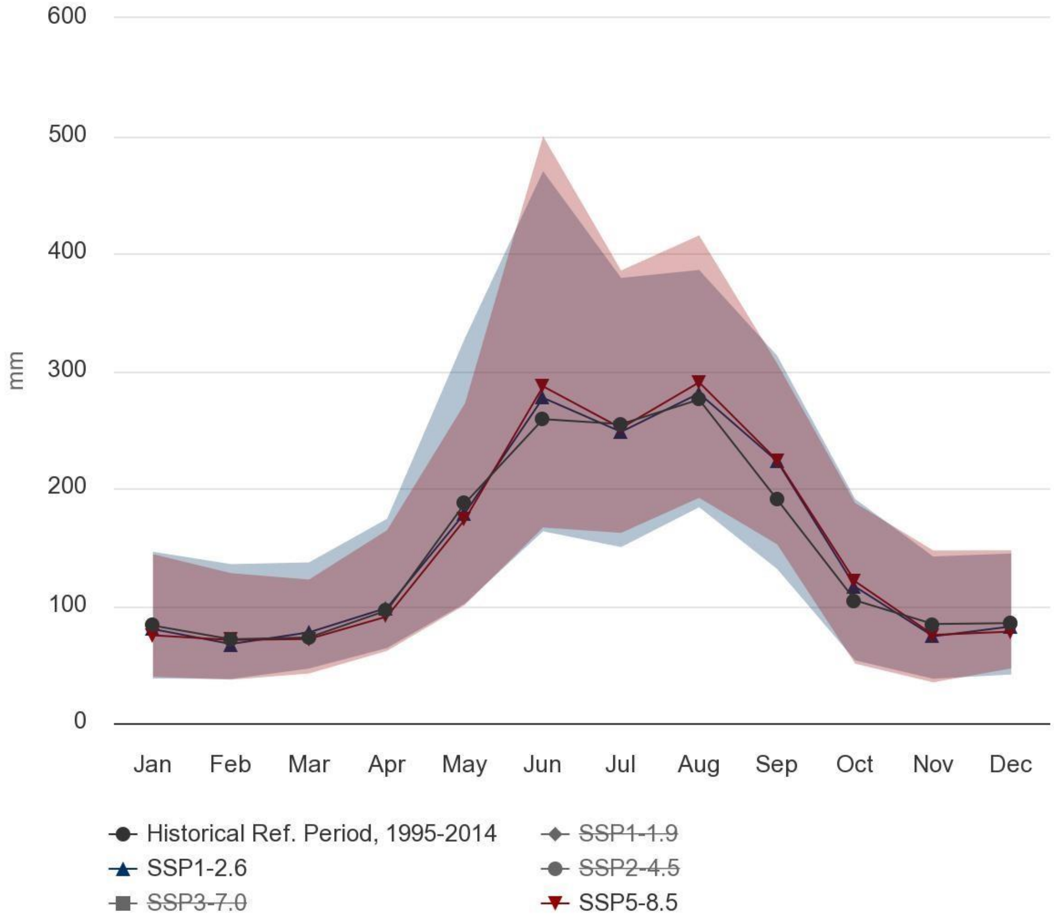
For the 50th percentile, the projections show decreases of up to -10% and -13% in November and increases of up to 14% and 17% in September, for SSP1-2.6 and SSP5-8.5, respectively. Generally, precipitation is projected to decrease from January to May under SSP8.5, with more variable signals under SSP1-2.6. Increases are projected for each month between June and October under SSP5-8.5, however under SSP1-2.6 July and August are projected to see no change in overall precipitation. However, it should be recognised that the large range between the 10th and 90th percentile projections represent a high level of uncertainty around the scale and sign of precipitation change in a given month or year.

Table 3-6: Projected change in precipitation (%) for 2040-2059, Taiwan, SSP5-8.5, 50th percentile, 1995-2014 reference period (10th, 50th and 90th percentile)

Month	Precip. Ref. Period	Projected change (SSP1-2.6)			Projected change (SSP5-8.5)		
		P10	P50	P90	P10	P50	P90
January	83.02mm	-38%	-5%	23%	-26%	-4%	12%
February	71.37mm	-26%	1%	26%	-26%	0%	20%
March	72.92mm	-16%	2%	23%	-23%	-5%	21%
April	95.9mm	-27%	0%	20%	-26%	-8%	18%
May	187.22mm	-20%	6%	26%	-25%	-4%	21%
June	258.7mm	-16%	6%	25%	-16%	6%	36%
July	254.5mm	-19%	0%	25%	-18%	3%	26%
August	275.36mm	-16%	0%	21%	-16%	4%	32%
September	190.29mm	-11%	14%	39%	-14%	17%	47%
October	104.46mm	-28%	3%	39%	-32%	6%	51%
November	84.31mm	-41%	-10%	25%	-44%	-13%	24%
December	85.1mm	-28%	1%	26%	-29%	-5%	28%

Source: WBCCKP

Figure 3-13: Projected change in annual precipitation (mm) for 2040-2059, Taiwan, SSP1-2.6 and SSP5-8.5, 1995-2014 reference period (10th, 50th and 90th percentile)



Source: WBCCKP

It is projected that intense rainfall events will increase in frequency and magnitude in the future as a direct result of a warmer atmosphere being able to hold more moisture. The rate of increase of intensity of extreme rainfall with temperature is governed by the Clausius-Clapeyron relationship which gives an approximate 7% increase in moisture per 1°C of warming. Despite the apparent simplicity of the relationship, there are a range of factors including moisture availability, temperature, cloud type and location which can result in much higher rates of scaling (in some cases 21% increase in moisture per °C of warming).

Projections for the precipitation amount on wettest days[47] for Taiwan reflect this relationship, with both SSP1-2.6 and SSP5-8.5 scenarios expected to have a greater amount of precipitation occur on the wettest days in all months except January and November (Table 3-7), pointing to an increase in the intensity of extreme rainfall events, especially during the summer rainfall peak from June to September (Figure 3-14). Specifically, the projected increase in wettest day precipitation is expected to be greatest during June and August, historically the wettest months of the year with the greatest amount of precipitation occurring on the wettest days - 89.07 mm and 91.07 mm, respectively – with 50th percentile wettest day precipitation in June projected to be 101.83 mm under SSP1-2.6, and 115.24 mm under SSP5-8.5, for the 2040-59 period, with the same values for August 97.74 mm and 101.18 mm, respectively.

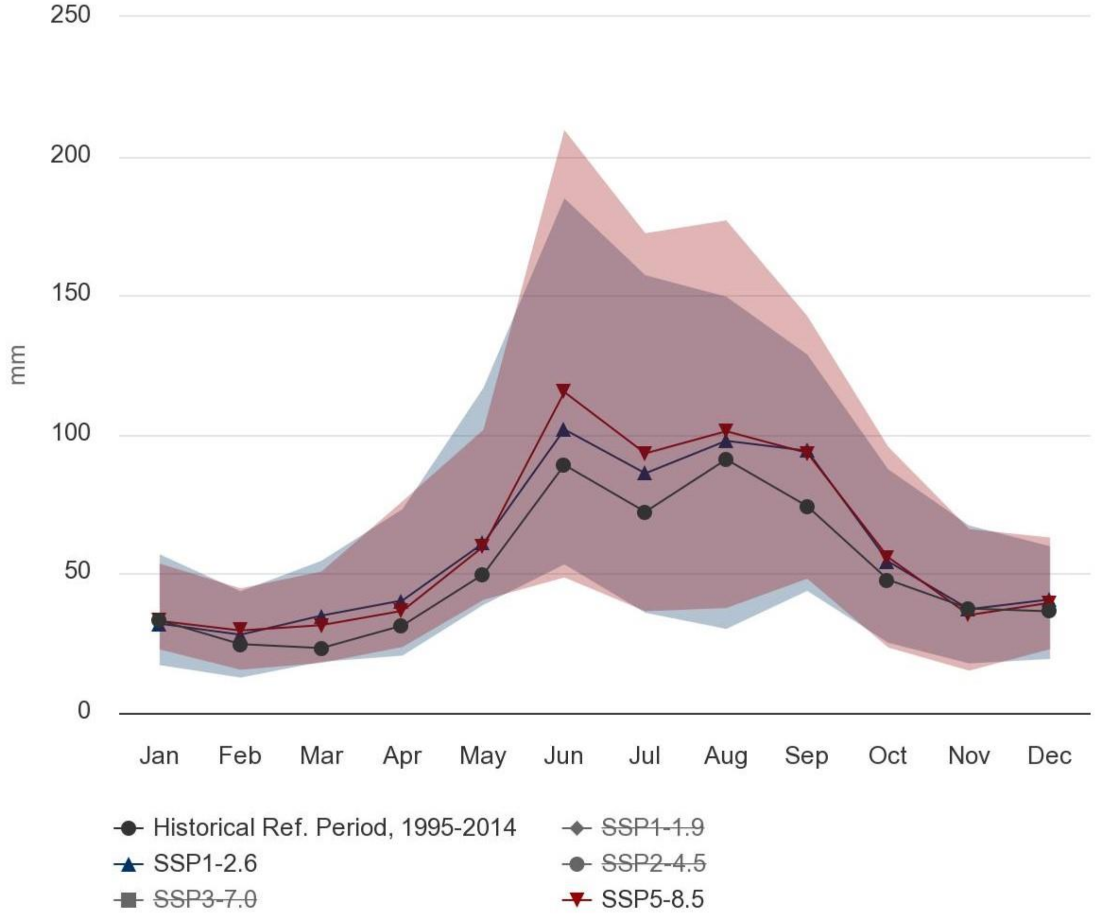
[47] Precipitation amount on wettest days is defined as the sum of precipitation over the measurement period that occurs on days when the daily precipitation rate exceeds the local 95th percentile.

Table 3-7: Projected precipitation amount on wettest days (mm) for 2040-2059, Taiwan, SSP1-2.6 and SSP5-8.5, 1995-2014 reference period (10th, 50th and 90th percentile)

Month	Precip. Ref. Period	Precipitation (SSP1-2.6)			Precipitation (SSP5-8.5)		
		P10	P50	P90	P10	P50	P90
January	33.24 mm	17.17	32.06	56.98	22.8	33.03	53.64
February	24.7 mm	12.67	28.09	43.68	15.5	29.61	44.74
March	23.29 mm	18.36	34.96	54.66	17.96	31.52	50.78
April	31.39 mm	20.56	40.4	73.17	23.68	36.68	76.04
May	49.81 mm	38.81	61	116.78	40.58	59.78	101.69
June	89.07 mm	53.34	101.83	184.83	48.64	115.24	209.38
July	72.22 mm	35.95	86.05	157.22	36.5	93.21	172.31
August	91.07 mm	30.16	97.74	149.51	37.67	101.18	176.92
September	74.24 mm	43.82	94.16	128.73	48.18	93.39	142.6
October	47.83 mm	25.21	54.39	87.5	23.49	55.89	95.63
November	37.48 mm	17.77	37.25	67.32	15.16	35.16	66.05
December	36.49 mm	19.37	40.76	59.85	22.89	39.56	62.97

Source: WBCCKP

Figure 3-14: Projected precipitation amount on wettest days (mm) for 2040-2059, Taiwan, SSP1-2.6 and SSP5-8.5, 1995-2014 reference period (10th, 50th and 90th percentile)



Source: WBCCKP As part of the Southeast Asia Climate Analyses and Modelling (SEACAM) framework[48], which provides high-resolution climate projections using the PRECIS model, the general conclusion is that 1-day rainfall and 5-day rainfall are projected to increase in areas north of the 15°N latitude, though local changes are strongly influenced by the driving GCM.

3.2.2.3 Sea level rise

Sea level rise as a result of climate is a global phenomenon impacting coastal communities and infrastructure worldwide. Rising temperatures cause ice sheets and glaciers to melt adding water to the oceans and the volume of the oceans also increase through thermal expansion of sea water, with both of these factors contributing to higher sea levels. There is overwhelming scientific evidence that the chronic threat of sea level rise associated with climate change is projected to occur throughout the 21st century and beyond[49,50]. Global future sea level rise projections range between 0.16m (SSP1-2.6) and 0.29m (SSP5-8.5) by 2050 and between 0.32m (SSP1-2.6) and 1.01m (SSP5-8.5) by the end of the century compared to a 1995-2014 baseline as shown in Table 3-8 for two of the SSP scenarios. However, sea level rise is not expected to be geographically constant but vary by region. Sea level rise may become a consideration in the Project's decommissioning phase after 2050.

Table 3-8: Projected global sea level rise by 2050 & 2100, relative to 1995-2014

	Sea level rise range	
SSP	**2050**	**2100**
SSP1-2.6	0.16-0.25m	0.32–0.62m
SSP5-8.5	0.20-0.29m	0.63–1.01m

Source: IPCC

In Taiwan analysis of tidal gauge records for the coastal regions has shown that sea-levels rose at a rate of 5.7 mm/year between 1993 and 2003[51]. The analysis also shows that the rate of sea-level rise is increasing as the rate in this period is twice that of the rate over the past 50 years and substantially higher than the global average rate of observed sea-level rise.

The Climate Change in Taiwan Scientific report (2011) states that "although global warming contributes to rising sea levels, increased sea levels near Taiwan may be partly attributed to regional causes, including decreasing sea levels in the Eastern Pacific Ocean in the last few decades, increasing sea levels in the Western Pacific Ocean, the effects of climate variations such as the El Nino-Southern Oscillation, and sea level changes in nearby basins (such as the South China Sea)."[52]

The DHI Metocean Study, undertaken for Greater Changhua Offshore Wind Farm South East, recommended applying a 0.3m allowance in the design to account for sea-level rise[53]. This recommendation was in line with the projections and considered a reasonable allowance for all the assets and infrastructure in the Greater Changhua Offshore Wind Farm South East project. This should be reviewed for this Project.

[48] SEACAM (2014). Available at: Regional-Climate-Modelling-Experiment-for-Southeast-Asia.pdf (weather.gov.sg)

[49] IPCC (2021). Available at: Summary for Policymakers (ipcc.ch)

[50] IPCC (2021). Available at: IPCC_AR6_WGI_Chapter_09.pdf

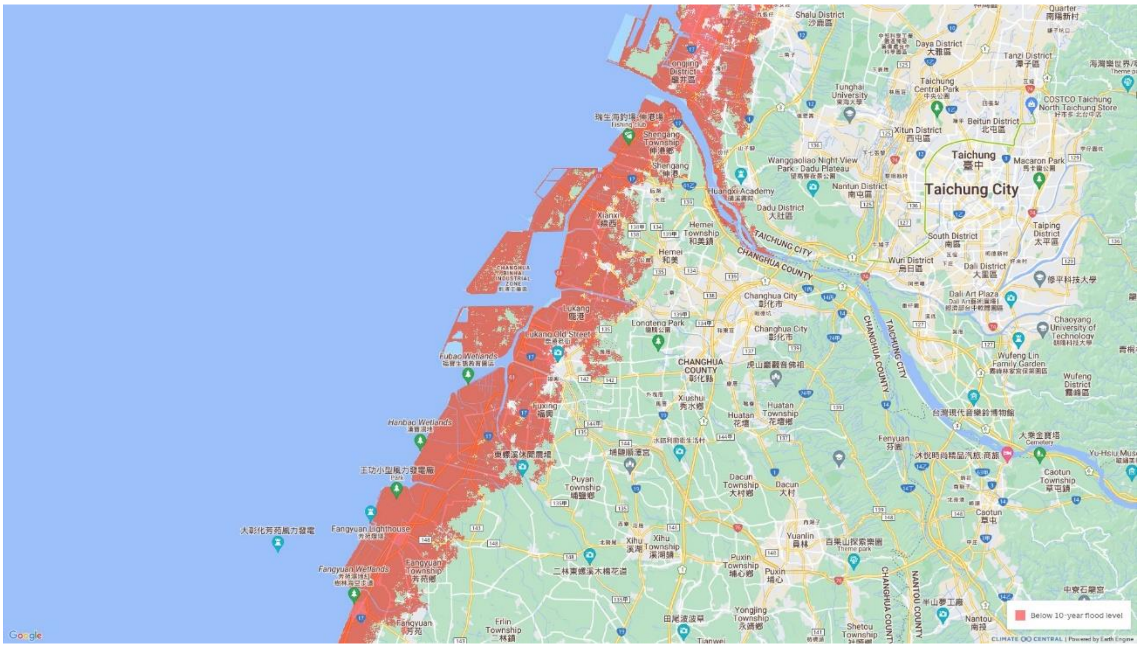
[51] TCCIP (2011). Available at: TCCIP (nat.gov.tw)

[52] TCCIP (2011). Available at: TCCIP (nat.gov.tw)

[53] DHI (2018). CHW01 Local Metocean Hindcast Study – Greater Changhua Offshore Wind Farm, Taiwan.

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[54]. The results of the analysis for the Project landing infrastructure location by 2050 for land below the 10-year flood level is shown in Figure 3-15[55]. 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.

Figure 3-15: Land projected to be below annual flood level in 2050



Source: Climate Central

3.2.2.4 Wind and Typhoons

The impact of climate change on wind patterns and wind speeds is complex, and limited data is available for the behaviour of wind fields under different climate projections. Data from the IPCC WGI Interactive Atlas tool[56], using both CMIP6 IPCC East Asia and CMIP5 CORDEX-South East Asia projections, suggest that Taiwan and the Taiwan Strait will experience small reductions in wind speed by mid-century under both SSP1-2.6 / RCP2.6 and SSP5-8.5 / RCP8.5 scenarios, respectively (Table 3-9). However, it is notable that there is low model agreement around projections for changes in wind speed.

There is uncertainty around the impact climate change will have on the frequency and intensity of typhoons and tropical cyclones both at a global and regional level. It is reported that the global proportion of the occurrence of major (category 3-5) tropical cyclones has increased over the last four decades, however there is lower confidence in projecting trends in the frequency of tropical cyclones across all categories in the future[57]. In South East and East Asia, there is medium confidence that tropical cyclones will have decreasing frequency, but that typhoon systems will increase in intensity overall in the future[58].

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

[55] Parameters used to determine future sea level rise via Climate Central: Year: 2070; Project Type: Sea level rise + moderate flood; Pollution pathway: unchecked pollution; and Luck: bad.

[56] IPCC WGI Interactive Atlas (2023). Available at: IPCC WGI Interactive Atlas

[57] IPCC (2021). Available at: Summary for Policymakers (ipcc.ch)

[58] IPCC (2021b). Available at: Technical Summary (ipcc.ch)

Table 3-9: Projected change in surface wind speed (%) for 2041-2060, East Asia / South East Asia, SSP1-2.6/RCP2.6 and SSP5-8.5/RCP8.5, 1995-2014 reference period (10th, 50th and 90th percentile)

Dataset	Wind Speed m/s Ref. Period	Wind Speed Change % (SSP1-2.6)			Wind Speed Change % (SSP5-8.5)		
	P50	P10	P50	P90	P10	P50	P90
CMIP6 – East Asia	4.7 m/s	-2.4%	-0.9%	0.8%	-1.4%	-0.6%	0.5%
CORDEX – South East Asia	5.2 m/s	-2.1%	-0.3%	1.3%	-3.0%	-1.0%	1.3%

Source: IPCC WGI Interactive Atlas

The potential increase in the most intense typhoons (category 3-5) due to climate change is supported by numerous studies and the IPCC reports. Furthermore, the path taken by a typhoon, and therefore the angle of attack upon the coast should a typhoon make landfall, will also influence storm surge and wave height. However there is very little information as to whether typhoon paths will change over time. In summary, although there is still considerable uncertainty regarding the change in frequency of typhoons, it is likely that the occurrence of the most severe typhoons will increase in the future, and projections for the northwest pacific region predict an increase in the intensity of typhoon systems through the 21st Century[59].

3.2.2.5 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[60].

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[61]. 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[62]. 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 lightning. However, the changes in intensity (heat and electrical power) are not known. The

59 Cha et al., "Third assessment on impacts of climate change on tropical cyclones in the Typhoon Committee Region – Part II: Future projections" Tropical Cyclone Research and Review, Vol. 9, issue 2, pp. 75-86, June 2020 (DOI: 10.1016/j.tcrr.2020.04.005)

60 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)

61 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

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

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.

3.3 Qualitative summary

In summary, in line with the IPCC's guidance note on likelihood scales (IPCC b, 2013)[63], the range of climate observations and projections for Taiwan predict:

- A ***virtually certain*** increase in average and extreme surface temperature
- An ***uncertain*** change in annual and monthly precipitation
- A ***very likely*** increase in precipitation intensity
- A ***virtually certain*** increase in sea surface temperatures
- A ***virtually certain*** increase in mean sea level
- An ***uncertain*** change in average wind speeds
- A ***more likely than not*** increase in the intensity, but decrease in the frequency of typhoons

[63] IPCC (2013). Available at: Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol — IPCC

4 Physical Climate Change Risk Assessment

4.1 Methodology

The following qualitative calculation method is used to determine the level of risk associated with current and future climate impacts to the Project to understand its risks:

Likelihood of impact (occurrence) x Severity of impact = Risk

Likelihood

The likelihood of impacts to the infrastructure is rated based on a uniform scale in Table 4-1 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 4-1: Likelihood of the occurrence of the climate variable

Rating	Likelihood of recurring events
Rare	Unlikely during next 25 years, or has not occurred in the past five years
Unlikely	May arise once in 10 years, or may have occurred in the last five years
Possible	May arise once in five years, or has happened during the past five years but not every year
Likely	May arise about once per year, or has happened at least once in the past year and in each of the previous five years
Almost certain	Could occur several times per year

Source: Mott MacDonald

Severity

The potential severity 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 4-2: Potential severity of consequence on the Project infrastructure

Rating	Likelihood of recurring events
Insignificant	No infrastructure damage, little change to service
Minor	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 10-20%. Need for new / modified equipment.
Moderate	Limited infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair. Early renewal of infrastructure by 50-90%.
Major	Extensive infrastructure damage requiring major repair. Major loss of infrastructure service. Early renewal of infrastructure by 50-90%.
Critical	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 by >90%.

Source: Mott MacDonald

Risk

The physical climate change risks assessment has been conducted to cover the operational lifetime of the Project which is stated as 20-25 years from 2025 when construction activities are due be completed. It is noted that the design life is 20-25 years although an assumption of life extension beyond 25 years has become relatively commonplace in offshore wind.

The risk to the assets of the Project is scored using the risk matrix in Table 4-3 below, which categorises the level of risk as low, medium, high, or extreme as defined in Table 4-4.

Table 4-3: Risk scoring matrix

		Severity of impact				
		Insignificant	Minor	Moderate	Major	Critical
Likelihood	Rare	Low	Low	Low	Medium	High
	Unlikely	Low	Low	Medium	Medium	High
	Possible	Low	Low	Medium	High	High
	Likely	Low	Medium	Medium	High	Extreme
	Almost certain	Low	Medium	High	Extreme	Extreme

Source: Mott MacDonald

Table 4-4: Risk category

Rating	Acceptance 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	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.

Source: Mott MacDonald

4.2 Physical Climate Change Risk Assessment

The physical climate change risk assessment carried out for the Project is presented in Table 4-6 and has been undertaken in line with the methodology presented in Section 4.1. 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.

It should be noted that 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. The following documents were used to inform the CCRA for the Project, including measures being taken into account to reduce climate related risks:

- Energy Assessment Report[64]
- Operation and Maintenance (O&M) Manual[65]

A CCRA was undertaken for the neighbouring Ørsted Group development, Greater Changhua Offshore Wind Farm South East, in 2020 and includes detail on the measures taken into account within the design in relation to climate change. The Project considered in this report is at a much earlier stage of development than the Greater Changhua Offshore Wind Farm South East project, and therefore not as much detail is available for this Project. Given Greater

[64] DNV. (2022). Energy Assessment Report – Changhua 4 Offshore Wind Farm.

[65] Ørsted. (2022). Operation and Maintenance Manual.

Changhua Offshore Wind Farm South East and this Project are being developed by Ørsted, and the proximity of the sites to one another (as shown in Figure 1-1), the Greater Changhua Offshore Wind Farm South East CCRA has been used to form the basis of this assessment alongside the Energy Assessment Report and O&M manual.

Assumptions are included in the assessment where information is missing. It is therefore assumed that the same or similar allowances for climate change and embedded resilience measures to reduce vulnerability will be applied within the next design phase of 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. In the case that these assumptions are not correct, i.e. the stated design considerations have not been made, then these statements should function as recommendations for the assumed allowances to be incorporated into the design. However, it should be noted that there are some key differences between the two which may alter what allowances are included:

- Turbine size of this Project is much higher compared to the other at 14.7MW compared to 8.1MW
- This Project is located approximately 50km offshore whereas the other is approximately 37.5km offshore
- Water depths are anticipated to be slightly different where this Project has water depths of between 30m and 45m compared to the other project with between 34m and 44m

As all the embedded climate allowance measures have not yet been confirmed for this Project, the CCRA should be read with caution. It is recommended that these measures are reviewed and taken into account within the design to contribute to the Project's resilience to future climate change. The CCRA should then be reviewed and scored appropriately in line with the measures taken into account.

In summary, the CCRA has identified a total of 30 risks of which 17 are identified to be of a low rating and the remaining 13 are of a medium rating as shown in Figure 4-1. The medium risks are summarised in Table 4-5 with more detail presented in Table 4-6.

Figure 4-1: Number of low and medium rated risks identified in the CCRA

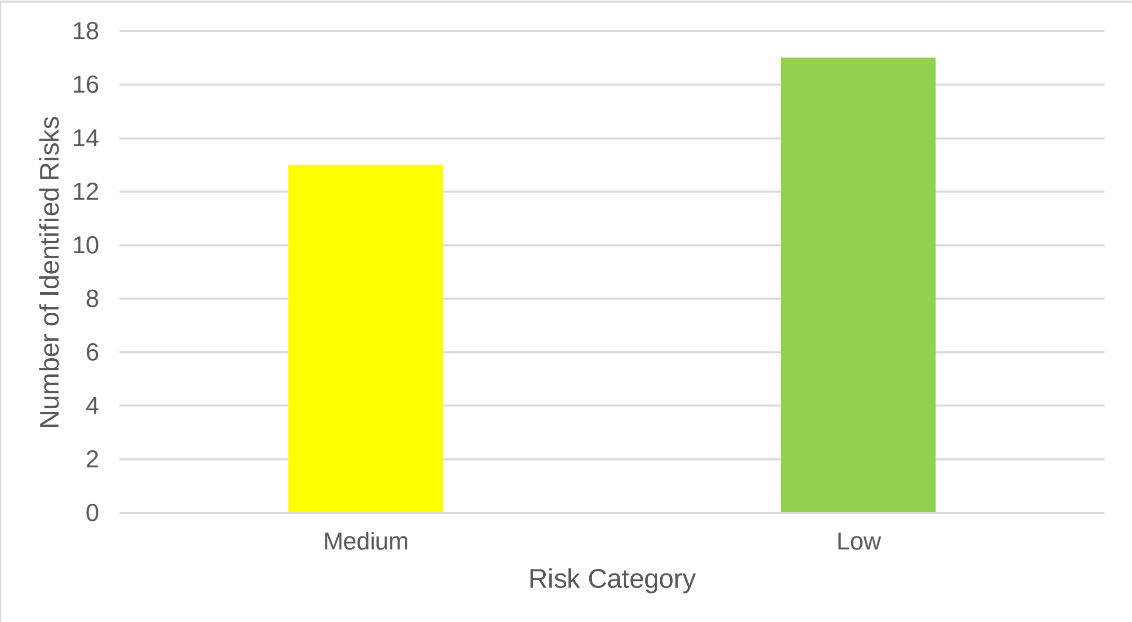


Table 4-5: Summary of medium rated risks identified

Project Component	Climate change impact	Direct impacts of climate change		Risk
		Component	Hazard	
WTG	Temperature (increases in mean temperature and increased extreme high temperatures)	Damage to infrastructure	Fatigue and degradation of turbines as a result of extreme heat	Medium
Offshore substation & export cable	Temperature (increases in mean temperature and increased extreme high temperatures)	Power generation	Increased temperatures can increase power losses within substations and transformers	Medium
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	Flooding of infrastructure	Flooding if precipitation rates exceed the drainage capacity of the substation	Medium
		Cable joint failure	Scour could cause failure at a cable joint	Medium
	Sea-level rise and extreme water levels (increase to both average sea level and more extreme acute events)	Flooding of infrastructure	Extreme surge events generated by typhoons can raise sea levels and in combination with high tides and sea-level rise result in flooding of infrastructure	Medium
	Waves (increase in wave heights during extreme events)	Damage to infrastructure	Wave overtopping and salt spray may lead to damage or degradation of assets	Medium
Onshore substation & grid connection	Temperature (increases in mean temperature and increased extreme high temperatures)	Power generation	Increased temperatures can reduce the carrying capacity of lines	Medium
			Increased temperatures can increase losses within substations and transformers	
		Damage to infrastructure	Increased temperatures leading to failure of electrical equipment	
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	Damage to infrastructure	Heavy precipitation can cause surface water flooding of sites and damage to underground cables.	Medium
	Sea-level rise and extreme water levels (increase to both average sea level and more extreme acute events)	Damage to infrastructure	Extreme surge events generated by typhoons can raise sea levels and in combination with high tides and sea-level rise result in flooding of infrastructure	Medium
			Increase in erosion risk to infrastructure	Medium
	Waves (increase in wave heights during extreme events)	Flooding of infrastructure	Wave overtopping of coastal flood defences during extreme events leading to flooding	Medium
Construction, operation & maintenance	Temperature (chronic increases and increased extreme high temperatures)	Working conditions	Extreme heat impacts on workers	Medium
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	Access to onshore and offshore sites	Heavy precipitation and flooding can impact access to onshore and offshore sites for construction, operation and maintenance	Medium

Table 4-6: Physical Climate Change Risk Assessment of the Project

Project component	Climate change impact	Likelihood of occurrence	Direct impacts of climate change		Potential consequence of direct impact (vulnerability)	Assumed / recommended allowances for climate in current design	Severity of consequence	Risk	Comments on physical risk and potential mitigating action(s)
			Component	Hazard					
WTGs and inter-array cables	Temperature (increases in mean temperature and increased extreme high temperatures)	**Almost certain**	Damage to infrastructure	Fatigue and degradation of turbines as a result of extreme heat	The Energy Assessment Report had presented the operational temperature range as appropriate to the Project's WTG model. High temperatures could affect the WTG and there is potential that it would be de-rated at high temperatures exceeding the operational temperature range of WTG , during a period of full load generation, contributing to energy losses.	• As noted in the O&M manual, each turbine has hundreds of sensors measuring temperature, amongst other variables, in 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. • The O&M manual states that targeted monitoring will be implemented to determine the best time to replace components with an expected lifetime that is less than the overall wind farm remaining lifetime. For example, if temperatures are forecast to be beyond specific parameters based on analysis of temperatures in the nacelle, a targeted campaign to top up coolant levels and replace or clean air duct filters would reduce the risk of lost availability because of overheating. • It is assumed that generators and cooling system will be designed to be efficient at full WTG load in conditions up to / over the upper limit of the operational temperature range.. There may be an allowance of nominal power production where temperatures reach over the specified temperature, depending on the thermal mode within the design. • As stated in the O&M manual, array cable temperature is monitored continuously for hotspots via distributed temperature sensors. • It is assumed that cables will be housed in a ventilated culvert box. It is assumed the turbines will have high-temperature ride through functionality.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account 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.
	Wind (chronic net increase / decrease)	**Possible**	Power generation	Changes in wind patterns impact on output within operating range; turbines cannot operate in very high or very low windspeeds; increased wear and tear on turbine elements resulting in reduced lifespan	Negligible increase or decrease in power production over time.	• The cut in wind speed and cut off wind speed for the WTGs is currently unknown. However, it is assumed that the cut in wind speed (point at which the WTG is able to generate power) and cut off wind speed (point at which the WTG shuts down) are similar to the neighbouring project (although it should be noted that this Project's wind turbines are larger in size therefore these values may be different): • Within the Technical Due Diligence (TDD) report, it is stated that the project will be planning to be certified to Class S for normal operating parameters. As state within the TDD, The TDD indicates that the project certification scheme and associated independent modelling would considers multiple technical factors (eg wind speed, air turbulence intensity and temperature). The adequacy and review outcome of the WTG and project design (ie against project location wind speeds) are as presented in detail within the TDD. • As noted in the O&M manual, each turbine has hundreds of sensors measuring temperature, amongst other variables, in 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.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. Risk caused by a net increase / decrease in wind is non-appreciable. No further action required other than ongoing maintenance checks.
	Wind (increase in extremes)	**Possible**	Damage to infrastructure	Extreme high wind speeds may damage blades or result in cut-out	The UK Climate Change Risks Assessment has been estimated that extreme weather conditions have caused about 80% of all North Sea offshore turbines to sustain failing grouted connections, causing some turbines to tip and no longer stand vertically. This has primarily been in monopile turbines, which can experience bending movement in the grouted joints between the monopile and the transition piece, resulting in the need for urgent repairs. Moreover, dissolved or cracked grouting has caused these turbines to shift on their foundations[66]. The O&M manual outlines that the foundation design will be based on a jacket design and hence the issues above should not be applicable. There may also be grouting used to secure the connection between the pin piles and the jacket, which negate the issues described above.	• The O&M manual states that the wind farm is designed to withstand extreme weather conditions whereby it .is outlined in the O&M manual that the WTGs are typhoon-class. • It is noted in the TDD report, there is a possibility that the intensity of extreme wind is predicted to increase at the project location due to climate change, which may exceed the extreme wind speed design specification of the project. Within the TDD report, it is stated that the project will be planning to be certified to Class T for extreme wind speed. As state within the TDD, The TDD indicates that the project certification scheme and associated independent modelling would considers multiple technical factors (eg wind speed, air turbulence intensity and temperature). The adequacy and review outcome of the WTG and project design (ie against project location wind speeds) are as presented in detail within the TDD. Further studies such as the modelling of future projected (ie due to climate change) extreme wind speeds associated with cyclones (ie a cyclone risk assessment) to develop mitigations to potential/severity of damage to project components could also be considered. • It is unknown whether there is protection against extreme wind force is embedded in the WTG and cable design. However, it is assumed that measures such as high wind ride through (HWRT) departure activation is included within the design. • As noted in the O&M manual, each turbine has hundreds of sensors measuring temperature, amongst other variables, in 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. • Jacket design foundations.	**Minor**	**(Low)**	Risk caused by a net increase in wind is non-appreciable. No further action required other than ongoing maintenance checks. Risk of damage to infrastructure from extreme wind speeds, wave force is low. Must be monitored during and after extreme wind and/or wave-related events, and contingencies must be put in place. Maintenance guide must account for possibility of excessive weathering.
	Sea-level rise and extreme water levels due to surges (increase to both mean sea	**Almost certain**	Damage to infrastructure	Extreme events such as typhoons, exacerbated by sea-level rise leading to		• Foundations are designed to stand out sufficiently above the water to protect the tower platform from large waves • The O&M manual states that the wind farm is design to withstand extreme weather conditions whereby it is outlined in the O&M manual that the WTGs are typhoon-class.	**Insignificant**	**(Low)**	

[66] Diamond, K, E. (2012). Available at: Extreme Weather Impacts on Offshore Wind Turbines: Lessons Learned on JSTOR

Project component	Climate change impact	Likelihood of occurrence	Direct impacts of climate change		Potential consequence of direct impact (vulnerability)	Assumed / recommended allowances for climate in current design	Severity of consequence	Risk	Comments on physical risk and potential mitigating action(s)
			Component	**Hazard**					
	level and more extreme acute events)			flooding of critical components.		• Bathymetric surveys will be carried out to check for the condition of scour protection and the development of scour at the foundations as outlined in the O&M manual. Where scour is worse that assumed, monitoring can be used to assess the remaining lifetime and mitigation action to limit scour development. • It is assumed that salt spray protection, flood protection and protection against wave force will be embedded in the WTG and cable design. • Jacket design foundations.			
	Waves (increase in wave heights during extreme events)	**Possible**	Damage to infrastructure	Extreme waves leading to damage to assets or salt spray degrading assets		• The O&M manual states that the wind farm is design to withstand extreme weather conditions. • Foundations are designed to stand out sufficiently above the water to protect the tower platform from large waves. • It is assumed that salt spray protection, flood protection and protection against wave force will be embedded in the WTG and cable design. • Jacket design foundations.	**Minor**	**(Low)**	
	Lightning (increase in frequency of lightning strikes)	**Possible**	Damage to infrastructure	Lightning strikes could damage electrical equipment or WTG turbines and interrupt operation	WTGs turbines have been known to catch fire due to lightning strikes. Additional maintenance or replacement of assets required due to storm damage.	• O&M facilities are equipped with an innovative lightning detection system which can detect lightning accurately from 80km away. • It is assumed lightning strike protection will be embedded in the WTG design.	**Minor**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. Given there are likely to be protections in place, the risk to infrastructure is low. Maintenance guide must account for possibility of damage caused by increased lightning strike
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	**Almost certain**	Damage to infrastructure	Extreme precipitation could damage WTG turbines.	There is potential for increase wear on the turbine blades. However, it is noted that increase wear is not expected due to design changes and mitigations that apply to the WTGS.	• The O&M manual states that increased inspection frequency and ongoing maintenance will be implemented. • Blades are installed with leading-edge protection for rain impact.	**Insignificant**	**(Low)**	It is assumed that these mitigating measures will be adequate if embedded. Maintenance guide must specify regular monitoring.
Offshore substation & export cable	Temperature (increases in mean temperature and increased extreme high temperatures)	**Almost certain**	Power generation	Increased temperatures can increase power losses within substations and transformers	There may be a reduction in net power export.	• It is assumed that designs will account for high temperature ride through functionality.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. Exacerbated temperature extremes and/or sustained high temperatures may inhibit power infrastructure performance and export. Ongoing monitoring required regarding materiality of losses if any.
				Increased average temperature would impact on ambient temperature of the cable, limiting the capacity of the cable surrounds to carry away heat.	This results in a lower capacity of the cable to transmit energy and a consequent derating of the circuit. This is not a loss of circuit; however, this could have consequent system capacity issues.	• It is assumed that cables will be housed in a ventilated culvert box. • It is assumed that designs will account for functionality in high temperatures.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. It assumed that these mitigating measures will be adequate if embedded.
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	**Almost certain**	Flooding of infrastructure	Flooding if precipitation rates exceed the drainage capacity of the substation	Inundation or direct precipitation damage to electrical equipment will lead to risk of failures in the system/integrity.	• Drainage of structures (above msl) at sea occurs in-situ at sea.	**Minor**	**(Medium)**	Ponding of water on any flat substation structure areas must be monitored to avoid inundation of equipment or risk to safety of workers
			Flooding of export cable at coast	Flooded link box will de-rate a cross bonded cable	Reduced or disrupted power export.	• It is assumed that export cable infrastructure will have in-built insulation and will be trenched at the coast, eliminating risk of flooding.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. It is assumed that these mitigating measures will be adequate if embedded. Maintenance guide must specify regular monitoring.
			Cable joint failure	Scour could cause failure at a cable joint	Subsidence and scour impacts on WTGs and inter array cables.	• Bathymetric surveys will be carried out to check for the condition of scour protection and the development of scour at the foundations as outlined in the O&M manual. Where scour is worse that assumed, monitoring can be used to assess the remaining lifetime and mitigation action to limit scour development.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. It is assumed that these mitigating measures will be adequate if embedded. Maintenance guide must specify regular monitoring.

Project component	Climate change impact	Likelihood of occurrence	Direct impacts of climate change: Component	Direct impacts of climate change: Hazard	Potential consequence of direct impact (vulnerability)	Assumed / recommended allowances for climate in current design	Severity of consequence	Risk	Comments on physical risk and potential mitigating action(s)
	Wind (increase in extreme wind events linked to increase in storms)	**Possible**	Damage to infrastructure	Extreme winds resulting in direct damage to substation	Additional maintenance requirements or early replacement of assets or structures required.	• It is unknown if the Project has overhead lines, however it is assumed that it does not. It is assumed that structures and assets will be built to appropriate design codes to withstand extreme wind force.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. Though weathering is expected, the risk of damage to infrastructure from extreme wind speeds is low. Maintenance guide must capture need for regular monitoring during and after extreme wind events.
	Sea-level rise and extreme water levels (increase to both average sea level and more extreme acute events)	**Almost certain**	Flooding of infrastructure	Extreme surge events generated by typhoons can raise sea levels and in combination with high tides and sea-level rise result in flooding of infrastructure	Flooding or direct storm damage to electrical equipment will lead to failures in the system.	• It is assumed salt spray protection, flood protection and protection against wave force will be embedded in the design. • Bathymetric surveys will be carried out to check for the condition of scour protection and the development of scour at the foundations as outlined in the O&M manual. Where scour is worse that assumed, monitoring can be used to assess the remaining lifetime and mitigation action to limit scour development.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. It is assumed that these mitigating measures will be adequate if embedded. Maintenance guide must specify regular monitoring.
			Flooding of export cable at coast	Flooded link box will de-rate a cross bonded cable	Reduced or disrupted power export.	• It is assumed that the export cable infrastructure will have in-built insulation and will be trenched at the coast eliminating risk of flooding.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. It is assumed that these mitigating measures will be adequate if embedded. Maintenance guide must specify regular monitoring.
	Waves (increase in wave heights during extreme events)	**Likely**	Damage to infrastructure	Wave overtopping and salt spray may lead to damage or degradation of assets	Subsidence and scour impacts.	• Bathymetric surveys will be carried out to check for the condition of scour protection and the development of scour at the foundations as outlined in the O&M manual. Where scour is worse that assumed, monitoring can be used to assess the remaining lifetime and mitigation action to limit scour development.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. It is assumed that these mitigating measures will be adequate if embedded. Maintenance guide must specify regular monitoring.
	Lightning (increase in frequency of lightning strikes)	**Possible**	Damage to infrastructure	Lightning strikes could damage electrical equipment and interrupt operation	Additional maintenance or replacement of assets required due to storm damage.	• As noted in the O&M manual, the meteorological state will be measured by a meteorological station on the OSS which will include a lightning sensor, real time kinematics beacons and cloud height sensors. • O&M facilities are equipped with an innovative lightning detection system which can detect lightning accurately from 80km away.	**Insignificant**	**(Low)**	It is assumed that these mitigating measures will be adequate if embedded. Maintenance guide must specify regular monitoring.
Onshore substation & grid connection	Temperature (increases in mean temperature and increased extreme high temperatures)	**Almost certain**	Power generation	Increased temperatures can reduce the carrying capacity of lines	Lowered net power transmission.	• It is assumed that designs will account for functionality in high temperatures.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. While mitigating measures are assumed to be implemented, exacerbated, unexpected temperature extremes and/or sustained high temperatures over time may inhibit power infrastructure performance and transmission capabilities. Ongoing monitoring required regarding materiality of losses if any.
				Increased temperatures can increase losses within substations and transformers	This results in a lower capacity of the system to transmit energy. This is not a loss of circuit; however, this could have consequent system capacity issues.				
			Damage to infrastructure	Increased temperatures leading to failure of electrical equipment	Electrical equipment is rated to work up to a certain max temperature, if this is exceeded it will fail. Reduction in lifespan of electrical equipment.				
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	**Almost certain**	Damage to infrastructure	Heavy precipitation can cause surface water flooding of sites and damage to underground cables.	Damage to all high voltage equipment such as circuit breakers, isolators, transformers etc. Damage to protection, automation and control equipment. Damage to HVAC systems and other substation services. Damage to Communication system Damage to DC and UPS system, as well as the batteries. These risks can lead to entire substations going offline, from fire or catastrophic loss.	• The design of the drain ditches surrounding any buildings is currently unknown. However, it is assumed that drainage will be incorporated and climate change uplifts should be taken into account. • The elevation of any buildings / substations are unknown at this stage; however it is recommended that they will be elevated higher than surrounding land. If not, adequate drainage design should be incorporated, taking appropriate uplifts for climate change into account. • The level of onshore flood protection is currently unknown at this stage; however, it is recommended the design will take flood risk into account.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. Consider appropriate elevation, placement and location of critical infrastructure. Ensure that the return period for drainage designs is adequately precautionary in light of changing precipitation intensities which in turn are likely to be exacerbated by ENSO cycles. There is a risk that the public drainage system could become overloaded or fail which is outside of the site's control, and which will require flood mitigation planning. Drainage channels and non-critical infrastructure (e.g., basement

Project component	Climate change impact	Likelihood of occurrence	Direct impacts of climate change		Potential consequence of direct impact (vulnerability)	Assumed / recommended allowances for climate in current design	Severity of consequence	Risk	Comments on physical risk and potential mitigating action(s)
			Component	**Hazard**					
									infrastructure) may be inundated, but this risk is tolerable.
		Possible	Damage to infrastructure	Drought can cause damage to assets due to increased dust and subsidence	Additional maintenance requirements or early replacement of asset required.	• Difficult to design for this risk, but operationally, it is assumed that a maintenance team will be in place	**Minor**	**(Low)**	Maintenance guide must specify regular monitoring.
	Wind (increase in extremes)	**Possible**	Damage to infrastructure	Strong winds can cause damage to assets, structures, overhead transmission and distribution lines	Additional maintenance requirements or early replacement of assets or structures required.	• It is assumed that structures and assets will be built to appropriate design codes to withstand extreme wind force.	**Minor**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. Maintenance guide must specify regular monitoring of potential wind-related damage, wear and tear.
	Sea-level rise and extreme water levels (increase to both average sea level and more extreme acute events)	**Almost certain**	Damage to infrastructure	Extreme surge events generated by typhoons can raise sea levels and in combination with high tides and sea-level rise result in flooding of infrastructure	Damage to all high voltage equipment such as circuit breakers, isolators, transformers etc. Damage to protection, automation and control equipment. Damage to HVAC systems and other substation services. Damage to Communication system. Damage to DC and UPS system, as well as the batteries. These risks can lead to entire substations going offline, fire or catastrophic loss.	• The design basis which will be used to calculate the highest high-sea water level (HHWL) for the Project is currently unknown at this stage. The Taiwan's CWB records could be used to calculate the HHWL. Based on the neighbouring project, CWB records for 1971-2017 for the Taichung Harbour were used to calculate the HHWL and based on this they assume the HHWL is +3.338m. This should be reviewed and taken into account as well as the probability and consequence of tsunamis to the Changhua coastal area. • The site elevation above sea level is currently unknown at this stage. • The elevation of the critical infrastructure is currently unknown at this stage. It is recommended that they will be elevated higher than surrounding land. If not, adequate drainage design should be incorporated, taking appropriate uplifts for climate change into account. It should also take into account the HHWL recorded by the CWB as well as the probability and consequence of tsunamis to the Changhua coastal area. • It is not clear at this stage if flooding will be induced by tide or sea water. It is assumed that appropriate design measures will be implemented to ensure this does not occur. • The MetOcean report (DHI)[67] for the neighbouring project offshore could be used to derive the extreme water levels – the 1 in 100 year and 1 in 500 year water levels are 3.3 m and 3.5 m above mean sea-level respectively.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. Given the sea level rise screening from Climate Central (presented in Figure 3-15 in Section 3.2.2.3) suggests that onshore infrastructure is likely to be affected by sea level rise by 2050. Sea level rise and coastal should be adequately considered in the final choice of infrastructure location and design requirements. It is unknown whether in-combination climate events such as sea level rise, storm surge and ENSO-driven extreme precipitation-driven flooding is likely to flood onshore critical infrastructure. However, it is assumed mitigation measures will be in place to reduce this risk. Non-critical infrastructure (e.g., basement infrastructure) may be inundated, but this risk is tolerable. There is a risk that the public drainage system could become overloaded or fail, contributing to flood risk which is outside of the site's control. This will require robust flood mitigation planning which has been taken into account based on the adjacent comments on the associated design allowances.
				Increase in erosion risk to infrastructure	Additional reinforcement, maintenance requirements and/or early replacement of assets or structures required. Potential disruption to site access.	• The risk of erosion is currently unknown at this stage. It is assumed only non-critical infrastructure would be at risk of erosion, if at all.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. It is assumed that elevation, placement and location of critical infrastructure will be considered and that the measures will be appropriate to manage this risk of in-combination climate impacts. Non-critical infrastructure may be inundated, but this risk is tolerable. Maintenance guide must specify regular monitoring of any erosion or apparent risk of erosion.
	Waves (increase in wave heights during extreme events)	**Likely**	Flooding of infrastructure	Wave overtopping of coastal flood defences during extreme events leading to flooding	Potential impacts to asset integrity, increased maintenance and disruption to site access.	• The risk of erosion is currently unknown at this stage. It is assumed only non-critical infrastructure would be at risk, if at all.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. Maintenance guide must specify regular monitoring of potential wave and flood damage, wear and tear. It is

[67] DHI (2018). CHW01 Local Metocean Hindcast Study – Greater Changhua Offshore Wind Farm, Taiwan.

Project component	Climate change impact	Likelihood of occurrence	Direct impacts of climate change: Component	Direct impacts of climate change: Hazard	Potential consequence of direct impact (vulnerability)	Assumed / recommended allowances for climate in current design	Severity of consequence	Risk	Comments on physical risk and potential mitigating action(s)
									hereby noted that the sea wall does not form part of the project is not owned by the project. Communication with Taiwan officials must be ongoing should maintenance requirements to the latter become evident.
Construction[68], operation & maintenance	Temperature (chronic increases and increased extreme high temperatures)	**Almost certain**	Working conditions	Extreme heat impacts on workers	Reduced windows for construction, operation and maintenance activities. Heat exhaustion is a possibility if workers need to tend to an emergency on site.	• Taiwan has a law for working in high temperatures that requires the application of certain work/rest patterns, although offshore wind is not currently captured under this legislation. The Project's Operation and Maintenance Manual highlights mitigation measures to minimise heat exposure and reduce the risk of potential heat stress, including: – 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 HSE plans for their respective scope of works and teams deployed to site.	**Minor**	**(Medium)**	HSE risks are significantly reduced if appropriate HSE plans are in place to manage climatic extremes like heat. Heat exhaustion is a residual risk if workers need to tend to an emergency.
		Almost certain	Damage to information and communication components	Extreme high temperatures can cause loss of information through communication networks or reduced quality of service	Disruption to service.	• It is assumed that designs account for functionality in high temperatures.	Insignificant	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. It is assumed that these mitigating measures will be adequate if embedded.
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	**Almost certain**	Access to onshore and offshore sites	Heavy precipitation, flooding, extreme wind and wave heights can impact access to onshore and offshore sites for construction, operation and maintenance	Delays in construction, maintenance or operational activities due to reduced access to sites. Reduced windows for operation and maintenance activities. Danger to workers if they need to tend to a site emergency in storm or flood conditions.	• Foundations are designed to stand out sufficiently above the water to protect the tower platform from large waves. • The O&M manual states that the wind farm is design to withstand extreme weather events whereby it is outlined in the O&M manual that the WTGs are typhoon-class. • It is assumed that measures for typhoon events (leading to heavy precipitation, flood, extreme wind and wave heights) during construction and operation will be in place and typhoon risk will be considered as part of the construction schedule, and operations planning. • Ørsted is considering chartering one or more Crew Transfer Vessels (CTVs) capable of safe transfer at wave heights superior to what is typical in Europe, given the conditions at the Project location. This is superior to what is implemented in Europe. • Jack up vessels which will be used for removal and replacement of major components such as blade, generators, amongst others, and are able to withstand large waves heights and strong winds. • It is assumed that all contractors will be required to provide HSE plans for their respective scope of works and teams deployed to site, whereby risk to workers from adverse conditions including high winds and waves are to be addressed.	**Minor**	**(Medium)**	Review assumed allowances within the design and take these into account if not already implemented. HSE risks are significantly reduced if appropriate HSE plans are in place to manage climatic extremes like extreme or 'loaded' typhoon events and associated wind, wave activity, precipitation and flood. Danger to life is a residual risk if workers need to tend to an emergency in stormy, windy or flood conditions.
	Wind (increase in extremes)	**Possible**						**(Low)**	
	Waves (increase in wave heights during extreme events)	**Possible**						**(Low)**	
	Sea surface temperatures (increase in mean temperatures)	**Almost certain**	Increased maintenance	Changes in sea surface temperature are likely to have impacts on local marine ecology	Any additional marine growth on offshore assets may require additional maintenance (e.g. removal or relocation of specimens)	• An O&M manual has been developed for the operational phase.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. Mitigating measures render residual risk low if they are carried out.
	Lightning (increase in frequency of lightning strikes)	**Possible**	Damage to infrastructure	Lightning strikes could damage electrical equipment or WTG turbines and interrupt operation	WTGs have been known to catch fire due to lightning strikes Additional maintenance or replacement of assets required due to storm damage. Danger to workers if they need to tend to a site emergency in storm or flood conditions.	• The O&M manual outlines that lightning intensity patterns are considered when planning of daily technician work shifts so that they accommodate the higher likelihood of lightning at those times even without the direct signals. • O&M facilities are equipped with an innovative lightning detection system which can detect lightning accurately from 80km away. • It is assumed that lightning strike protection will be embedded in the WTG design. • It is assumed that all contractors will be required to provide HSE plans for their respective scope of works and teams deployed to site, whereby lightning risk to workers are to be addressed.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented. Mitigating design and HSE measures are considered adequate and render residual risk low if they are carried out.
	Temperature (chronic increases and increased extreme high temperatures)	**Almost certain**	Damage to infrastructure	Extreme high temperatures, heavy precipitation, flooding,	Disruptions to operations power output could result in wider social impacts if local communities are dependent on supply from the Project. However, by incorporating wind energy into	• It is assumed that designs account for functionality in high temperatures.	**Insignificant**	**(Low)**	Review assumed allowances within the design and take these into account if not already implemented.

[68] Construction is expected to be completed by 2025, and climate change attribution to these events in the short term is not expected to be appreciable.

Project component	Climate change impact	Likelihood of occurrence	Direct impacts of climate change		Potential consequence of direct impact (vulnerability)	Assumed / recommended allowances for climate in current design	Severity of consequence	Risk	Comments on physical risk and potential mitigating action(s)
			Component	Hazard					
	Precipitation changes (increase in extreme precipitation events, uncertain changes in annual average precipitation)	**Almost certain**		extreme wind and wave heights could impact onshore and offshore assets which could interrupt operations and lead to reductions in energy outputs	the energy mix, the wider energy network may become more resilient if other disruptions occur elsewhere in the network.	• It is assumed that measures for typhoon events (leading to heavy precipitation, flood, extreme wind and wave heights) during construction and operation will be in place and typhoon risk will be considered as part of the construction schedule, and operations planning. • It is assumed that structures and assets will be built to appropriate design codes to withstand extreme wind force. • It is assumed the wider energy generation, transmission and distribution network will have resilience measures in place.			It is assumed that these mitigating measures will be adequate if embedded.
	Wind (increase in extremes)	**Possible**							
	Waves (increase in wave heights during extreme events)	**Likely**							

5 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). Emissions from fuel combustion during the project construction phase (scheduled to occur between March – November 2025) are estimated to be approximately 193,526 tonnes CO_2e. As construction activity is to be undertaken through the contractors (ie appointed by the Project) who employs (or even sub-contract) vessel operators, this activity would typically be classified as Scope 3 emissions.

The GHG emissions assessment was undertaken in alignment with the GHG protocol and the results are presented below. As the project does not have detailed data for construction activities and is not yet in operation, actual activity data could not be used to calculate the annual construction or operational emissions. In order to develop the assumptions necessary to calculate the project's construction and operational scope 1 and 2 emissions, Construction Schedules as well as Operations and Maintenance plans for similar Offshore Windfarms in the region were studied and discussed with experienced project engineers. Key assumptions for quantifying activity data, as well as notes on the sources of emissions factors are detailed in Section 5.2 of this chapter.

5.1 Results

5.1.1 Construction Phase

The results of the GHG emissions assessment for the construction phase show that estimated annual emissions during the project's construction are expected to be approximately 193,526 tonnes CO_2e (Table 5-1). The project owner intends to complete the project's offshore construction phase between March to November 2025 (ie the typical weather period for offshore works in Taiwan). It is noted that the adherence to this timeline would be subject to any weather delays, particularly during the typhoon season. The construction duration could also be extended to be over the period of two years or more, if there are changes in the construction schedule for an earlier start or later end date.

Table 5-1: Annual GHG emissions from fuel combustion during project construction

Asset	Activity Data Type	Quantity	Unit	Emissions Factor (kg CO_2-e/unit)	tCO_2-e
Fuel Combustion During Construction					
Offshore Installation Vessels	Marine Fuel Oil	31,920,000	L	3.1	98,952.00
Heavy Lift Transport Vessel	Marine Fuel Oil	5,184,000	L	3.1	16,070.40
Cable-laying Vessel	Marine Fuel Oil	11,040,000	L	3.1	34,224.00
Tugs	Marine Fuel Oil	14,283,780	L	3.1	44,279.72
				Sub-Total	**193,526.12**
Estimated Construction Period Duration				Years	1
Annual Total					**193,526.12**

GHG emissions during the construction phase of the project are expected to result from the operation of the fleet of vessels that are required to transport and install the various offshore project components. The assumptions for the types, number, operational days and fuel consumption of these vessels are detailed in Table 5-2. 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 31.92 million litres of marine fuel oil. This will result in approximately 98.95 kT of CO_2e emissions, which is slightly more than half of all direct construction related emissions. The second largest contributor to construction emissions are expected to be the tugs which will manoeuvre barges holding project materials from the port to and around the work sites. Cumulatively, tugs are estimated to emit 44.3 kT of CO_2e, or 23% of construction emissions. The barges themselves do not have engines and therefore are not anticipated to have associated emissions.

Table 5-2: Construction Vessel Assumptions

Task	Vessel Assumption	Number of Vessels	Operation Days	Fuel Consumption per vessel per day (L)
Pile & Jacket / Transition Piece Installation	Offshore Installation	1	270	48000
	Heavy Lift Transport	1	108	48000
	Tug	4	270	7455
	Barge	2	270	
Foundation Installation (incl. transport)	Offshore Installation	1	202	48000
	Tug	4	202	7455
	Barge	2	202	
WTG Installation	Offshore Installation	1	279	48000
Cable laying (inter-array & export)	Cable-laying Vessel	1	230	48000
Substation Installation	Offshore Installation	1	14	48000
	Tug	2	14	7455
	Barge	1	14	

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 as such this activity would fall under Scope 3 emissions.

There are not expected to be any material emissions from the purchase of grid electricity during the construction phase of the project.

5.1.2 Operational Phase

The results of the GHG emissions assessment show that estimated annual Scope 1 and 2 emissions from the operational phase of the project are far below 100,000 tonnes and are expected to be approximately 2,288 tonnes CO_2e per year (Table 5-3).

Table 5-3: Annual Scope 1 and 2 GHG emissions during project operation

Asset	Activity Data Type	Quantity	Unit	Emissions Factor ($kg\ CO_2$-e/unit)	tCO_2-e
Scope 1					
Crew Transfer Vessels (CTVs)	Diesel	268,800.00	L	2.70	725.76
CTV Gensets	Diesel	5,644.80	L	2.70	15.24
Helicopter	Aviation Turbine Fuel	255,360.00	L	2.55	651.17
Project Vehicles	Distance	40,000.00	km	0.20	8.12
Onshore Substation / Office	GFA refrigerated space	500.00	m2	5.22	2.61
Offshore Substation / Office	GFA refrigerated space	500.00	m2	5.22	2.61
				Sub-Total	**1405.51**
Scope 2					
Onshore Substation / Office	kWh	100,000.00	kWh	0.42	41.86
Offshore Substation / Office	kWh	100,000.00	kWh	0.42	41.86
WTGs	kWh	1,907,640.00	kWh	0.42	798.58
				Sub-Total	**882.30**
Total					**2,287.81**

The largest contributors to this total are the grid electricity drawn by the WTGs when they are idle (799 t CO_2e), and the operation of Crew Transfer Vessels (726 t CO_2e) and a Helicopter (651 t CO_2e) for servicing and maintenance activities. Other sources of emissions include the generators used on the CTVs when they are stationary (15 t CO_2e), use of project vehicles (8 t CO_2e), and the operation of a combined onshore project office / substation building (42 t CO_2e from grid electricity and 3 t CO_2e from fugitive refrigerants), and the same for an offshore substation building.

It should be noted that Scope 2 emissions, which account for 882 t CO_2e, and 39% of total Scope 1 and 2 emissions, are calculated based on a projected Taiwanese Grid Electricity emissions factor for 2025. However, the Taiwanese government has a plan to reach zero emissions from electricity generation by 2050, and 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 2021 emissions, substantially reduced Scope 2 emissions can be expected from the project over its lifetime, decreasing from 882 t CO_2e in 2025, to just 21 t CO_2e in 2050. This would constituent an approx. 98% reduction in annual Scope 2 emissions and a 37% reduction in total annual operational combined Scope 1 and 2 emissions by 2050. Further emissions reductions from this assessment may occur with the electrification of land and maritime transport, and the use of sustainable aviation fuels.

5.2 Notes, Assumptions and Limitations

As the project does not yet have detailed construction activity data and is not operational, a number of assumptions have been made to estimate annual Scope 1 and 2 emissions during construction and operations. These assumptions, as well as notes and limitations on the GHG assessment are detailed here.

- Emissions Factors for Scope 1 fuel combustion activities and driving distances were taken from the UK DEFRA GHG conversion factors 2022.
- The emissions factor for fugitive refrigerants used in the Onshore Substation / Office air conditioning was calculated assuming the use of R410a refrigerant, with 0.2 kW of cooling per m2, 0.25kg of charge capacity per kW, and an annual leakage rate of 5%.
- Grid emissions factors for 2025 to 2050 were calculated by assuming a linear annual reduction in the grid EF from 0.484 kg CO_2e / kWh in 2021 (data from Harmonised IFI default grid factors 2021 v3.2) to an assumed residual EF of 0.01 kg CO_2e / kWh in 2050, based on the Taiwanese governments plan to have zero emissions from electricity generation by 2050.
- The size of the onshore and offshore substation / office building is based on the people per 100 m2 assumptions for office space from ASHRAE standard 62.1-2013, and the expert input of project engineers on the required O&M staffing levels for the project.
- The energy usage intensity of the substation / office building is assumed to be 200 kWh/m2/year, from the CRREM energy intensity assumptions for office buildings in Hong Kong (data for Taiwan was unavailable, and Hong Kong has a similar climate).
- The use of Crew Transfer Vessels is calculated from the estimated servicing and repair hours per WTG from similar regional Offshore Wind projects, and assuming that crews are at the windfarm for 7 hours per day, the average travel distance from Changhua port to the centre of the windfarm, and the average fuel consumption of a typical crew transfer vessel. CTVs are assumed to be used for all scheduled servicing and ~20% of repair work.
- The use of Helicopters is calculated from the estimated repair hours per WTG from similar regional Offshore Wind projects, the average travel distance from Taichung Airport to the centre of the windfarm, and the average fuel consumption of a typical crew helicopter. Helicopters are assumed to be used for ~80% of repair work.
- There were assumed to be 2 x Offroad project vehicles each with an annual usage of 20,000km.
- A Power Requirement of 60kVA for idling WTGs was assumed from discussion with an expert project engineer with knowledge of similar projects. The idle / non-operational time per WTG was estimated from the expected servicing and repair schedules from O&M plans from similar projects and expected unfavourable wind conditions 6% of the time.
- Offshore installation vessel fuel usage estimates are based on the assumption that vessels used will be similar to the Sea Challenger vessel[69], and have a fuel consumption of 300 barrels per day (48,000 L per day). The heavy lift transport vessel and cable laying vessel are assumed to have similar sizes and fuel consumption rates.
- It is assumed that two tugs will be required to manoeuvre each barge, and tugs will have a fuel consumption rate of 7,455 L per day. Barges are assumed to have no independent mode of propulsion and as such no fuel combustion.
- 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

[69] Sea Challenger is an offshore installation vessel that was contracted by Orsted for use in the development of the Hornsea Two wind farm in the UK and is scheduled to redeploy to East Asia later this decade. Sea Challenger | DEME Group (deme-group.com)

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)

6 Summary

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.

It should be noted that these measures are assumed at this stage given the lack of available information and the scoring of medium or low should be read with caution given it has not yet been confirmed that Project designs will embed these mitigations. The measures have been based off those which are being embedded in the neighbouring project which is also being developed by Orsted. 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 2,288 tonnes in 2025, falling to approximately 1,427 tonnes in 2050 based on Taiwan’s plan for electricity grid decarbonisation reducing Scope 2 emissions. Annual GHG emissions from fuel combustion during the construction phase are estimated to be approximately 193,526 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..

A. Climate Change Limitations 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. A CCRA was undertaken for the neighbouring Ørsted Group development, Greater Changhua Offshore Wind Farm South East, in 2020 and includes detail on the measures taken into account within the design in relation to climate change. Given Greater Changhua Offshore Wind Farm South East 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 Greater Changhua Offshore Wind Farm South East CCRA has 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 will be applied within the next design phase of 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. However, it should be noted that there are some key differences between the two which may alter what allowances are included such as:
  - Turbine size of this Project is much higher at 14.7MW compared to the 8.1MW turbines within the other project

- This Project is located approximately 50km offshore whereas the other is approximately 37.5km offshore
- Water depths are anticipated to be slightly different where this Project has water depths of between 30m and 45m compared to the other project with between 34m and 44m

As the embedded climate allowance measures have not yet been confirmed for this Project, the CCRA should be read with caution. It is recommended that these measures are reviewed and taken into account within the design to contribute to the Project’s resilience to future climate change. The CCRA should then be reviewed and scored appropriately in line with the measures taken into account.