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Climate Change Impact Assessment to the Proposed Coal Fired Power Plant Project at East Coast of Peninsular Malaysia

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Abstract

Tenaga Nasional Berhad (TNB) exploring possibility to build a coal-fired power plant at the East Coast of Peninsular Malaysia. With the growing awareness of potential challenges that may arise in the future power plants as a result of climate change, TNB has appointed a team which encompasses of Energy Ventures Division (EV), TNB and Tenaga Nasional Berhad Research (TNBR) to conduct Climate Change Impact Assessment to the Proposed Coal Fired Power Plant at the East Coast of Peninsular Malaysia. This study are to provide guideline on how climate change impacts assessment can be carried out, investigate potential climate change threats to be considered in the design of a coal-fired power plant. Potential sites siting for the proposed coal fired plant were assessed whilst literature review on global and local climate change prediction and projection was conducted. Only 3 sites had fulfilled the criteria for a coal fired power plant which only 1 was selected as the Pilot Site (JG5) for this Study. The study had concluded that the climate change had significant impact to the proposed coal-fired power plant. The climate change threats are sea level rise, increase intensity of rainfall and extreme wind to the associated coal-fired power plant design i.e. coal import and handling facilities, shore and flood protection which based A1B scenario outlined in the SRES Storyline of AR4.

Keywords: *Adaption Strategy; Climate Change Impact; Coal Fired Power Plant; East Coast of Peninsular Malaysia*

1. Introduction

Climate change is defined as the changes in the state of climate due to natural variability or as a result of human activities, which persists for an extended period of time. This phenomenon has been happening around the world for the past two to three centuries. Climate change is primarily attributed to emissions of long lived greenhouse gases (GHGs) from human activities, of which emissions have increased rapidly since pre- industrial times back in 1750. Climate change has caused an increase in global average air and ocean temperatures which causes melting of glaciers and ice caps, leading to rising of global mean sea levels. There is no general agreement in scientific, media or policy documents as to the precise term to be used to refer to anthropogenic forced change; either "global warming" or "climate change" may be used [1].

As actual and potential climate change impacts become more apparent, adaptation to climate change is growing in importance. Recognizing the urgency of responding to climate change, Tenaga Nasional Berhad (TNB) has initiated studies to include climate change impacts assessment as part of the planning for the coal-fired power plant to reduce exposure and increase resilience to the potential adverse climate change impacts such as sea level rise, changes in the frequency and intensity of storms, increase in rainfall intensity and temperature.

Coal power, an established electricity source that provides vast quantities of inexpensive, reliable power has become more important. Although combined cycle gas turbines were the most competitive form of generation for baseload based on current domestic gas prices, coal fired plants are expected to take over as the cheapest option for baseload, with over 60% of generation expected to be from coal in 2019 before dropping back with power imports from Sarawak and nuclear. All of the coal-fired power plants in Malaysia are currently concentrated at the West Coast of Peninsular Malaysia [2].

The energy demand at the East Coast of Peninsular Malaysia is expected to increase with the advent of the East Coast Economic Region (ECER) launched as one of the three economic corridors in the Peninsular. To meet the forecasted energy demand, Tenaga Nasional Berhad (TNB) has ventured into the possibility of locating the coal-fired power plants along the coastline of the East Coast but was shelved due to the monsoon related factors and risk.

2. Methodology

2.1. Literature Review on Climate Change Model

In 1992, the IPCC released emission scenarios IS92 (1992 Supplementary Report to the IPCC Assessment) to be used for framing global circulation models, embodying a wide array of assumptions affecting how future GHG emissions might evolve based on varying levels of population growth, economic growth, and fossil fuel usage. The IPCC 4th Assessment Report (AR4) was developed based on the Special Report on Emission Scenarios (SRES 2000) as a progression of the IS92. The AR4 projects future climatic conditions based on GHGs (Carbon Dioxide, Methane, Nitrous Oxides, Hydrofluorocarbons, Sulphur Dioxide etc.) from anthropogenic activity, and is thus important to be used in this research study. [3]

2.2. Site Selection Process

A site selection identification process was carried out to choose onshore land areas along the East Coast coastline of Peninsular Malaysia that have suitable physical characteristics for a coal-fired power plant as outlined in Figure 1.

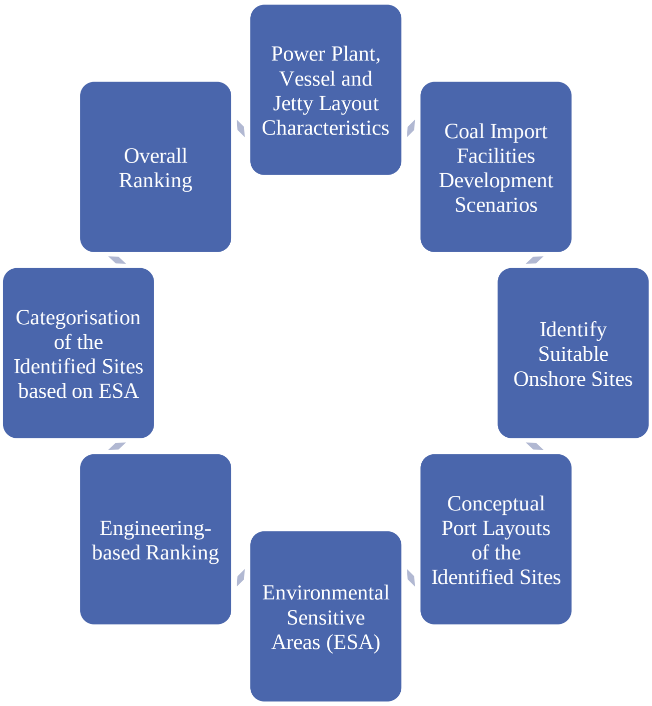

Fig. 1: Site Selection Process

2.2. Climate Change Impact Assessment

A case study on climate change impact assessment was conducted for a pilot Project Site named JG5, The scopes of the study are:
• To conduct a baseline assessment of the existing condition of the Project Site.
• To determine the climate change threats through an analyses of past extreme events and trends (i.e. extreme wind conditions, sea level rise, and flood level).
• To carry out impact assessments through the analyses of the projected climatic threats to the Project Site for defined time slices. The following modelling and analyses were carried out to assess the impact of extreme weather condition to the Project Site:
(a) Hydrological analyses and hydraulic modelling to assess the catchment flooding by considering the climate change impacts on increase in rainfall.
(b) Storm surge modelling by including the impacts of sea level rise and changes in the frequency and intensity of storms.
(c) Air dispersion modelling under various extreme wind speed condition.
• Recommendations on adaptation measures to address the effects of climate change on the following coal-fired power plant related design planning:
(a) Flood protection
(b) Coastline protection
(c) Coal import facilities
(d) Coal handling system
Methodology of climate change impact assessment and the particular potential climate change threats to be considered in the modelling scenarios for the coal-fired power plant are summarized in the following Figure 2 [4].

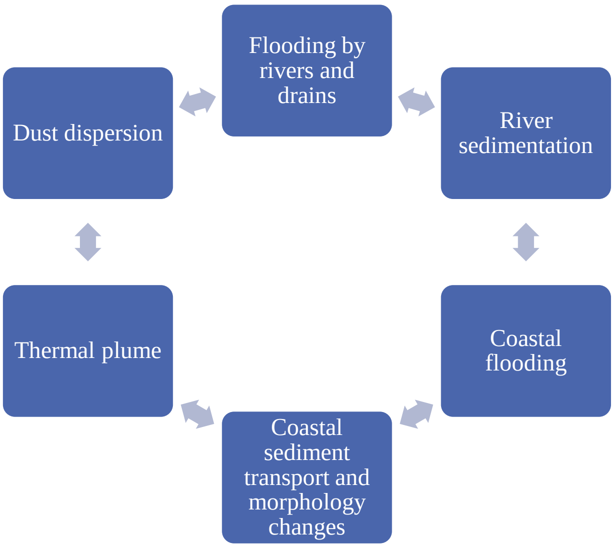

Fig. 2: Climate Change Impact Assessment

3. Result Findings

3.1. Climate Change Model.

The AR4 is primarily characterized by four SRES's storylines and scenario families (A1, A2, B1 and B2); predicting the dynamics of demographic distribution, technology and wealth. The A1 family is further subdivided into 3 scenario groups (A1F1, A1T and A1B) for a total of 6. This is illustrated in Figure 3. A total number of 40 scenarios are covered under all the scenario groups.
A1 represents a scenario of rapid economic growth, with a global population peaking at around 2050 (8.7 billion) and declining to about 7 billion nearing 2100 (based on the International Institute for Applied Systems Analysis 1996, IIASA projections). The premise represents newer and more efficient technologies, with homogeneity across the globe becoming commonplace due to convergence amongst regions, cultural and social interactions, and a gradual reduction in income gaps by region. The sub-scenarios A1F1 represent a more fossil fuel intensive progression of A1, while A1T represents a progression towards non-fossil energy sources. A1B represents a balance of both sources, implying similar improvement rates to all energy supply and end use technologies.
In contrast, A2 represents a heterogeneous progression of the world, emphasizing on self- reliance and preservation of local identities. As the result; cultural and social interactions are reduced, convergence is slowed, and economic growths and economic gaps are maintained at regional rather than global levels. A slow but continuous increase in global population results in a population of about 15 billion by 2100, comparable to the United Nations 1998 high prediction of 18 billion. Technological change is also at a slower pace than the A1 scenario.
B1 represents rapid economic changes towards a service and information industry, reducing the intensity of material demand. Clean and resource efficient technologies pave the way for global solutions, in which the homogeneity described in A1 is actively involved to optimize sustainability and improve equity across the world. B2 indicates a similar awareness to the importance of combating climate change as in B1, but maintaining the heterogeneity as in A2. Thus there is intermediate economic growth at regional levels, coupled with less rapid but more diverse

technological changes as part of local and regional solutions to climate change. The United Nations 1998 prediction expects a population of about 10.4 billion by 2100 following this trend [4].

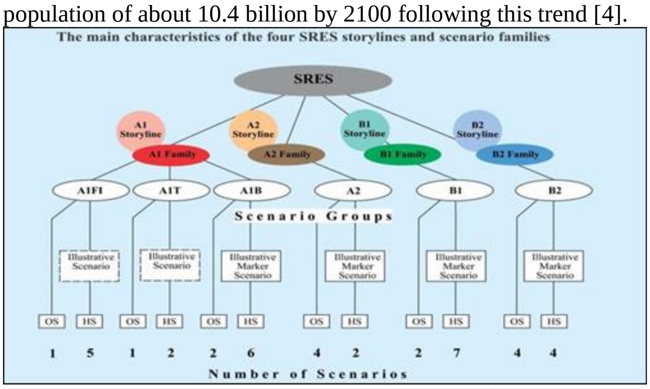

Fig.3: The illustrated storylines and scenarios of AR4 [4]

It is important to note that the IPCC does not attach probabilities of occurrence to any of these scenarios or models. However, research concentrating in and around Peninsular Malaysia mainly focuses on A1B as being the most 'likely' representation for the region. The NAHRIM CCF Guideline utilized downscaled models used by the IPCC during the AR4, such as ECHAM6 (atmospheric circulation model developed by Max Planck Institute for Meteorology, Dutch), MRI-CGCM 2.3.2 (Japan Meteorological Research Institute) and CCSM5 (coupled Global Climate Model by University Corporation for Atmospheric research (UCAR), USA. The publication is useful in projecting future rainfall data for this study, and the most commonly shared scenario between all the aforementioned models is the scenario A1B [5].

3.2. Site Selection Process

This study will provide an initial impression of the possibilities for locating a coal-fired power plant and its associated coal import facilities infrastructure at the East Coast of Peninsular Malaysia. This section presents the final evaluation of the identified sites by combining both the engineering and ESA assessments. Only 3 of the identified sites are generally not constrained by both engineering and ESA factors, thus considered for further evaluation. It is noteworthy that all 3 sites are located in Johor and the areas are out of ECER. Only 1 site (JG5) is selected as the Potential/Pilot Site, which is located in Mukim Sedili Kecil, Daerah Kota Tinggi, Johor. The Project Site is located approximately 2.5 km and 7.5 km north of Tanjung Balau and Bandar Penawar respectively.

3.3. Climate Change Impact Assessment

3.3.1. Climate Change Projection at the Pilot Site (JG5)

Rainfall

From the analysis, it was found that the annual rainfall at JG5 may experience an increasing trend of up to 5.7% as a result of climate change. In terms of monthly rainfall distribution, there may be a redistribution of monsoonal rainfall towards September for the Southwest monsoon, and a possible prolonged Northeast monsoon influence extending into February. However, the monthly rainfall trend analysis also suggest that future monthly rainfall may be less varied on an individual month basis, with a potential up to 10% overall increase. On the other hand, the daily rainfall at JG5 is anticipated to increase by 3.3% to 11.5% in the future under the climate change scenario A1B while the short duration rainfall (less than 1 day) at JG5 is expected to have an increase of 30% in the 100-year ARI design rainfall from the current condition [6].

Sea Surface Temperature

6 sampling stations with 40 years (1976 – 2016) sea surface temperature (SST) data were acquired from MMD. The annual average SST at the Project Site ranged from 26°– 33°C with annual variation of temperature between 0.5°– 4°C. The 40 years' average SST at 6 sampling stations is 28.9°C .The MMD SST historical data was further analysed using a 20-year moving average. The average SST is projected to increase from current 29.1°C to 29.9 °C by year 2050 and to 30.8°C by year 2095.It was stated that by the year 2050, the annual mean SST was predicted to rise by 1.05°C on average in the tropics (Xie et al. 2009). Therefore, the future SST around the Project Site would be between 27.05° – 34.05 °C based on Xie et al. (2009) prediction. Our projected SST using MMD historical data of 29.9°C does lies within that range [7].

Sea Level Rise

The projections of the sea level rise in Malaysia by considering the climate change scenarios in IPCC AR4, were carried out by merging the observed spatial distribution of the sea level change along the Malaysian's coastline with the Atmospheric Ocean General Circulation Models (AOGCM) (NAHRIM, 2010). The mean sea level rise rate projections using SRES A1B scenario at the nearest satellite altimeter to the Project Site (20N 1050E) is shown in Figure 4. The mean of the sea level rise predictions in 2020, 2040, 2060, 2080, and 2100 is presented in Figure 5. The mean sea level rise is predicted using all of the SRES B1, A1B and A2 scenarios and all the available AOGCMs. These SLR projections will be used in this study [8].

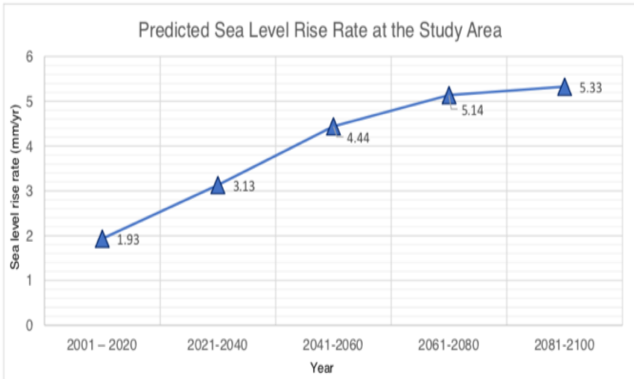

Fig. 4: Mean Sea Level Rise Rate using SRES A1B

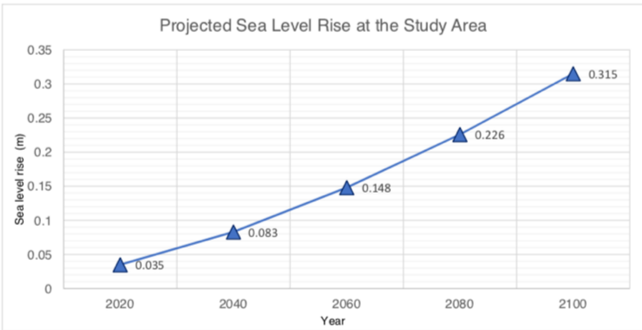

Fig. 5: Mean Sea Level Rise Prediction

Storm Climatology

While rising sea levels will increase water depths along the coastline, which will in turn result in greater potential for wave and surge propagation further inland, there may also be increased intensity and frequency of large coastal storm events that are induced by changing climate. Wind contributes a major role in the climate system having direct implications on coastal processes such as wave setup during extreme weather events, coastal flooding and coastal morphological changes. However, there are limited literatures connecting climate change to wind projection. The published study by ESCAP/WMO Typhoon Committee Secretariat at Western North Pacific (WNP) was the closest to South China Sea and was adopted in this study.As such, based on the literature, the frequency of the TC in Malaysia is expected to be on a decreasing trend. The increase of 18% in the wind speed intensity was adopted in this study as the future worst case storm scenario. The future wind speed series has the mean and maximum wind speeds of 15.22 m/s and 20.46 m/s, respectively [9].

3.3.2. Climate Change Impact at the Pilot Site (JG5)

Coastal Flooding

The following can be deduced from the model output:

• Under the highest historical storm surge scenario (Scenario A), the simulated maximum flood depth is 0.6 m and limited to the waterfront areas of the Project Site only. Hence, the vulnerability concerns under current climate conditions are mostly focused on the waterfront areas.

• Under the 100-year ARI wind series with intensified wind (Scenario F), the simulated maximum flood depth increase to 0.8 m along the waterfront areas of the Project Site. The extent and depth of flooding increases with greater sea level rise. The maximum flood depth under the 100-year ARI wind series with the projected sea level rise (SLR) scenario in 2100 (Scenario J) increase to 1.0 m along the waterfront areas.

• Under future storm scenario (Scenario K), the impact changes quite drastically. Flooding at the Project Site is no longer limited to the waterfront area but resulting in more extensive inland flooding with maximum flood depth of 1 m within the Project Site. The flooding conditions become severe when the future storm scenario coincide with the sea level rise. The maximum flood depth can be up to 1.3 m within the Project Site when coincide with the projected SLR scenario in 2100 (Scenario O).

• Tropical cyclone Vamei did not cause significant flooding to the Project Site. The maximum flood depth during Vamei scenario is only about 0.1 m at the waterfront area (Scenario P).

Waves

The following can be deduced from the model output:

• Under the highest historical storm scenario (Scenario A), the maximum significant wave height of 1.8 m can be predicted at the coast of the Project Site. Under the 100- year ARI (Scenario B) and future storm scenarios (Scenario C), the maximum significant wave height can reach up to 2.0 m and 2.2 m, respectively at the coast of the Project Site.

• The significant wave height is predicted to increase approximately 0.4 m at the Project Site due to the intensification of the winds resulting from climate change, under the current study scenarios

Coastal Morphology

The following can be deduced from the model results:

• Under the existing climate condition (Scenario A), model simulations show that the maximum annual erosion and deposition rates near the coastline of the Project Site are 0.8 m and 0.6 m, respectively. The wave causes erosion at the upper beach and deposition at the lower beach.

• Under the future climate condition with intensified winds (Scenario B), the simulated maximum annual erosion and deposition rates would increase to 1.0 m and 0.8 m, respectively. This corresponds to 0.2 m/yr increase due to intensified wind under climate change.

• Under the projected SLR scenario by 2100 (Scenario F), the simulated maximum annual erosion and deposition rates are 0.8 m and 0.6 m, respectively. However, the erosion and deposition extent increases.

• The form of a shoreline depends strongly on the wave characteristics it is exposed to. With intensified wind, larger waves will be generated and erode the upper beach and push the eroded sediment to the lower beach, as evidenced by the bigger extent of erosion and deposition zone.

River Flooding

Comparing the changes in water levels of different scenarios, it may be concluded that climate change has a larger impact on Sg Tengah itself, compared to the floodplains within the Project Site. Flooding within the Project Site is also observed to be localized due to the various sources of floodwaters and changes of ground levels within the Project Site. Different adaptation measures is recommended to cater for the differing flooding characteristics within the Project Site. The maximum flood extent is shown in the following Table 1.

Table 1: Maximum Flood Extent

Scenario	Maximum Flooded Area % of Project Site)	Scenario	Maximum Flooded Area (% of Project Site)
1a	20.5	4a	26.9
1b	20.8	4b	39.7
2a	20.6	5a	38.2
2b	21.9	5b	54.4
3a	30.5	6a	41.9
3b	32.1	6b	55.7

River Sediment

In the vicinity of the Project Site, Sg Tengah is the only sizable river that may carry significant amount of sediment. The other catchments from Culvert 1 to Culvert 10 (Sg Tanjung Balau) are very small catchments with mainly agriculture land use and hence not expected to carry high sediments. Subsequently, an assessment was carried out to evaluate the sediment yield from the Sg Tengah river catchment.

The land use within Sg Tengah catchment is largely oil palm plantations with apparently good management practices and no significant land erosion activities were observed. Based on the observed river water quality during the site visits, the existing TSS level is less than 100 mg/l. With the estimated annual flows, the annual sediment discharge for Baseline and Climate Change scenarios were computed. The annual sediment discharge is estimated to be 3,270 tonnes for existing condition and increases to 4,485 tonnes under climate change condition. Despite the 37% increment in the sediment discharge due to climate change factor, the sediment discharge is still very low and not likely to cause significant river sedimentation. The sediment loading to the coastal area is also quite insignificant as compared with the littoral transport and the simulated sea bed level changes.

Nevertheless, the above estimation is based on existing catchment land use which generates little sediment outflow. If the oil palm plantations were to be developed with large scale land clearing, serious soil erosion and high sediment outflows may take place. Although river management and control comes under the Government agencies, it is recommended that TNB shall monitor the condition of Sg Tengah and all other waterways in the vicinity of the Project Site. Adverse river conditions shall be reported to the authorities to prevent escalating negative impacts.

Dust Dispersion

The wind rose of the project site is plotted and shown in the Figure 6;

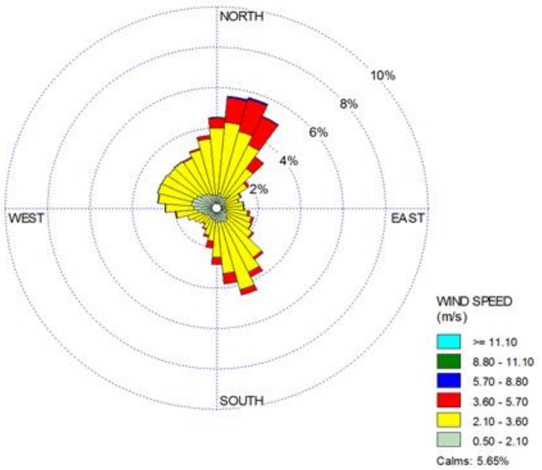

Fig.6: Wind Rose of the Project Site

The most frequent wind direction is from the north-northeast sector with average wind speeds of between 2.1 m/s and 5.7 m/s with speed reaching 8.8 m/s on some occasions. Winds from the south-southeast sector is also frequent with slightly weaker wind speeds. The least frequent wind direction is from the southwest sector. Dispersion modelling of PM10 emissions from potential sources of a coal fired power plant which consist of stack emissions, coal handling and coal stockpiles showed that PM10 concentrations in ambient air are within the Department of Environment Malaysian Ambient Air Quality Guideline limits of 100 ug/m3 for the maximum 24-hour average concentration and 40 ug/m3 for the annual average concentration [10].

Seasonally, higher concentrations occur during the Southwest Monsoon season and the most affected areas are different for different seasons mainly due to changes in the wind speed and prevailing wind direction.

Comparison of different coal yard alignments and coal stockpile heights showed that PM10 concentrations are dependent on the distance of the receptors to the coal yard, the closer the receptor, the higher the concentration and vice-versa. With different stockpile heights, concentrations are lower with higher stockpile height. However, this is only evident for receptors close to the coal yard. Tabulated in Table 2 and Table 3 are the predicted incremental PM10 concentrations at the discrete and sensitive receptors for different coal yard alignments and coal stockpile heights [11].

Table 2: Maximum 24-hour Average PM10 Incremental Concentration (ug/m3)

Receptor	Alignment 00 deg.		Alignment 15 deg.		Alignment 30 deg.	
	7m	9m	7m	9m	7m	9m
S1	4.2	3.5	5.0	3.7	6.8	4.1
S2	4.1	4.0	4.0	3.9	4.0	3.9
S3	3.4	3.4	3.4	3.4	3.4	3.4
S4	4.8	4.4	4.6	4.2	4.4	4.0
S5	4.5	4.4	4.5	4.4	4.6	4.4
S6	3.9	4.0	4.2	4.4	4.5	4.6
S7	2.2	2.2	2.2	2.2	2.2	2.2
MAAQG	100					

Table 3: Annual Average PM10 Incremental Concentration (ug/m3)

Receptor	Alignment 0 deg.		Alignment 15 deg.		Alignment 30 deg.	
	7m	9m	7m	9m	7m	9m
S1	0.9	0.8	0.9	0.8	0.9	0.8
S2	1.0	0.9	0.9	0.9	0.9	0.9
S3	0.9	0.9	0.9	0.9	0.9	0.9
S4	0.8	0.7	0.8	0.7	0.8	0.7
S5	0.7	0.6	0.7	0.6	0.7	0.6
S6	1.1	1.1	1.1	1.1	1.1	1.1
S7	0.5	0.5	0.5	0.5	0.5	0.5
MAAQG	40					

For cases when there are highest wind gusts, short term maximum 1-hour average PM10 concentrations are above the MAAQG 24-hour average concentration limit of 100 ug/m3. However, over a longer period, which is the 24-hour average, concentrations are below the MAAQG limit.

4. Conclusion

Climate change adaptation measures are important element that deserved special attention from the power plant designer. Climate change can give rise to high impacts such as destruction of assets and loss of human life. Although risks cannot be fully eliminated, adaptation of climate change factor in future plans and development of power stations are very important to reduce exposure and increase resilience to the potential adverse impacts of climate extremes.

The following threats are identified as the most significance to the coal fired power plant design at the Project Site:

• Increase in rainfall – Based on the NAHRIM Technical Guide: Estimation of Future Design Rainstorm under the Climate Change Scenario in Peninsular Malaysia (2013), the 100-year ARI design rainfall around the Project Site is predicted to increase by 30% from the current condition .

• Sea level rise – The sea level around the Project Site coastline is predicted by NAHRIM (2010) to rise with a mean of 0.083 m, 0.148 m, 0.226 m and 0.315 m in 2040, 2060, 2080 and 2100, respectively.

• Increase intensity of extreme wind – Wind contributes a major role in the climate system having direct implications on coastal processes such as wave setup during extreme weather events, coastal flooding and coastal morphological change. However, there are limited literatures connecting climate change to wind projection. A published study by ESCAP/WMO Typhoon Committee Secretariat (TCS) indicated that the changes in maximum wind speeds at Western North Pacific (WNP) ranged from - 3% to +18%. This study area was the closest to South China Sea.

Through this climate change study, the research team had integrated the climate change factors into the design of the proposed coal-fired power plant at East Coast of Peninsular Malaysia particularly at the JG5 Site. To date, coastal power plant has been designed with the assumption that the average and extreme conditions observed in the past will continue throughout the design life of the plant. As the threat and impact of climate change becomes better understood, it is increasingly clear that this assumption is contested. There has been complex feedback loop on the impact of climate change affecting the energy sector and posing risks to future infrastructure investments within design lifetimes.

Engineers and plant designers need to acknowledge that the design of the power plant must better reflect an increasingly dynamic and uncertain future under a warming climate. However, the challenge is to determine which climate change threats pose tangible risks to the future power plant, what adaptation response is required and how best to phase adaptation in order to minimise the incremental investment required.

5. Acknowledgement

The production of this research's report would not have been possible without the support of Tenaga Nasional Berhad (TNB) and the specialist collaborators from TNB Research Sdn. Bhd., Technical Review Committee (TRC), COE (Projects), Energy Venture Division, TNB and my supervisor. The authors are very grateful for the cooperation and support from all parties involved.

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