Oakajee Power Station

AIR QUALITY IMPACT AND GREENHOUSE GAS ASSESSMENT

- Rev 1
- 29 June 2010
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LIMITATIONS STATEMENT

The sole purpose of this report and the associated services performed by Sinclair Knight Merz (‘SKM’) is to provide atmospheric dispersion modelling and greenhouse gas estimates in connection with the potential development of a 30 megawatt (MW) power station at Oakajee Industrial Estate on behalf of Oakajee Port and Rail (‘the Client’). The services were provided in accordance with the scope of services set out in the contract between SKM and the Client. That scope of services, as described in this report, was developed with the Client.

Modelling and forecasting is not a precise science. Forecasts are only an indication of what might happen in the future and they may not be achieved. They rely upon complex sets of input data and assumptions. There is no guarantee that these assumptions will in fact be correct or accurate and there are numerous factors which can influence the actual impact of the project, many of which are beyond the control or reasonable foresight of the forecaster, for example, extreme weather events. Whilst the risk of inaccuracies cannot be eliminated, it can be reduced through a detailed process, including, but not limited to the adoption of reasonable assumptions, the use of accepted modelling standards and techniques, peer review and appropriate sensitivity testing. This process, in particular the key assumptions, applied by SKM for the purposes of this report were discussed and agreed with the client at various stages of the report.

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SINCLAIR KNIGHT MERZ
EXECUTIVE SUMMARY

Oakajee Port and Rail (OPR) is investigating power supply options for the Oakajee Port development. This report considers the option of a gas fired 30 megawatt (MW) station with a 2 MW diesel backup unit. Sinclair Knight Merz (SKM) was requested to conduct an air quality impact assessment and greenhouse gas assessment of this option together with an assessment of the greenhouse gas impact of land clearing for the port development to assist the proposal in obtaining regulatory approval.

Air Quality

The Air Pollution Model (TAPM) was the model used to predict air quality impacts in this assessment. Nitrogen dioxide (NO₂), sulfur dioxide (SO₂) and particulate matter (PM) were assessed to be the key air quality impacts from the proposed power generation setup. The concentrations of the modelled pollutants were compared with criteria from the National Environmental Protection Measures for Ambient Air Quality (NEPC 2003) and the World Health Organisation (WHO) Air quality guidelines for Europe, 2nd edition (WHO 2000).

Stack parameters and emission estimates for NO₂ and PM were based on supplier published data for Siemens SGT-700 (gas) and Caterpillar 3516B (diesel) units. SO₂ emissions were derived from AP-42 emission factors (US EPA 1996). Potential PM impacts were evaluated using a screening level model (AUSPLUME) and found to be unlikely to have a significant impact (Appendix A).

Emissions from the gas turbine were compared to WA EPA and NSW emission standards which show the modelled gas turbine meets Australian emission standards. The modelled diesel generator exceeds some of the NSW emission targets, however, it is believed this will provide the model with a conservative emission rate given a specific generator unit has not being selected at this stage.

TAPM generated meteorological data was used for the modelling and verified against Bureau of Meteorology (BoM) data to confirm suitability for modelling.

The model results show the backup diesel generator will have a larger impact than normal operation of the gas turbine. No exceedences of any criteria were predicted for any pollutants at any location in the model grid.

Greenhouse Gas

An assessment of greenhouse gas (GHG) emissions associated with the proposed power station and land clearance for port construction was conducted as an inventory of future emissions expressed as total mass of CO₂ equivalent per annum. The National Greenhouse Accounts (NGA) Factors (DCC 2009a) reference manual prepared by the
Department of Climate Change (DCC) was used to calculate GHG emissions in this assessment.

This assessment only considered the GHG emissions directly associated with power generation and land clearing. The following activities have therefore been excluded from this assessment:

- transport of raw materials and energy by contractors to the Oakajee Power Station
- transmission of generated electricity
- travel by personnel outside of sites (for example, business travel, company vehicles), except as noted above
- transport and disposal of generated waste off-site
- port operations e.g. diesel consumption of vehicles/ships/machinery for operations.

Fuel used for the power station is expected to generate 133.3 kilotonnes CO$_2$-e per annum and land clearing for the port is predicted at 33.27 kilotonnes CO$_2$-e per annum. As such both exceed the National Greenhouse and Energy Reporting Act 2007 (the NGER act) threshold and therefore OPR would be required to register and report on GHG emissions.
# CONTENTS

1. Introduction 1
   1.1. Project Background and Overview 1
   1.2. Overview of this Report 1

2. Study Objectives 3
   2.1. Air Quality Modeling 3
   2.2. Environmental Impact Assessment and Reporting 3

3. Air Pollutants and Effects 5
   3.1. Overview 5
   3.2. Oxides of Nitrogen 5
      3.2.1. Human Health Impacts (NOX) 5
      3.2.2. Environmental Impacts (NOX) 5
   3.3. Sulfur dioxide 6
      3.3.1. Human Health Impacts (SO2) 6
      3.3.2. Environmental Impacts (SO2) 6
   3.4. Airborne Particulate Matter 6
      3.4.1. Human Health Impacts (PM) 6
      3.4.2. Environmental Impacts (PM) 7
   3.5. Summary of Compounds Assessed in This Study 7

4. Air Quality Objectives 8
   4.1. Overview 8
   4.2. Ambient Air Quality Criteria 8
   4.3. Ambient Ground-level Guidelines for Vegetation 9

5. Greenhouse Gases and Climate Change 10
   5.1. Greenhouse Gases 10
      5.1.1. Impact on Climate 10
      5.1.2. Australian Context 11
   5.2. Study Boundaries 11
   5.3. Greenhouse Gas Emissions 13
      5.3.1. Power Generation 13
      5.3.2. Vegetation Removal (loss of carbon sink) 14
      5.3.3. Greenhouse Gas Summary 15

6. Modelling Methodology 16
   6.1. Dispersion Model Selection 16
      6.1.1. Model Description 16
6.1.2. Model Limitations
6.2. Model Setup
6.3. Emission Information
6.4. Other Emission Sources
6.5. Building Characteristics
6.6. Meteorology
6.7. Topography
6.8. Conversion of NO\textsubscript{X} to NO\textsubscript{2}
6.9. Assessing Model Uncertainty

7. Model Results
7.1. Model Uncertainty
7.2. Model Accuracy

8. Conclusions
8.1. Ambient Air
8.2. Greenhouse Gas

9. References

Appendix A PM Screening Assessment
Appendix B Power Generation Technical Specifications
Appendix C Pollution Concentration Isopleth Plots
Appendix D TAPM files
  D.1 .LIS File
  D.2 .PSE File
  D.3 .BLD File
Appendix E Statistical Calculations
## DOCUMENT HISTORY AND STATUS

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1. INTRODUCTION

1.1. Project Background and Overview

Oakajee Port is a proposed deep water port development approximately 24 km north of Geraldton (see Figure 1-1). The port has a nominal throughput of 45 million tonnes per annum of bulk iron ore product. Oakajee Port and Rail (OPR) are investigating power supply options for the facility. One option is a gas fired 30 megawatt (MW) station with a 2 MW diesel backup unit. Sinclair Knight Merz (SKM) was requested to conduct an air quality impact assessment and greenhouse gas assessment of this option together with an assessment of the greenhouse gas impact of land clearing for the port development to assist the proposal in obtaining regulatory approval.

1.2. Overview of this Report

The proposed power station has the potential to impact on local sensitive receptors in and around the Geraldton region. SKM has been commissioned to estimate and quantify potential air quality impacts from the power station emissions. Based on emissions data the primary pollutants of concern from the development are nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) arising from combustion processes at the station. Other pollutants of note include particulate matter (PM) from diesel combustion.

The report is structured as follows:

- a review of air quality standards and criteria (Section 4)
- estimation of greenhouse gas emissions from power generation and land clearance (Section 5)
- discussion on model inputs and model methodology (Section 6)
- model results and conclusions (Sections 7 and 8).
Figure 1-1 Regional Map (OPR 2009)
2. STUDY OBJECTIVES

2.1. Air Quality Modeling

Atmospheric dispersion or air quality modelling is a mathematical simulation process by which emissions from a source are forecast to disperse through the atmosphere under specified meteorological conditions. This enables the linking of environmental and health criteria to air emissions. The quality of source-specific characteristics, meteorological data and model parameters and optimisations affects the accuracy of such predictions.

The emissions from the proposed power station were modelled using a dispersion model appropriate for the location and pollutant types (see Section 6.1 for a discussion of the dispersion model selected for this study). This document reports the findings of the modelling process by including or addressing the following:

- a full description of the air dispersion model selected for this study
- a discussion of the model’s suitability for the study location, including a discussion on the limitations and accuracy of the model’s results
- selection of appropriate model input parameters based on the proposed output parameters of the power plant including:
  - stack height
  - stack diameter
  - stack emission exit temperature
  - emission exit velocity
  - emission volume flow rate
- a full year of representative hourly meteorological data processing
- presentation of dispersion modelling results as contour plots of ground-level concentrations.

2.2. Environmental Impact Assessment and Reporting

This report also includes an assessment of the impacts associated with the proposed development and predicts the likelihood of the occurrence of any exceedences of the assessment criteria (as discussed in Section 4). The concentrations of the modelled pollutants are compared with the National Environmental Protection Measures for Ambient Air Quality (NEPC 2003) for impact on human health, and the World Health Organisation...
(WHO) *Air quality guidelines for Europe, 2nd edition* (WHO 2000). This assessment is focused on compliance of criteria and guidelines outside the Oakajee Industrial Estate buffer zone where the nearest receptors are expected to be.

Additionally, an assessment of greenhouse gas (GHG) emissions directly associated with the proposed power station and land clearance for port construction was conducted as an inventory of projected future emissions expressed as total mass of CO₂ equivalent per annum. This information includes the methodologies by which estimates were made. The GHG emissions assessment was undertaken with due consideration of relevant protocols, agreements and strategies (see Section 5 for the relevant discussion).
3. AIR POLLUTANTS AND EFFECTS

3.1. Overview

The key atmospheric pollutants identified for the modelling include all pollutants that may be deemed to cause a human health effect or an environmental impact. The pollutants addressed in this section are considered the most relevant to the assessment based on the nature of the works to be undertaken during the overall development and operation of a potential Oakajee Power Station. These pollutants are listed in the National Environment Protection (Ambient Air Quality) Measure (NEPC 2003) (Ambient Air Quality NEPM) for which national standards have been prescribed.

3.2. Oxides of Nitrogen

‘Oxides of nitrogen’ (NO\textsubscript{x}) is the collective term for nitric oxide (NO), nitrogen dioxide (NO\textsubscript{2}) and nitrous oxide (N\textsubscript{2}O). NO\textsubscript{x} is formed naturally by the high voltage discharges occurring in lightning and by the oxidation of ammonia. The main anthropogenic source is the combustion of fossil fuels, primarily in urban areas from automobiles and electricity production. Power stations produce NO\textsubscript{x} from high temperature combustion promoting the reaction of atmospheric nitrogen and oxygen (USEPA 1996).

3.2.1. Human Health Impacts (NO\textsubscript{x})

NO\textsubscript{2} is a pungent, brown, acidic, highly corrosive gas that causes significant impacts to human health. NO\textsubscript{2} can have detrimental effects on the human respiratory tract, leading to increased susceptibility to asthma and respiratory infections. Nitrate ions (NO\textsubscript{3}\textsuperscript{-}) oxidises iron in the blood rendering it incapable of carrying oxygen.

3.2.2. Environmental Impacts (NO\textsubscript{x})

Vegetation is adversely affected by exposure to NO\textsubscript{x} at very high concentrations through retarded growth rates and crop yields. N\textsubscript{2}O is a GHG, trapping long wave radiation emitted by the earth and warming the atmosphere (see Section 5 for a more comprehensive discussion on the link between GHGs and climate change). NO\textsubscript{x} is also one of the main contributors to ozone production and can also contribute to acid rain by the formation of nitrous and/or nitric acid in airborne water droplets.
3.3. **Sulfur dioxide**

Sulfur dioxide (SO$_2$) is a colourless gas with an irritating odour that can contribute to or exacerbate respiratory illnesses (such as asthma or bronchitis), especially in elderly or young people.

### 3.3.1. Human Health Impacts (SO$_2$)

SO$_2$ has also been linked with the aggravation of existing heart and lung diseases. SO$_2$ can attach itself to small ambient particulates which can then be inhaled deeply into the lungs. This can intensify the health effects of SO$_2$.

### 3.3.2. Environmental Impacts (SO$_2$)

SO$_2$ can also have detrimental effects on the environment by contributing to the formation of acid rain which damages crops, ecosystems, monuments and historic buildings.

3.4. **Airborne Particulate Matter**

Airborne or suspended particulate matter is typically defined by its size, chemical composition or source. Particles can also be defined by whether they are primary particles (such as a suspension of the fine fraction of soil by wind erosion, sea salt from evaporating sea spray, pollens or soot particles from incomplete combustion) or secondary particles (such as are formed from gas to particle conversion of sulfate and nitrate particles from SO$_2$ and NO$_x$).

For the assessment of impacts to human health arising from ambient exposure, particulate matter is characterised by its size. The particulate size ranges specified in ambient air criteria are total suspended particulate (TSP), particulate matter less than 10 microns (µm) in aerodynamic diameter (PM$_{10}$) and particulate matter less than 2.5 µm in aerodynamic diameter (PM$_{2.5}$).

#### 3.4.1. Human Health Impacts (PM)

The principal health effect of particulates is the exacerbation of pre-existing respiratory problems. The population groups that are most susceptible include the elderly, people with existing respiratory and/or cardiovascular problems and children. The majority of particles greater than 10 µm in aerodynamic diameter do not pass further than the upper respiratory tract (nose and throat). Health impacts are most severe from the fine 2.5 µm particles that penetrate deeper into the respiratory system.
3.4.2. Environmental Impacts (PM)

Particulate matter can also enhance some chemical reactions in the atmosphere and reduce visibility. The deposition of larger particles can have the following consequences:

- staining and soiling surfaces
- aesthetic or chemical contamination of water bodies or vegetation
- effects on personal comfort, amenity and health.

3.5. Summary of Compounds Assessed in This Study

- NO$_X$ and SO$_2$ are expected to be the primary emissions from the proposed power station. PM has been assessed with a screening model (Appendix A) to demonstrate the minimal impact operations are expected to have on ambient concentrations.

- Background concentration data for NO$_X$ and SO$_2$ has not been included in this assessment as there is no existing industry in the region. While PM$_{10}$ background data is available, the PM screening model demonstrates the low impact expected from a 2 MW diesel generator. Thus, this background has not been included in assessment.
4. **AIR QUALITY OBJECTIVES**

4.1. **Overview**

The Environmental Protection Authority of Western Australian (WA EPA) requires that ‘all reasonable and practicable means should be used to prevent and minimise the discharge of waste’ (EPA 2000). For new development proposals the WA EPA requires an assessment of the best available technologies for minimising the discharge of waste from the processes and justification for selection of the adopted technology.

4.2. **Ambient Air Quality Criteria**

The WA EPA requires that air pollutants meet the national environment protection standards of the Ambient Air Quality NEPM (NEPC 2003). This NEPM was created to provide a benchmark against which ambient air quality may be assessed for the protection of human health. The criteria were developed by taking into account current information regarding health-related air pollution research from around the world and available information on the state of Australia’s major airsheds.

As NEPM standards are intended to apply to general ambient air in both urban and regional areas, the pollutants of most concern identified for inclusion in the Ambient Air Quality NEPM were determined to be O₃, NO₂, particulates (as PM₁₀), carbon monoxide (CO), SO₂ and lead (Pb). In 2003 the NEPM was extended to include an advisory reporting standard for particulates as PM₂₅ to collect data for future management strategies.

The WA EPA and Department of Environment and Conservation (DEC) routinely apply these NEPM standards and goals in WA. The WA EPA proposes to incorporate the NEPM standards in a State Environmental Policy (SEP) which would apply across all areas of WA (excluding industrial areas and residence free buffer zones) (Government of Western Australia 2009). As such, and in the absence of other standards relevant to WA, it is considered appropriate to use these standards as the criteria for comparison in this air quality assessment. As detailed in Section 3.5, NO₂, SO₂ and PM are the relevant pollutants for this assessment. The NEPM criteria for NO₂, SO₂ and PM are listed in Table 4-1.
Table 4-1 National Environment Protection Standards used as assessment criteria

<table>
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<tr>
<th>Pollutant</th>
<th>Averaging Period</th>
<th>Maximum Concentration</th>
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<tbody>
<tr>
<td>NO₂</td>
<td>1-hour</td>
<td>120 ppb</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>30 ppb</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>24-hour</td>
<td>50 µg/m³</td>
</tr>
<tr>
<td></td>
<td>24-hour</td>
<td>25 µg/m³</td>
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<tr>
<td>PM₂.₅</td>
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<td>8 µg/m³</td>
</tr>
<tr>
<td></td>
<td>1-hour</td>
<td>200 ppb</td>
</tr>
<tr>
<td>SO₂</td>
<td>24-hour</td>
<td>80 ppb</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>20 ppb</td>
</tr>
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</table>

4.3. Ambient Ground-level Guidelines for Vegetation

As well as having an impact on human health, many pollutants also impact on vegetation which has indirect implications for human wellbeing. The World Health Organisation (WHO) has provided guidelines for the protection of vegetation from the direct effects of gaseous SO₂, NOₓ and O₃ (WHO 2000). The guidelines for the pollutant of interest for this project, NOₓ (as NO₂) and SO₂ are listed in Table 4-2.

Table 4-2 WHO air quality guidelines for the protection of vegetation

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Vegetation Category</th>
<th>Averaging Period</th>
<th>Guideline (ppb)</th>
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<tr>
<td>NOₓ</td>
<td>All vegetation</td>
<td>24-hour</td>
<td>39.9</td>
</tr>
<tr>
<td></td>
<td>All vegetation</td>
<td>Annual</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>Lichens</td>
<td>Annual</td>
<td>3.8</td>
</tr>
<tr>
<td>SO₂</td>
<td>All vegetation</td>
<td>24-hour</td>
<td>39.9</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>15.9</td>
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In addition to direct impacts on vegetation, NOₓ can affect vegetation through the deposition of nitrogen on the soils adding to soil nitrogen levels and the acidification of rain, mists and fogs. However, deposition of nitrogen and associated changes in soil acidity are beyond the scope of this air quality study. Comparison will therefore only be made to the WHO guidelines for direct effects on vegetation in Table 4-2 to indicate the acceptability of the impacts.
5. GREENHOUSE GASES AND CLIMATE CHANGE

5.1. Greenhouse Gases

GHGs are found naturally in the atmosphere. They absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation, which is emitted by the Earth’s surface, the atmosphere and clouds. This re-emission property results in what is known as the ‘greenhouse effect’, which traps heat within the surface-troposphere system and increases the Earth’s average surface temperature (Baede 2007).

The primary GHGs in the atmosphere are water vapour (H2O), CO2, N2O, CH4 and O3, although human-made or anthropogenic gases such as sulfur hexafluoride (SF6), hydroflurocarbons (HFCs) and perfluorocarbons (PFCs) are recognised as playing an increasingly important role in impacts on climate (Baede 2007).

5.1.1. Impact on Climate

An increase in the concentrations of GHGs in the atmosphere leads to an increased infrared opacity of the atmosphere, and hence to radiative forcing¹ and an increase in the greenhouse effect – sometimes known as the enhanced greenhouse effect. The enhanced greenhouse effect, in turn, influences the state of the climate by changing its properties, which over time leads to climate change (Baede 2007). Although this process may occur naturally, any further reference to ‘climate change’ in this report will refer to a change in climate ‘which is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability’, as defined by the United Nations Framework Convention on Climate Change (UNFCCC undated). Such change is brought about through the emission of GHGs into the atmosphere by human activity.

The individual properties of GHG species have different effects on radiative forcing, depending on their global warming potential (GWP). GWP is an index measuring the radiative forcing of a unit mass of a given well-mixed GHG in today’s atmosphere relative to that of CO2. The GWP represents the combined effect of the differing times that these gases remain in the atmosphere as well as their effectiveness in absorbing outgoing thermal infrared radiation (Baede 2007). The GWPs of the GHGs pertinent to this study are summarised in Table 5-1. This table shows two datasets: the National Greenhouse

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¹ ‘Radiative forcing’ is defined as the change in the net (downward minus upward) irradiance at the tropopause due to a change in an external driver of climate change – e.g. CO2 concentration (Baede 2007, p. 86)
Accounts (NGA) Factors, which are derived from the Kyoto Protocol accounting provisions (DCC 2009a, p. 51), and the Intergovernmental Panel on Climate Change’s Fourth Assessment Report which is provided for context (Forster et al. 2007, p. 212).

Table 5-1 Global warming potential of GHGs relative to CO₂

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<th>Gas</th>
<th>GWP (NGA Factors)*</th>
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<tr>
<td></td>
<td></td>
<td>20-year</td>
</tr>
<tr>
<td>CO₂</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CH₄</td>
<td>21</td>
<td>72</td>
</tr>
<tr>
<td>N₂O</td>
<td>310</td>
<td>289</td>
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* The GWPs specified by the NGA Factors reference have been used in this assessment.
** The different year values indicate the GWP based on different time integrals with respect to the substance radiative forcing capacity and time-dependant abundance.

5.1.2. Australian Context

The Australian National Greenhouse Strategy ‘maintains a comprehensive approach to tackling greenhouse issues’ and focuses on three main areas: improving awareness of greenhouse issues, limiting the growth of GHG emissions and developing climate change adaptation responses (AGO 1998). Essentially, the National Greenhouse Strategy provides a framework for the implementation of measures that address the three aforementioned action areas.

The Kyoto Protocol aims to address climate change by enforcing binding international GHG emission targets under the United Nations Framework Convention on Climate Change (UNFCCC). The Australian Parliament recognised the significance of climate change through ratification of the Kyoto Protocol on 12 December 2007 (Joint Standing Committee on Treaties 2008). The promulgation of the National Greenhouse and Energy Reporting (NGER) Act in 2007 made provision for a single, national system for the establishment of a GHG emissions and management reporting structure, with the first reporting period occurring between 1 July 2008 and 30 June 2009. Subsequent legislative and policy tools developed to further the aims of the National Greenhouse Strategy and NGER Act include an emissions trading system and the Carbon Pollution Reduction Scheme (CPRS) (DCC 2007). A particularly pertinent publication produced by the Federal Department of Climate Change (DCC) is the National Greenhouse Gas Inventory, which allows for the benchmarking of a facility or entity’s GHG emissions against national emissions (DCC 2009b).

5.2. Study Boundaries

It is important to define those aspects of the Oakajee Power Station that will be included and excluded from this assessment. As with life cycle studies, GHG assessments are able
to follow the cradle-to-grave methodology of investigating the GHG emissions associated with the extraction, manufacturing, production, transportation, use, reuse, recycling and final disposal of a particular product.

The NGA Factors (DCC 2009a) reference manual has been prepared by the DCC, and is designed for use by companies and individuals to estimate GHG emissions for the NGER system. The NGA Factors (last updated in June 2009) have been used to calculate GHG emissions in this assessment.

The NGA Factors recognise three types of emission factors.

1) Direct (or point-source) emission factors give the kilograms of carbon dioxide equivalent (CO₂-e) emitted per unit of activity at the point of emission release (i.e. fuel use, energy use, manufacturing process activity, mining activity, on-site waste disposal, etc.). These factors are used to calculate scope 1 emissions.

2) Indirect emission factors are used to calculate scope 2 emissions from the generation of the electricity purchased and consumed by an organisation as kilograms of CO₂-e per unit of electricity consumed. Scope 2 emissions are physically produced by the burning of fuels (coal, natural gas, etc.) at the power station.

3) Various emission factors can be used to calculate scope 3 emissions. For ease of use, the NGA Factors workbook reports specific ‘scope 3 emission factors’ for organisations that:

   a. burn fossil fuels: to estimate their indirect emissions attributable to the extraction, production and transport of those fuels; or

   b. consume purchased electricity: to estimate their indirect emissions from the extraction, production and transport of fuel burned at generation and the indirect emissions attributable to the electricity lost in delivery in the transmission and distribution (T&D) network.

The definition, methodologies and application of scope 3 factors are currently subject to international discussions (DCC 2009a) and will not be considered in this assessment.

This assessment only considered the GHG emissions associated with power generation and land clearing. The following activities have been excluded from this assessment:

- transport of raw materials and energy by contractors to the Oakajee Power Station
- transmission of generated electricity
- travel by personnel outside of sites (for example, business travel, company vehicles), except as noted above
Air Quality Impact and Greenhouse Gas Assessment

- transport and disposal of generated waste off-site
- port operations e.g. diesel consumption of vehicles/ships/machinery for operations.

5.3. Greenhouse Gas Emissions

5.3.1. Power Generation

The NGA Factors reference manual provides the formula presented in Equation 5-1 to estimate greenhouse gas emissions from combustion

**Equation 5-1**

\[ E_{ij} = Q_i \times EC_i \times EF_{ij,CO2-e}/1000 \]

Where:
- \( E_{ij} \) is the emissions of gas type \( j \), from fuel type \( i \) as CO\(_2\)-e (equivalent) tonnes.
- \( Q_i \) is the quantity of fuel type \( i \) (cubic meters for gas fuel and kilolitres for liquid fuel).
- \( EC_i \) is the energy content factor of fuel type \( i \) as gigajoules per unit volume (GJ/m\(^3\) – gas) (GJ/kL – liquid). If \( Q_i \) is measured in GJ then \( EC_i \) is 1.
- \( EF_{ij,CO2-e} \) is the emissions factor for each gas type \( j \) for fuel type \( i \) as kg CO\(_2\)-e per gigajoule.

The power station has a nominal power rating of 30 MW. Each gas turbine runs at a heat rate of 9.882 GJ/MWh (Appendix B). To maintain a conservative estimate of GHG emission it is assumed the power rating of the station is maintained at a 30 MW output at all times. The NGA Factors provide emission factors for the consumption of natural gas. These are presented in **Table 5-2**.

**Table 5-2 Emission factors for the consumption of combustibles**

<table>
<thead>
<tr>
<th>Fuel combusted</th>
<th>Energy Content Factor</th>
<th>Emission factor (kg CO(_2)-e/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CO(_2)</td>
</tr>
<tr>
<td>Natural Gas distributed in a pipeline</td>
<td>39.3 x 10(^{-3}) (GJ/m(^3))</td>
<td>51.2</td>
</tr>
</tbody>
</table>

Using this data **Equation 5-1** can be solved for gas consumption:

\[ Q_i = 9.882 \times 30 \times 8760 \]
\[ Q_i = 2\,596\,990 \,GJ/\text{annum} \]

\[ E_{ij} = 2\,596\,990 \times 1 \times (51.2 + 0.1 + 0.03)/1000 \]
\[ E_{ij} = 133.3 \text{ kilotonnes CO}_2\text{-e per annum} \]

The use of diesel fuel is not considered in this calculation as the backup unit is not part of normal operations.
5.3.2. Vegetation Removal (loss of carbon sink)

GHG emissions due to land clearing were calculated using the Department of Climate Change (DCC) FullCAM Modelling tool. FullCAM is a fully integrated carbon accounting model for estimating and predicting all biomass, litter and soil carbon pools in forest and agricultural systems.

The proposed works would result a total ground disturbed area of approximately 350 hectares (ha) including 220 ha of remnant vegetation, 90 ha of agricultural land, and 40 ha of land otherwise cleared or bare sand of a dune blowout. According to the Oakajee Port and Rail, Terrestrial Port Development Referral Document (OPR 2009) the 220 ha of remnant vegetation which would be disturbed as part of the construction works hosts a number of native species including Melaleuca huttensis, Acanthocarpus parviflorus, Blackallia nudiflora, Grevillea triloba, Lasiopetalum oppositifolium and Verticordia penicillaris. Agricultural land within the study area is primarily used for cropping (wheat and lupins) and some grazing of livestock.

Tree and crop species and management information are contained in FullCAM databases as developed by the National Carbon Accounting System (NCAS). This database currently does not contain native species and regime information for the Oakajee region. Therefore for the purpose of this assessment carbon masses per hectare were calculated for typical ‘local species’ for Western Australia coastal regions in the project region.

The following assumptions have been made to predict the carbon masses per hectare for the agricultural land using FullCAM:

- Continuous cropping
- 1:1 crop rotation of cereal and lupins
- Stubble is retained following harvest
- Continuous grazing between harvesting and plowing periods.

The model simulation for agricultural land was run for 4 years to allow for two rotations of both cereal and lupins. Planting and harvesting times for wheat have been based on figures for the WA northeastern wheat belt within the WA Department of Agriculture and Foods’ “The Wheat Book, Principles and Practice”(DAF 2000). Planting and harvesting times for lupins have been based on growth figures stated in the DAFs “Lupin Essentials – Growing a successful lupin crop.” for Mingenew, WA.

An estimate of construction GHG emissions from the clearing of vegetation is provided in Table 5-3. It is estimated from FullCAM that a maximum of 42.61 tonnes of carbon per hectare (tC/ha) is stored within the native vegetation within the study area. Stored carbon within the agricultural land varies depending on the type of crop and the activity being undertaken (i.e. harvesting, grazing, planting, plowing and crop growth). It is estimated
from FullCAM between 0 and 2.83 tonnes of carbon per hectare (tC/ha) is stored within the agricultural land at any one time. For the purpose of this assessment it is assumed that the tC/ha for agricultural land is equal to the average tC/ha the day before wheat harvest equating to 1.29 tC/ha.

Table 5-3 Estimation of construction GHG emissions from the clearing of vegetation

<table>
<thead>
<tr>
<th>Source</th>
<th>Usage</th>
<th>Average tonnes carbon per ha (FullCAM)*</th>
<th>Emission Factor (tonnes CO₂-e per tonne of carbon cleared)**</th>
<th>Total emissions (kilotonnes CO₂-e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Clearing local native species</td>
<td>210 ha</td>
<td>42.61</td>
<td>3.67</td>
<td>32.84</td>
</tr>
<tr>
<td>Land Clearing Crops</td>
<td>90 ha</td>
<td>1.29</td>
<td>3.67</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td>33.27</td>
</tr>
</tbody>
</table>

* Carbon contained in soil and existing debris has not been included.
** Source: Snowdown et al (2000)

The estimate of greenhouse gas emissions from the loss of carbon sinks is based on numerous assumptions as outlined above. As such the above estimated emissions should be considered as indicative estimates only.

5.3.3. Greenhouse Gas Summary

While there are no criteria to compare GHG emissions against, it is worth noting that under the National Greenhouse and Energy Reporting Act 2007 (the NGER act), facilities emitting 25 kilotonnes (kt) CO₂-e or more (and/or consuming 100 terajoules (TJ) or more) in a year and organizations emitting 50 kt CO₂-e or more (and/or consuming 200 TJ or more) from 2010/2011 financial year onwards are required to register and report GHG emissions to the Greenhouse and Energy Data Officer (DCC 2008).

The GHG estimates for the proposed power station indicates that OPR would need to register under the NGER Act and report emissions from land clearance during construction, as well as for ongoing power station and port operations.
6. MODELLING METHODOLOGY

6.1. Dispersion Model Selection

The Air Pollution Model (TAPM), developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), was used for this assessment. TAPM is a three-dimensional, prognostic air dispersion model capable of predicting meteorological and pollution parameters on an hourly basis over the modelled period (Hurley 2005).

6.1.1. Model Description

Air pollution models that can be used to predict hour by hour pollution concentrations for periods of up to a year are generally semi-empirical/analytical approaches based on Gaussian plumes or puffs. These models typically use either a simple surface-based meteorological file or a diagnostic wind field model based on available observations. TAPM is different to these approaches in that it solves approximations to the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentration for a range of pollutants important for air pollution applications. TAPM consists of coupled prognostic meteorological and air pollution concentration components which eliminates the need for site-specific meteorological observations. Instead, the model predicts the flows important to local-scale air pollution (e.g. terrain-induced flows) against a background of larger-scale meteorology provided by synoptic analyses.

The meteorological component of TAPM is an incompressible, non-hydrostatic, primitive equation model with a terrain-following vertical co-ordinate for three-dimensional simulations. The model solves the momentum equations for horizontal wind components, the incompressible continuity equation for vertical velocity and scalar equations for potential virtual temperature and specific humidity of water vapour, cloud water/ice, rain water and snow. The Exner pressure function is split into hydrostatic and non-hydrostatic components and a Poisson equation is solved for the non-hydrostatic component. Explicit cloud microphysical processes are included. The turbulence terms in these equations have been determined by solving equations for turbulence kinetic energy and eddy dissipation rate and then using these values to represent vertical fluxes by a gradient diffusion approach, including counter-gradient terms. A vegetative canopy, soil scheme and urban scheme are used at the surface, while radiative fluxes both at the surface and at upper levels are also included (Hurley 2008).

The air pollution component of TAPM uses the predicted meteorology and turbulence from the meteorological component and consists of four modules.
1) The Eulerian Grid Module (EGM) solves prognostic equations for the mean and variance of concentration.

2) The Lagrangian Particle Module (LPM) can be used to represent near-source dispersion more accurately.

3) The Plume Rise Module is used to account for plume momentum and buoyancy effects for point sources.

4) The Building Wake Module allows plume rise and dispersion to include wake effects on meteorology and turbulence.

6.1.2. Model Limitations

- TAPM is suitable for horizontal domain sizes below approximately 1,500 km by 1,500 km. It should not generally be used for larger domains because of the neglect in the model of the curvature of the earth.

- TAPM cannot be used to accurately represent deep atmospheric circulations or extreme weather events due to the above reasons, the assumption of incompressibility in the model and the fact that non-hydrostatic effects are not represented above 5,000 m. The winds, temperature and humidity are increasingly smoothed from this level up to the model top at 8,000 m in order to minimise reflections of waves from the model top back into the lower part of the model.

- TAPM cannot be used for very steep terrain because of the use of a terrain-following coordinate system in the model. This approach cannot represent discontinuities in terrain height (for example, cliffs or bluff bodies).

- TAPM assumes that cloud processes are resolved by the typical inner grid spacing used in the model (that is, 3 km or less). Therefore, no large-scale cloud convection parameterisation is included.

- The GRS photochemistry option in the model may not be suitable for examining small perturbations in emissions inventories, particularly in VOC emissions due to the highly lumped approach taken for VOCs in this mechanism. VOC reactivities should also be chosen carefully for each region of application.

6.2. Model Setup

TAPM was configured with five nested 25 x 25 computational grids to optimise model resolution and run time. Default grid meshes of 30 km, 10 km, 3 km, 1 km and 300 m were used with a pollutant grid of 150 m. The model domain was centred at the point -28° 35’S and 114° 36’ 50”E. This corresponds to 265500E 6836500N on the Map Grid of Australia.
Air Quality Impact and Greenhouse Gas Assessment

(MGA). TAPM was run in pollution mode APM, NOX, NO2 and ozone with chemistry and deposition. In lieu of SO2 emission information for the generators a conversion factor was applied to NOX emissions (see Section 6.3). The limitations mentioned in the previous section are not relevant to this current modelling study because:

- the modelling domain is within 1500 x 1500 km²
- although the topography is not flat it does not represent exceedingly complex terrain and the model can handle the minimal variations within the domain
- large scale cloud physics are not applicable to the pollution modelling grid scale.

6.3. Emission Information

For this assessment the gas turbine selected was the SGT-700. The diesel generator selected was the Caterpillar 3516B. It is expected the generating units to be installed will be similar to this plant in terms of emissions. Manufacturer specifications, emission concentrations, exhaust temperature, volume flow rate and exhaust composition for the generators were obtained from manufacturer technical data sheets (Appendix B) and summarised in Table 6-1. Emission rates are compared to WA EPA guidance for emissions of oxides of nitrogen from gas turbines (EPA 2000) and NSW regulatory emission limits (NSW Government 2009) which show the modelled gas turbine meets Australian emission standards.

It is noted the modelled diesel generator exceeds some of the NSW emission targets, however, it is believed this will provide the model with a conservative emission rate given a specific generator unit has not being selected at this stage.

Table 6-1 Emission parameters supplied

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Generators required</td>
<td>1</td>
<td>1</td>
<td>34 ppm</td>
<td>500 mg/m³ (as NO2 equivalent)</td>
</tr>
<tr>
<td>Stack height</td>
<td>11 m</td>
<td>3 m</td>
<td></td>
<td>40 mg/m³</td>
</tr>
<tr>
<td>Stack radius</td>
<td>2 m</td>
<td>0.2 m</td>
<td></td>
<td>50 mg/m³</td>
</tr>
<tr>
<td>Exhaust Rate</td>
<td>94 000 g/s</td>
<td>8.127 m³/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOX @15%O2 dry</td>
<td>15 ppm (10 mg/m³)</td>
<td>1813.3 mg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOC @15%O2 dry</td>
<td>N/A</td>
<td>48.7 mg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM @15%O2 dry</td>
<td>N/A</td>
<td>42.3 mg/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exit velocity</td>
<td>17.2 m/s</td>
<td>62.6 m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exit temp</td>
<td>528 °C</td>
<td>511.1 °C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Power station considered as group 6 when referencing schedule 3 (electricity generation) and 4 (general standards).

Emissions are calculated by using the Ideal Gas Law equation.
Equation 6-1 Ideal Gas Law

\[ PV = nRT \text{ and replacing } n = \frac{m}{M} \text{ (where } m = \text{ mass and } M = \text{ Molar mass}\]

NO\textsubscript{X} is 15 ppmv (dry air) and mostly air is released. Rearranging to solve for volume:

Equation 6-2

\[ V_{\text{gas}} = \frac{15 \text{ ppm}}{10^6} \times \frac{m_{\text{air}}}{M_{\text{exhaust}}} \times \frac{RT}{P} \]

\( V_{\text{gas}} \) can also be expressed in terms of the mass and molar mass of the gas:

Equation 6-3

\[ V_{\text{gas}} = \frac{m_{\text{gas}}}{M_{\text{gas}}} \times \frac{RT}{P} \]

Setting Equation 6-2 = Equation 6-3, cancel RT/P and rearrange:

Equation 6-4

\[ m_{\text{gas}} = \frac{15 \text{ ppm}}{10^6} \times \frac{m_{\text{exhaust}}}{M_{\text{gas}}} \times \frac{M_{\text{gas}}}{M_{\text{exhaust}}} \]

Dividing the mass (g) on both sides of Equation 6-4 by time (s) to convert to release rates (g/s) yields:

Equation 6-5

\[ \text{NO}_\text{X} \text{ (g/s)} = \frac{15 \text{ ppm}}{10^6} \times \frac{\text{exhaust (g/s)}}{M_{\text{gas}}} \times \frac{M_{\text{gas}}}{M_{\text{exhaust}}} \]

Using \( M_{\text{gas}} \) as 46 and \( M_{\text{exhaust}} \) as 29, this gives a \( \text{NO}_\text{X} \) emission rate of 2.2 g/s for the gas turbine and 14.7 g/s for the diesel generator.

In lieu of specified SO\textsubscript{2} emission data, SO\textsubscript{2} emissions were calculated using the \( \text{NO}_\text{X} \) emission rate and the AP-42 emission factors for \( \text{NO}_\text{X} \) and SO\textsubscript{2} (USEPA 1996). These emission factors are presented in Table 6-2.
Table 6-2 US EPA AP-42 Emission Factors for Diesel Industrial Sources

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emission Factor (lb/hp-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{X}</td>
<td>0.031</td>
</tr>
<tr>
<td>SO\textsubscript{X}</td>
<td>0.00205</td>
</tr>
</tbody>
</table>

The SO\textsubscript{X} emission factor in this assessment is based on a fuel sulphur content of 400 ppm (USEPA 1985). As the sulphur content of diesel to be combusted is expected to be no greater than 50 ppm, this emission factor is considered highly conservative.

Assuming using a conservative conversion rate of 100% for SO\textsubscript{X} to SO\textsubscript{2}, this provided an SO\textsubscript{2} emission rate of 1.0 g/s for the CAT3516B generator unit. It is noted that a more desirable methodology, such as having plant specific data available, would be preferred to estimate SO\textsubscript{2} impact. The use of emission factors provides the assessment with values that should be taken as indicative only, and used only to demonstrate SO\textsubscript{2} emissions will not have a major impact across the region.

6.4. Other Emission Sources

Oakajee Industrial Estate is undeveloped at the time of this assessment. As there are no high concentrations of traffic nearby, no other anthropogenic emission sources of NO\textsubscript{X} or VOC require consideration in this assessment. Biogenic emissions have not been considered in this assessment due to the low risk of pollutants exceeding criteria limits.

6.5. Building Characteristics

Dispersion of emissions from the Oakajee Power Station may be subject to wake effects from nearby buildings and other site structures due to the relatively low stack height for the gas turbine. As such, the building characteristics for the power station have been included in this assessment. Detailed characteristics of these buildings are presented in Appendix D which lists the TAPM output LIS file, the stack parameters (PSE) and the buildings (BLD) files.

6.6. Meteorology

The Australian Bureau of Meteorology (BoM) maintains a meteorological station at the Geraldton Airport. The BoM also has records of meteorology data from the Geraldton Port. However the port station discontinued recording wind data in 1953 and as such was not considered appropriate for use in this assessment. Meteorological data for the years 2003 to 2009 inclusive have been sourced from the BoM and compared to determine an adequately representative year (BoM 2010).
Meteorological data were also available from a station located within the Oakajee Industrial Estate. Data from this station was not used in the assessment as it is only available from June 2007 onwards. This length of time was not considered sufficient to be analysed for modelling purposes.

The 2005 calendar year was chosen based on a comparison of wind speeds and direction from the BoM airport data. The wind speeds and direction were categorised into speed and direction ranges and a normalised wind speed histogram (Figure 6-1) and wind direction radar plot (Figure 6-2) produced. There are minimal visual differences between the years, with 2005 showing a reasonable mean when compared to other years.
Figure 6-1 Wind speed histogram (2003-2009) extracted from BOM data
Figure 6-2 Wind direction radar plot (2003-2009)
To confirm that the meteorological year modelled was representative the wind roses of the 2005 Geraldton Airport meteorology and the TAPM generated meteorology for the Oakajee Industrial Estate were compared. The quarterly wind roses for the actual and generated meteorology are presented side by side in Figure 6-3 through Figure 6-10. A visual analysis of wind roses was considered acceptable based on the modelling approach to predict the maximum on grid, rather than a discrete location which would be more susceptible to changes in wind speed and direction. The maximums predicted will be expected at some point within the modelling domain.

For the first and fourth quarter TAPM generated data shows a lower wind speed range when compared to BoM data with a wider distribution of wind directions, though the general pattern is similar. The second and third quarter wind roses show very similar patterns with the TAPM generated data showing a slight clockwise rotation compared to the BoM data, possibly due to slight terrain differences (see Section 0) at both the BoM site and in the Oakajee region.

The wind roses indicate wind patterns are similar between the two locations with no notable disparity between the BoM and TAPM meteorology, the TAPM data was considered representative and used in modelling. ‘Nudging’ of predicted meteorology with observed data was not undertaken as the BOM site is situated about 20km away and the incorporation of this data would increase modelling uncertainty.

Analysis of the quarterly wind roses shows prevailing winds for each quarter demonstrates the following:

- predominantly strong southerly winds for January to March
- medium winds ranging from north-easterly to south-westerly with a dominant north-easterly breeze for April to June
- medium north-easterly to easterly winds for July to September
- strong southerly winds for October to December, similar to the January-March quarter.

---

2 ‘Nudging’ is using recorded meteorology from a discrete point to better align model predictions to observation
Figure 6-3 Jan - Mar 2005 BoM wind rose

Figure 6-4 Jan - Mar 2005 TAPM wind rose
Figure 6-5 Apr - Jun 2005 BoM wind rose

Figure 6-6 Apr - Jun 2005 TAPM wind rose
Air Quality Impact and Greenhouse Gas Assessment

Figure 6-7 Jul - Sep 2005 BoM wind rose

Figure 6-8 Jul - Sep 2005 TAPM wind rose
Figure 6-9 Oct - Dec 2005 BoM wind rose

Figure 6-10 Oct - Dec 2005 TAPM wind rose
A comparison of wind speed ranges and wind directions predicted by TAPM and recorded by Geraldton BoM for 2005 are presented in Figure 6-11 and Figure 6-12.

TAPM is shown to be predicting a higher number of low wind speed events and lower number of high wind speeds. The TAPM predicted wind direction is largely dominated by the winds predicted from the south and south-southeast. The BoM data, while also demonstrating a southerly dominance, shows more pronounced southerly winds, as well as a number of winds to the north-northeast which TAPM does not predict.

![Figure 6-11 TAPM and Geraldton BoM wind speed histogram for 2005](image-url)
A further comparison of the statistics between the TAPM predicted meteorology and the BoM observations is presented in Table 6-3. The root mean square error (RMSE) is a commonly used measure that determines the differences between predicted and observed values. The lower the RMSE value the closer the model is to predicting the observed values. The index of agreement (IOA) is a measure of the differences between the predicted and observed parameters. An IOA of 1 indicates perfect agreement while an IOA of 0 indicates no agreement. Further details of the RMSE and IOA are contained in Appendix E.

From Table 6-3 the average temperatures predicted by TAPM are close to BoM recordings, varying by 0.9°C. This is further confirmed by a low RMSE and a high IOA. The difference in the average wind speeds in Table 6-3 shows TAPM is slightly underpredicting the wind speed, though the RMSE and IOA values indicate a level of agreement between the TAPM predicted wind speed and the BoM observations.
Table 6-3 Summary of statistics of TAPM predictions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>RMSE</th>
<th>IOA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Observed</td>
<td>Predicted</td>
<td>Observed</td>
</tr>
<tr>
<td>Temperature</td>
<td>19.4</td>
<td>18.5</td>
<td>4.5</td>
<td>5.9</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>4.5</td>
<td>5.4</td>
<td>2.0</td>
<td>2.7</td>
</tr>
</tbody>
</table>

6.7. Topography

Synoptic conditions are the main drivers of the climatic conditions experienced at a region. This arises as a direct consequence of the differential heating between the poles and the equator coupled with the rotation of the earth creating large-scale circular air movements. In contrast, local meteorology is more strongly influenced by local heating and cooling effects including topography-induced temperature profiles and local heat islands. These temperature profiles cause air masses to move thus generating winds. Apart from the direct movement of air, topography not only impacts on the wind speeds but also channels the winds along preferred directions where winds blow around (or over) hills. Wind then reverts back to the general synoptic flow once the topographical influence is past. In exceedingly complex terrain, meteorological models may not be able to accurately resolve wind fields because of these effects.

The topography around Oakajee may be described as undulating based on analysis of the height data shown in Figure 6-13. The terrain slopes upwards with the highest point (shown in pink) approximately 130 m above sea level (TAPM database at 300 m resolution). A key feature in this figure is the presence of a shallow river valley where the Oakajee River exits into the ocean.

An example of the modelled wind vectors at Oakajee is displayed in Figure 6-13. As wind is channelled into a smaller volume it must speed up to maintain balance (owing to the principal of conservation of mass and energy). The wind vectors in the figure show there is minimal localised changes to the wind field over the region indicative that topography is not creating perturbations to the wind field. This can be expected considering that the maximum vertical height change over the region is 130m with no abrupt cliffs. Studies of wind breaks (which consider significant vertical changes in height) indicate the localised disturbance only affects the downwind region between three and ten times the vertical height (Lee & Kim 1999). For small hills with no abrupt height changes, the disturbance generally only affects the downwind distance to the same extent as the height of the hill. Therefore the effect of topography of a one kilometre grid domain at Oakajee is not expected to extend beyond the immediate grid cell.
6.8. **Conversion of NO$_x$ to NO$_2$**

Upon exiting the exhaust stack, oxides of nitrogen are predominantly comprised of NO and NO$_2$. Over time, NO is oxidised to NO$_2$ in a complex balance with ambient ozone and VOCs.

Studies at Kwinana and Pinjar (near Perth) have developed empirical relationships for the conversion of NO$_x$ to NO$_2$ as a function of ground-level concentrations (Dames & Moore...
1993 and Bowman, Bishaw & Gorham 1990). These studies have found that, for higher NOX concentrations, the NO2 conversion is limited and usually does not exceed around 60%. To estimate the proportion of NOX in the form of NO2, the ozone-limiting method (OLM) which is a conservative screening technique of the USEPA for short term NOX impacts has been considered (Cole & Sumerhays 1979). The concentration of NO2 is estimated using Equation 6-6 through to Equation 6-8 for various O3/ NOX ratios.

**Equation 6-6**

\[
[NO_2] = [NO_X] \\
\text{if } \frac{46}{48} \times [O_3] > 0.9 \times [NO_X]
\]

**Equation 6-7**

\[
[NO_2] = \frac{46}{48} \times [O_3] + 0.1 \times [NO_X] \\
\text{if } \frac{46}{48} \times [O_3] < 0.9 \times [NO_X]
\]

**Equation 6-8**

\[
[NO_2]_{(total)} = [NO_2] + [NO_2]_{(background)}
\]

Where:

- \([NO_2]\) is the calculated NO2 concentration in micrograms per cubic metre (µg/m³)
- \([NO_X]\) is the predicted NOX concentration in µg/m³
- \([O_3]\) is the measured background concentration of ozone in µg/m³
- \([NO_2]_{(background)}\) is the measured background concentration of NO2 in µg/m³
- 46/48 is the molecular weight ratio between NO2 and O3 used in the conversion between parts per million per volume (ppmv) and µg/m³.

For this assessment the TAPM default background ozone concentration of 20 parts per billion (ppb) (equivalent to 39.3 µg/m³) was used. This was considered appropriate given there is no industry or large volumes of traffic in the area.

At this background concentration O3 is likely to be greater than NOX concentrations over most of the study domain and hence the conservative **Equation 6-6** (NO2 = NOX) has been used for conversion in this report.
6.9. Assessing Model Uncertainty

Modelling results are usually presented as lines of equal concentrations (isopleth plots) where concentrations are expressed with no indication of accuracy or concern for significant figures. Additionally, many closely-spaced isopleths of similar concentrations portray a confidence in the results that is not scientifically justifiable.

Uncertainty is related to confidence in:

- emission estimates
- plume location (wind direction)
- dispersion dilutions (wind speed and wind turbulence; that is, ‘sigma theta’ of the wind)
- model parameterisations (stability classes, similarity theory, inversions)
- chemical and physical accounting done by the model
- closure schemes used by the model to ensure that the model can be practically used.

The concentration is usually calculated in terms of the Gaussian distribution where concentrations are inversely related to wind speed. Thus a 0.5 m/s error in wind speed for a mean wind speed of 2 m/s accounts for a 20% error in concentration. (Concentration $\propto 1/\text{ws}$ i.e. ½ compared to $1/2.5$). Similarly, a 10º error in wind direction over a 2 km fetch equates to a 350 m uncertainty in position (from $R \sin \theta$).

Model uncertainty for this assessment is described in more depth in Section 7.1.
7. MODEL RESULTS

The predicted maximum impacts of modelled pollutants compared against their respective criteria are presented in Table 7-1. Contour plots of the modelled pollutants are presented in Appendix C. No exceedences of any criteria are predicted for any pollutants at any location in the model grid.

Table 7-1 Predicted pollutant concentrations compared to assessment criteria

<table>
<thead>
<tr>
<th>Pollutant and Agency</th>
<th>Averaging Period</th>
<th>Criteria/Guideline Level</th>
<th>Maximum on Grid</th>
<th>Percentage of Criteria/Guideline</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂ NEPM (health)</td>
<td>1-hour</td>
<td>120 ppb</td>
<td>14.05 ppb</td>
<td>12%</td>
<td>730 m south of power station</td>
</tr>
<tr>
<td>NO₂ NEPM (health)</td>
<td>Annual</td>
<td>30 ppb</td>
<td>1.21 ppb</td>
<td>4%</td>
<td>240 m northwest of power station</td>
</tr>
<tr>
<td>SO₂ NEPM (health)</td>
<td>1-hour</td>
<td>200 ppb</td>
<td>0.93 ppb</td>
<td>&lt;1%</td>
<td>300 m southwest of power station</td>
</tr>
<tr>
<td>SO₂ NEPM (health)</td>
<td>24-hour</td>
<td>80 ppb</td>
<td>0.36 ppb</td>
<td>&lt;1%</td>
<td>730 m south of power station</td>
</tr>
<tr>
<td>SO₂ NEPM (health)</td>
<td>Annual</td>
<td>20 ppb</td>
<td>0.08 ppb</td>
<td>&lt;1%</td>
<td>240 m northwest of power station</td>
</tr>
<tr>
<td>NOₓ WHO (vegetation)</td>
<td>24-hour</td>
<td>39.9 ppb</td>
<td>5.46 ppb</td>
<td>14%</td>
<td>730 m south of power station</td>
</tr>
<tr>
<td>NOₓ WHO (vegetation)</td>
<td>Annual</td>
<td>15.9 ppb</td>
<td>1.21 ppb</td>
<td>8%</td>
<td>240 m northwest of power station</td>
</tr>
<tr>
<td>SO₂ WHO (vegetation)</td>
<td>Annual</td>
<td>3.8 ppb</td>
<td>0.08 ppb</td>
<td>2%</td>
<td>240 m northwest of power station</td>
</tr>
</tbody>
</table>

The model results presented in Appendix C show the backup diesel generator (when operational) will have a larger impact than regular operation of the gas turbine.

7.1. Model Uncertainty

The modeling uncertainty may be further examined by comparing the eight grid cells surrounding a cell that experienced the maximum concentration (for this calculation the NO₂ 1 hour model results have been used). Statistically analyzing these nine grid cells (on the basis that the different concentrations are related to minor wind field differences) would then enable the uncertainty that could be expected from the model assuming minor changes to the wind field. Using a specified confidence level the expected data range is given by the Students t-test formula in Equation 7.1:

Equation 7-1 Students t-test confidence levels

\[ \text{Range} = \bar{x} \pm \frac{t \times s}{\sqrt{n}} \]
where: $t$ is looked up in statistical tables (or computed using the Excel® confidence function).

$x$ is average of sample set

$\sigma$ is the standard deviation

$n$ is the sample size

At the 95% confidence level, using the sample average of $(11.3 \ \mu g/m^3)$ and standard deviation of $1.6 \ \mu g/m^3$, yields a confidence level of $1 \ \mu g/m^3$ or a relative confidence level of $9\%$. This relative standard deviation can be expected across the entire modeling domain for all pollutants and timescales and gives an approximation of the model uncertainty based on wind field perturbations.

7.2. **Model Accuracy**

Model accuracy is harder to quantify without resorting to comparisons between measured and predicted concentrations. Previous studies using TAPM at Kincaid (Hurley et al. 2005) indicated that TAPM under predicted concentrations by about $10\%$ for typical average concentrations and by $23\%$ for maximum concentrations. This can typically be expected for this modelling study as well and correlates well with the wind field perturbation estimate.

Taking into account the model uncertainty, no exceedences of any criteria are predicted for any pollutants at any location in the model grid.
8. CONCLUSIONS

OPR are investigating potential power supply scenarios for the Oakajee Port development. One scenario is the operation of a 30 MW gas turbine with a 2 MW backup diesel generator. For this assessment, a SGT-700 gas turbine and CAT3516B diesel generator were modelled.

8.1. Ambient Air

The key pollutants identified were NO\textsubscript{x} (as NO\textsubscript{2}), SO\textsubscript{2}, and PM.

TAPM was selected to model the impact of emissions. Emissions data was obtained from product technical data sheets. Meteorology used in the assessment was generated by TAPM using 2005 synoptic data. This was compared against BoM data obtained from the Geraldton airport meteorology station. The TAPM generated data was found to under predict higher wind speeds and had a higher range of wind directions, but still exhibited the same general weather patterns and was determined to be representative.

The model predictions were compared to NEPM and WHO criteria for human health and vegetation. The assessment shows that the operation of a 30 MW gas power station (with 2 MW diesel backup) is unlikely to cause an exceedence of specified air quality criteria at any location outside the Oakajee Industrial Estate buffer zone.

8.2. Greenhouse Gas

GHG emissions from power station operations and land clearing were estimated using the NGA Factors and FullCAM calculator respectively. The operation of a gas turbine operating at 30 MW consistently throughout the year is estimated to produce 133.3 kilotonnes CO\textsubscript{2}-e per annum.

Clearing of 310 ha of vegetation is estimated using FullCAM to give rise to a GHG emission estimate of 33.27 kilotonnes CO\textsubscript{2}-e.

Both these emissions exceed NGER reporting thresholds and OPR will be required to register and report GHG emissions from construction and operation of port and power facilities under the NGER Act.
9. REFERENCES


DAF (Date Unknown) Lupin Essentials – Growing a successful lupin crop, Chapter 3 Environmental influences on lupin growth, Department of Agriculture and Food, Western Australia.


Department of Climate Change (2009a). *National Greenhouse Accounts (NGA) Factors*. June 2009, DCC, Canberra

Department of Climate Change (2009b). *National Greenhouse Gas Inventory Accounting for the Kyoto Target*, May 2009, DCC, Canberra.


APPENDIX A  PM SCREENING ASSESSMENT

A screening level assessment for diesel PM was undertaken using generator technical specifications (Appendix B) and AUSPLUME with the following key settings:

- ‘metsamp’ meteorological screening data (standard issue with AUSPLUME)
- no depletion, terrain or building effects

The maximum hourly concentrations at set distances from the diesel generator are presented in Table A-1. Compared to the NEPM 24 hour PM$_{2.5}$ criterion of 25 $\mu$g/m$^3$ and that these PM emissions will only occur when the backup diesel generator is running, the hourly predicted values indicate PM from the diesel generator will not have significant impact.

Table A-1 PM Screening assessment results for a 2 MW diesel generator

<table>
<thead>
<tr>
<th>Distance from Source</th>
<th>100 m</th>
<th>200 m</th>
<th>300 m</th>
<th>400 m</th>
<th>500 m</th>
<th>600 m</th>
<th>800 m</th>
<th>1000 m</th>
<th>2000 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollutant Concentration ($\mu$g/m$^3$)</td>
<td>16.7</td>
<td>8.4</td>
<td>5.39</td>
<td>4.35</td>
<td>3.66</td>
<td>3.19</td>
<td>2.61</td>
<td>2.52</td>
<td>3.09</td>
</tr>
</tbody>
</table>

The screening model setup is detailed below:

```
1

ODPS Screening

Concentration or deposition Concentration
Emission rate units grams/second
Concentration units microgram/m3
Units conversion factor 1.00E+06
Constant background concentration 0.00E+00
Terrain effects None
Smooth stability class changes? No
Other stability class adjustments ("urban modes") None
Ignore building wake effects? Yes
Decay coefficient (unless overridden by met. file) 0.000
Anemometer height 10 m
Roughness height at the wind vane site 0.300 m
Use the convective PDF algorithm? No
Averaging time for sigma-theta values 60 min.
```

DISPERSION CURVES
Horizontal dispersion curves for sources <100m high  Sigma-theta
Vertical dispersion curves for sources <100m high  Pasquill-Gifford
Horizontal dispersion curves for sources >100m high  Briggs Rural
Vertical dispersion curves for sources >100m high  Briggs Rural
Enhance horizontal plume spreads for buoyancy?  Yes
Enhance vertical plume spreads for buoyancy?  Yes
Adjust horizontal P-G formulae for roughness height?  Yes
Adjust vertical P-G formulae for roughness height?  Yes
Roughness height  0.100m
Adjustment for wind directional shear  None

PLUME RISE OPTIONS
Gradual plume rise?  Yes
Stack-tip downwash included?  Yes
Building downwash algorithm:  PRIME method.
Entrainment coeff. for neutral & stable lapse rates  0.60, 0.60
Partial penetration of elevated inversions?  No
Disregard temp. gradients in the hourly met. file?  No

and in the absence of boundary-layer potential temperature gradients
given by the hourly met. file, a value from the following table
(in K/m) is used:

<table>
<thead>
<tr>
<th>Wind Speed Category</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.020</td>
<td>0.035</td>
</tr>
<tr>
<td>2</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.020</td>
<td>0.035</td>
</tr>
<tr>
<td>3</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.020</td>
<td>0.035</td>
</tr>
<tr>
<td>4</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.020</td>
<td>0.035</td>
</tr>
<tr>
<td>5</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.020</td>
<td>0.035</td>
</tr>
<tr>
<td>6</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.020</td>
<td>0.035</td>
</tr>
</tbody>
</table>

WIND SPEED CATEGORIES
Boundaries between categories (in m/s) are:  1.54, 3.09, 5.14, 8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Urban" values (unless overridden by met. file)

AVERAGING TIMES
1 hour

ODPS Screening

SOURCE CHARACTERISTICS
STACK SOURCE: D1

<table>
<thead>
<tr>
<th>X(m)</th>
<th>Y(m)</th>
<th>Ground Elev.</th>
<th>Stack Height</th>
<th>Diameter</th>
<th>Temperature</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0m</td>
<td>3m</td>
<td>0.40m</td>
<td>511°C</td>
<td>62.6m/s</td>
</tr>
</tbody>
</table>

No building wake effects.
(Constant) emission rate = 3.40E-01 grams/second
No gravitational settling or scavenging.

ODPS Screening

RECEPTOR LOCATIONS

DISCRETE RECEPTOR LOCATIONS (in metres)

<table>
<thead>
<tr>
<th>No.</th>
<th>X</th>
<th>Y</th>
<th>ELEVN</th>
<th>HEIGHT</th>
<th>No.</th>
<th>X</th>
<th>Y</th>
<th>ELEVN</th>
<th>HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
<td>6</td>
<td>600</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
<td>7</td>
<td>800</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
<td>8</td>
<td>1000</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>400</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
<td>9</td>
<td>2000</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

METEOROLOGICAL DATA: "METSAMP" test meteorological file
APPENDIX B  POWER GENERATION TECHNICAL SPECIFICATIONS
The Siemens SGT-700 industrial gas turbine is a high-performance gas turbine with excellent environmental compatibility. It combines the reliability and robustness of an industrial design with the high efficiency and low emission levels of the latest turbine technology.

The SGT-700 gas turbine package represents reliable, clean and efficient power generation equipment characterized by low Life Cycle Cost, compact plant and short delivery time.

The SGT-700 is a standardized product to suit every need. It is designed for heavy-duty operation under tough conditions, both onshore and offshore, floating or fixed, in hot or cold climates, for application in simple cycle, combined-cycle, or cogeneration.

In simple cycle, the SGT-700 can be operated at base load with an in-built capacity to meet national grid code specifications.

Its rapid start-up times make it invaluable when operating in peak load application. The compact design, small footprint and low weight are of particular benefit in offshore applications. The standard equipment design has been fully adapted for Ex-proof installation in hazardous areas and to meet offshore codes and standards.

A single-lift power generation module for floating platforms such as FPSO (Floating Production, Storage and Offloading) and semi-submersibles is available for both the SGT-600 and the SGT-700.
SGT-700 Industrial Gas Turbine

Technical specifications

Overview
- Power generation: 31.21MW(e)
- Frequency: 50/60Hz
- Electrical efficiency: 36.4 %
- Heat rate: 9,882 kJ/kWh (9,367 Btu/kWh)
- Turbine speed: 6,500 rpm
- Compressor pressure ratio: 18.6:1
- Exhaust gas flow: 94 kg/s (208 lb/s)
- Exhaust temperature: 528°C (983°F)
- NOx emissions (with DLE corrected to 15% O2 dry)
  - Gas fuel: ≤15 ppmV
  - Liquid fuel: ≤42 ppmV

Generator
- Four-pole design
- Rated voltage: 10.5/11.0/13.8 kV
- 50 or 60 Hz
- Protection IP54
- PMG for excitation power supply
- Complies with -IEC/EN 6034-1 standard

Axial Compressor
- 11-stage axial-flow compressor
  - 2 stages variable guide vanes
  - Electron-beam welded rotor

Combustion
- 18 dual-fuel Dry Low Emissions (DLE) burners
- Welded annular sheet metal design

Compressor Turbine
- 2-stage turbine air-cooled

Power Turbine
- 2-stage turbine uncooled
- Interlocking shrouds

Fuel System
- Natural gas - Liquid fuel - Dual fuel
- On load fuel-changeover capability
- Gas-supply pressure requirement: 27.0 bar(a) ±0.5 bar (395 ±7 psi(a))

Bearings
- Tilting pad radial and thrust
- Vibration and temperature monitoring

Lubrication
- Common lubricating oil system integrated in skid using mineral oil
- 3 x 50% AC-driven lube oil pumps with DC backup

Gearbox
- 50 or 60Hz

Starting
- Electric VSD start-motor

Control System
- Siemens Simatic S7

Gas turbine

Key features
- Robust and stable DLE performance
- Robust design – long-life components
- Low emissions – DLE ≤15 ppm NOx
- Unique dual-fuel DLE capability
- Fuel efficiency 36.4% SC PG
- Wide range of fuel capability
- Long-term efficiency – low deterioration
- Excellent operational availability and reliability

Maintenance
- On-site maintenance or 24-hour exchange of gas generator
- Flexible standardized concepts for maintenance planning
- Overhaul interval of 40,000 hours
- Condition-based maintenance
- The 18 burners are easily removable from the outside
- Can be balanced in-field
- Staff training in operation and maintenance
- 24/7 Siemens support
- Remote diagnostics
Package

Key features
- Compact layout
- Same footprint and commonality with the SGT-600
- Flexible installations based on standardized package solutions
- Major components delivered on a common base frame
- Fast and easy installation
- Skid-mounted with single-lift capacity
- Pre-commissioned at the Siemens workshop to reduce time at site
- Simple on-site works due to flexible package design
- State-of-the-art control system fulfills all requirements for control and safety
- Can easily communicate with other control systems

Cogeneration and combined cycle

Due to its high exhaust heat, the SGT-700 is one of the most efficient units on the market for cogeneration and combined cycle applications.

In combined cycle application it has the economic advantage of a simple single-string concept (gas turbine, generator, steam turbine) with double-end drive of a single generator.

Combined-cycle performance:
- Output: 43.9 MW
- Top class efficiency: 51.9%
### Nominal generator output and heat rate

**Conditions/assumptions:**
- **Fuel:** Natural gas LHV, 46,798 kJ/kg (20,118 Btu/lb)
- **Altitude:** Sea level
- **Ambient pressure:** 1.013 bar(a) (14.7 psi(a))
- **Relative humidity:** 60%
- **Inlet pressure loss:** 5 mbar (2” H₂O)
- **Outlet pressure loss:** 5 mbar (2” H₂O)
- **Fuel temperature:** 5°C (41°F)

**Diagram conversion factors:**

<table>
<thead>
<tr>
<th>To convert</th>
<th>To Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C to °F</td>
<td>(°C × 9/5) + 32</td>
</tr>
<tr>
<td>MJ/kWh to Btu/kWh</td>
<td>949</td>
</tr>
</tbody>
</table>

### Nominal exhaust mass flow and temperature

**Conditions/assumptions:**
- **Fuel:** Natural gas LHV, 46,798 kJ/kg (20,118 Btu/lb)
- **Altitude:** Sea level
- **Ambient pressure:** 1.013 bar(a) (14.7 psi(a))
- **Inlet pressure loss:** 5 mbar (2” H₂O)
- **Outlet pressure loss:** 5 mbar (2” H₂O)
- **Fuel temperature:** 5°C (41°F)

**Diagram conversion factors:**

<table>
<thead>
<tr>
<th>To convert</th>
<th>To Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C to °F</td>
<td>(°C × 9/5) + 32</td>
</tr>
</tbody>
</table>

### Unfired heat-recovery steam generation

**Conditions/assumptions:**
- **Fuel:** Natural gas LHV, 46,798 kJ/kg (20,118 Btu/lb)
- **Altitude:** Sea level
- **Ambient temperature:** 15°C (59°F)
- **Boiler pinch point:** 8 K (14°F)
- **Boiler approach point:** 5 K (9°F)
- **Inlet pressure loss:** 5 mbar (2” H₂O)
- **Outlet pressure loss:** 25 mbar (10” H₂O)

**Diagram conversion factors:**

<table>
<thead>
<tr>
<th>To convert</th>
<th>To Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C to °F</td>
<td>(°C × 9/5) + 32</td>
</tr>
</tbody>
</table>

**Steam flow, kg/s**

**Steam pressure, bar (a)**

**Saturated steam**
Caterpillar is leading the power generation marketplace with Power Solutions engineered to deliver unmatched flexibility, expandability, reliability, and cost-effectiveness.

FEATURES

**FUEL/EMISSIONS STRATEGY**
- Low Emissions

**FULL RANGE OF ATTACHMENTS**
- Wide range of bolt-on system expansion attachments, factory designed and tested
- Flexible packaging options for easy and cost effective installation

**SINGLE-SOURCE SUPPLIER**
- Fully prototype tested with certified torsional vibration analysis available

**WORLDWIDE PRODUCT SUPPORT**
- Caterpillar® dealers provide extensive post sale support including maintenance and repair agreements
- Caterpillar dealers have over 1,600 dealer branch stores operating in 200 countries
- The Cat® S•O•S™ program cost effectively detects internal engine component condition, even the presence of unwanted fluids and combustion by-products

**CAT 3516B-HD TA DIESEL ENGINE**
- Reliable, rugged, durable design
- Field-proven in thousands of applications worldwide
- Four-stroke-cycle diesel engine combines consistent performance and excellent fuel economy with minimum weight

**CAT SR5 GENERATOR**
- Matched to the performance and output characteristics of Caterpillar engines
- Industry leading mechanical and electrical design
- Industry leading motor starting capabilities
- High Efficiency

**CAT EMCP 3 SERIES CONTROL PANELS**
- Simple user friendly interface and navigation
- Scalable system to meet a wide range of customer needs
- Integrated Control System and Communications Gateway
## FACTORY INSTALLED STANDARD & OPTIONAL EQUIPMENT

<table>
<thead>
<tr>
<th>System</th>
<th>Standard</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Inlet</td>
<td>• Single element canister type air cleaner</td>
<td>• Dual element &amp; heavy duty air cleaners (with pre-cleaners)</td>
</tr>
<tr>
<td></td>
<td>• Service indicator</td>
<td>• Air inlet adapters &amp; shutoff</td>
</tr>
<tr>
<td>Exhaust</td>
<td>• Dry exhaust manifold</td>
<td>• Mufflers and Silencers</td>
</tr>
<tr>
<td></td>
<td>• Flanged faced outlets</td>
<td>• Stainless steel exhaust flex fittings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Elbows, flanges, expanders &amp; Y adapters</td>
</tr>
<tr>
<td>Fuel</td>
<td>• Secondary fuel filters</td>
<td>• Water separator</td>
</tr>
<tr>
<td></td>
<td>• Fuel priming pump</td>
<td>• Duplex fuel filter</td>
</tr>
<tr>
<td></td>
<td>• Flexible fuel lines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fuel cooler*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>*Not included with packages without radiators</td>
<td></td>
</tr>
<tr>
<td>SRS Generator</td>
<td>• Class H insulation</td>
<td>• Premium &amp; oversize generators</td>
</tr>
<tr>
<td></td>
<td>• CAT digital voltage regulator (CDVR) with KVAR/PF control, 3-phase sensing</td>
<td>• Winding temperature detectors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Anti-condensation heaters</td>
</tr>
<tr>
<td>Power Termination</td>
<td>• Bus bar (NEMA and IEC mechanical lug holes)</td>
<td>• Circuit breakers, UL listed, 3 pole with shunt trip, 100% rated, choice of trip units, manual or electrically operated (low voltage only)</td>
</tr>
<tr>
<td></td>
<td>• Right side standard</td>
<td>• Circuit breakers, IEC compliant, 3 or 4 pole with shunt trip (low voltage only), choice of trip units, manual or electrically operated</td>
</tr>
<tr>
<td></td>
<td>• Top and bottom cable entry</td>
<td>• Shroud cover for bottom cable entry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power terminations can be located on the left and/or rear as an option. Also, multiple circuit breakers can be ordered (up to 2)</td>
</tr>
<tr>
<td>Governor</td>
<td>• ADEM™ 3</td>
<td>• Load share module</td>
</tr>
<tr>
<td>Control Panels</td>
<td>• User Interface panel (UIP) - rear mount</td>
<td>• EMCP3.3</td>
</tr>
<tr>
<td></td>
<td>• EMCP3.1 Genset Controller</td>
<td>• Option for right or left mount UIP</td>
</tr>
<tr>
<td></td>
<td>• Voltage and Speed adjust</td>
<td>• Local &amp; remote annunciator modules</td>
</tr>
<tr>
<td></td>
<td>• AC&amp;DC customer wiring area (right side)</td>
<td>• Load share module</td>
</tr>
<tr>
<td></td>
<td>• Reactive droop</td>
<td>• Discrete I/O module</td>
</tr>
<tr>
<td></td>
<td>• Emergency Stop Pushbutton</td>
<td>• Generator temperature monitoring &amp; protection</td>
</tr>
<tr>
<td>Lube</td>
<td>• Lubricating oil and filter</td>
<td>• Oil level regulator</td>
</tr>
<tr>
<td></td>
<td>• Oil drain line with valves</td>
<td>• Deep sump oil pan</td>
</tr>
<tr>
<td></td>
<td>• Fumes disposal</td>
<td>• Electric &amp; air prelube pumps</td>
</tr>
<tr>
<td></td>
<td>• Gear type lube oil pump</td>
<td>• Manual prelube with sump pump</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Duplex oil filter</td>
</tr>
<tr>
<td>Mounting</td>
<td>• Structural steel tube</td>
<td>• Isolator removal</td>
</tr>
<tr>
<td></td>
<td>• Anti-vibration mounts (shipped loose)</td>
<td>Spring-type isolator, zone 4</td>
</tr>
<tr>
<td>Starting/Charging</td>
<td>• 24 volt starting motor(s)</td>
<td>• Battery chargers (10&amp;20AMP)</td>
</tr>
<tr>
<td></td>
<td>• Batteries with rack and cables</td>
<td>• 45 amp charging alternator</td>
</tr>
<tr>
<td></td>
<td>• Battery disconnect switch</td>
<td>• Oversize batteries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ether starting aid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Heavy duty starting motors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Barring device (manual)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Air starting motor with control &amp; silencer</td>
</tr>
</tbody>
</table>
## CAT GENERATOR

**Caterpillar Generator**
- Frame size: 1844
- Excitation: Permanent Magnet
- Pitch: 0.6667
- Number of poles: 4
- Number of bearings: 2
- Number of leads: 6
- Insulation: UL 1446 Recognized Class H with tropicalization and antiabrasion
- IP Rating: IP23
- Overspeed capability: 150%
- Wave form: 0.03.00
- Parallel kit/Droop transformer: Standard
- Voltage regulator: 3 Phase sensing with selectable volts/Hz
- Voltage regulation: Less than +/- 1/2% (steady state)
- Less than +/- 1% (no load to full load)
- Telephone Influence Factor: Less than 50
- Harmonic Distortion: Less than 5%

## CAT DIESEL ENGINE

**3516B-HD, V-16, 4-stroke-cycle watercooled diesel**
- Bore: 170.00 mm (6.69 in)
- Stroke: 215.00 mm (8.46 in)
- Displacement: 78.08 L (4764.73 in³)
- Compression ratio: 15.5:1
- Aspiration: TA
- Fuel system: Electronic unit injection
- Governor type: ADEM3

## CAT EMCP CONTROL PANEL

- EMCP 3.1 (Standard)
- EMCP 3.2 / EMCP 3.3 (Option)
- Single location customer connector point
- True RMS AC metering, 3-phase
- Controls
  - Run / Auto / Stop control
  - Speed adjust
  - Voltage Adjust
  - Emergency Stop Pushbutton
  - Engine cycle crank
- Digital Indication for:
  - RPM
  - Operating hours
  - Oil pressure
  - Coolant temperature
  - System DC volts
  - L-L volts, L-N volts, Phase amps, Hz
  - ekW, kVA, kVAR, kWhr, %kW, PF (EMCP 3.2 / 3.3)
- Shutdowns with common indicating light for:
  - Low oil pressure
  - High coolant temperature
  - Low coolant level
  - Overspeed
  - Emergency stop
  - Failure to start (overcrank)
- Programmable protective relaying functions: (EMCP 3.2 & 3.3)
  - Under and over voltage
  - Under and over frequency
  - Overcurrent (time and inverse time)
  - Reverse power (EMCP 3.3)
- MODBUS isolated data link, RS-485 half-duplex (EMCP 3.2 & 3.3)
- Options
  - Vandal door
  - Local annunciator module
  - Remote annunciator module
  - Input / Output module
  - RTD / Thermocouple modules
  - Monitoring software
## TECHNICAL DATA

<table>
<thead>
<tr>
<th>Open Generator Set - 1500 rpm/50 Hz/400 Volts</th>
<th>DM7973</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Emissions</strong></td>
<td></td>
</tr>
<tr>
<td>Coolant to aftercooler</td>
<td></td>
</tr>
<tr>
<td>Coolant to aftercooler temp max</td>
<td>30 °C</td>
</tr>
<tr>
<td><strong>Generator Set Package Performance</strong></td>
<td></td>
</tr>
<tr>
<td>Genset Power rating @ 0.8 pf</td>
<td>2500 kVA</td>
</tr>
<tr>
<td>Genset Power rating with fan</td>
<td>2000 ekW</td>
</tr>
<tr>
<td><strong>Fuel Consumption</strong></td>
<td></td>
</tr>
<tr>
<td>100% load with fan</td>
<td>542.7 L/hr</td>
</tr>
<tr>
<td>75% load with fan</td>
<td>409.7 L/hr</td>
</tr>
<tr>
<td>50% load with fan</td>
<td>273.4 L/hr</td>
</tr>
<tr>
<td><strong>Cooling System</strong></td>
<td></td>
</tr>
<tr>
<td>Engine coolant capacity</td>
<td>233.0 L</td>
</tr>
<tr>
<td><strong>Inlet Air</strong></td>
<td></td>
</tr>
<tr>
<td>Combustion air inlet flow rate</td>
<td>178.8 m³/min</td>
</tr>
<tr>
<td><strong>Exhaust System</strong></td>
<td></td>
</tr>
<tr>
<td>Exhaust stack gas temperature</td>
<td>511.1 °C</td>
</tr>
<tr>
<td>Exhaust gas flow rate</td>
<td>487.6 m³/min</td>
</tr>
<tr>
<td>Exhaust flange size (internal diameter)</td>
<td>203.2 mm</td>
</tr>
<tr>
<td>Exhaust system backpressure (maximum allowable)</td>
<td>6.7 kPa</td>
</tr>
<tr>
<td><strong>Heat Rejection</strong></td>
<td></td>
</tr>
<tr>
<td>Heat rejection to coolant (total)</td>
<td>662 kW</td>
</tr>
<tr>
<td>Heat rejection to exhaust (total)</td>
<td>2228 kW</td>
</tr>
<tr>
<td>Heat rejection to aftercooler</td>
<td>629 kW</td>
</tr>
<tr>
<td>Heat rejection to atmosphere from engine</td>
<td>153 kW</td>
</tr>
<tr>
<td>Heat rejection to atmosphere from generator</td>
<td>87.7 kW</td>
</tr>
<tr>
<td><strong>Alternator</strong></td>
<td></td>
</tr>
<tr>
<td>Motor starting capability @ 30% voltage dip</td>
<td>6537 skVA</td>
</tr>
<tr>
<td>Frame</td>
<td>1844</td>
</tr>
<tr>
<td>Temperature Rise</td>
<td>125 °C</td>
</tr>
<tr>
<td><strong>Lube System</strong></td>
<td></td>
</tr>
<tr>
<td>Sump refill with filter</td>
<td>401.3 L</td>
</tr>
<tr>
<td><strong>Emissions (Nominal)</strong></td>
<td></td>
</tr>
<tr>
<td>NOx mg/nm³</td>
<td>1813.3 mg/nm³</td>
</tr>
<tr>
<td>CO mg/nm³</td>
<td>462.8 mg/nm³</td>
</tr>
<tr>
<td>HC mg/nm³</td>
<td>48.7 mg/nm³</td>
</tr>
<tr>
<td>PM mg/nm³</td>
<td>42.3 mg/nm³</td>
</tr>
</tbody>
</table>

1 For ambient and altitude capabilities consult your Caterpillar dealer. Air flow restriction (system) is added to existing restriction from factory.
2 Generator temperature rise is based on a 40°C (104°F) ambient per NEMA MG1-32.
3 Emissions data measurement procedures are consistent with those described in EPA CFR 40 Part 89, Subpart D & E and ISO8178-1 for measuring HC, CO, PM, NOx. Data shown is based on steady state operating conditions of 77°F, 28.42 in HG and number 2 diesel fuel with 35° API and LHV of 18,390 btu/lb. The nominal emissions data shown is subject to instrumentation, measurement, facility and engine to engine variations. Emissions data is based on 100% load and thus cannot be used to compare to EPA regulations which use values based on a weighted cycle.

**Standby** - Output available with varying load for the duration of the interruption of the normal source power. Average power output is 70% of the standby power rating. Typical operation is 200 hours per year, with maximum expected usage of 500 hours per year. Standby power in accordance with ISO8528. Fuel stop power in accordance with ISO3046. Standby ambients shown indicate ambient temperature at 100% load which results in a coolant top tank temperature just below the shutdown temperature.

**Ratings** are based on SAE J1349 standard conditions. These ratings also apply at ISO3046 standard conditions. **Fuel rates** are based on fuel oil of 35º API [16º C (60º F)] gravity having an LHV of 42 780 kJ/kg (18,390 Btu/lb) when used at 29º C (85º F) and weighing 838.9 g/liter (7.001 lbs/U.S. gal.). Additional ratings may be available for specific customer requirements, contact your Caterpillar representative for details. For information regarding Low Sulfur fuel and Biodiesel capability, please consult your Caterpillar dealer.
### DIMENSIONS

<table>
<thead>
<tr>
<th>Package Dimensions</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>6358.6 mm</td>
<td>250.34 in</td>
</tr>
<tr>
<td>Width</td>
<td>2286.0 mm</td>
<td>90 in</td>
</tr>
<tr>
<td>Height</td>
<td>2342.0 mm</td>
<td>92.2 in</td>
</tr>
<tr>
<td>Weight</td>
<td>17 332 kg</td>
<td>38,210 lb</td>
</tr>
</tbody>
</table>

NOTE: For reference only - do not use for installation design. Please contact your local dealer for exact weight and dimensions. (General Dimension Drawing #3274640).
APPENDIX C  POLLUTION CONCENTRATION ISOPOLETH PLOTS
Figure 9-1 Gas generator NO₂ 1-hour maximum concentrations (ppb)
Figure 9-2 Gas generator NO₂ 24-hour maximum concentrations (ppb)
Figure 9-3 Gas generator NO$_2$ annual average concentrations (ppb)
Figure 9-4 Diesel generator NO₂ 1-hour maximum concentrations (ppb)
Figure 9-5 Diesel generator NO₂ 24-hour maximum concentrations (ppb)
Figure 9-6 Diesel generator NO₂ annual average concentrations (ppb)
Figure 9-7 Diesel generator SO₂ 1-hour maximum concentrations (ppb)
Figure 9-8 Diesel generator SO₂ 24-hour maximum concentrations (ppb)
Figure 9-9 Diesel generator SO₂ annual average concentrations (ppb)
APPENDIX D  TAPM FILES

D.1 .LIS FILE

<table>
<thead>
<tr>
<th></th>
</tr>
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<tbody>
<tr>
<td>THE AIR POLLUTION MODEL (TAPM V4.0.3).</td>
</tr>
<tr>
<td>Copyright (C) CSIRO Australia.</td>
</tr>
<tr>
<td>All Rights Reserved.</td>
</tr>
<tr>
<td>----------------------------------------</td>
</tr>
</tbody>
</table>

----------------
RUN INFORMATION:
----------------
NUMBER OF GRIDS= 5
GRID CENTRE (longitude,latitude)=( 114.6083 , -28.58333 )
GRID CENTRE (cx, cy)=( 265500 , 6836500 ) (m)
GRID DIMENSIONS (nx, ny, nz)=( 25 , 25 , 25 )
NUMBER OF VERTICAL LEVELS OUTPUT = 15
DATES (START, END)=( 20041230 , 20050331 )
DATE FROM WHICH OUTPUT BEGINS = 20050101
LOCAL HOUR IS GMT+ 7.600000
TIMESTEP SCALING FACTOR = 1.000000
VARY SYNOPTIC WITH 3-D SPACE AND TIME
V4 LAND SURFACE SCHEME
EXCLUDE NON-HYDROSTATIC EFFECTS
INCLUDE PROGNOSTIC RAIN EQUATION
EXCLUDE PROGNOSTIC SNOW EQUATION
TKE-EPS TURBULENCE (PROGNOSTIC TKE + EPS, EDMF)
POLLUTION : CHEMISTRY (APM, NOX, NO2, O3)
EXCLUDE POLLUTANT VARIANCE EQUATION
EXCLUDE 3-D POLLUTION OUTPUT (*.C3D)
POLLUTANT GRID DIMENSIONS (nxf, nyf)=( 45 , 45 )
BACKGROUND APM = 0.0000000E+00 (ug/m3)
BACKGROUND NOX&NO2= 0.0000000E+00 (ppb)
BACKGROUND O3 = 20.00000 (ppb)
BACKGROUND Rsmog = 0.1000000 (ppb)
pH of liquid water= 4.500000

----------------
START GRID 1 OPSG300a
GRID SPACING (delx, dely)=( 30000 , 30000 ) (m)
POLLUTANT GRID SPACING (delxf, delyf)=( 15000 , 15000 ) (m)
NO MET. DATA ASSIMILATION FILE AVAILABLE
NO CONCENTRATION BACKGROUND FILE AVAILABLE
NUMBER OF BUILDINGS = 1
NUMBER OF pse SOURCES= 1
NO lse EMISSION FILE AVAILABLE
NO ase EMISSION FILE AVAILABLE
NO gse EMISSION FILE AVAILABLE
<table>
<thead>
<tr>
<th>pse KEY</th>
<th>is</th>
<th>ls</th>
<th>xs, ys</th>
<th>hs</th>
<th>rs</th>
<th>es</th>
<th>fs_no</th>
<th>fs_fpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1, 1</td>
<td>267600.00, 6835280.00</td>
<td>11.00</td>
<td>2.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td></td>
</tr>
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</table>

LAGRANGIAN (LPM) MODE IS OFF FOR THIS GRID

### D.2 .PSE FILE

<table>
<thead>
<tr>
<th>is, ls, xs, ys, hs, rs, es, fs_no, fs_fpm</th>
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<tbody>
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<td>1, 1, 267600.00, 6835280.00, 11.00, 2.00, 1.00, 1.00, 0.50</td>
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</tbody>
</table>

### D.3 .BLD FILE

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</thead>
<tbody>
<tr>
<td>1, 4, 12, 267598, 6835271, 267598, 6835275, 267602, 6835275, 267602, 6835271</td>
</tr>
</tbody>
</table>

INITIALISE
LARGE Timestep = 300.0000
Meteorological Advection Timestep = 150.0000 (s)
Pollution Advection Timestep = 300.0000 (s)
APPENDIX E  STATISTICAL CALCULATIONS

The Root Mean Square Error (RMSE) is a statistical technique that is used to measure the difference between the values predicted by a model to the observed values. It is commonly used in meteorology to determine how effective a model is in predicting the weather (Hurley et al, 2005). The RMSE is represented as:

\[
RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (P_i - O_i)^2}
\]

Where:
N = number of observations,
P_i are the predictions,
O_i are the observations

The Index of Agreement (IOA) is a statistical methodology that determines the correlation of predicted and measured values. It differs from the alternative correlation coefficient (r) and coefficient of determination (r^2) in that it is a relative measure and is consistently related to the accuracy of the prediction. The IOA is represented as:

\[
IOA = 1 - \frac{\sum_{i=1}^{N} (P_i - O_i)^2}{\sum_{i=1}^{N} (|P_i - O_{meas}| + |O_i - O_{meas}|)^2}
\]