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APPENDIX

7

AIR QUALITY IMPACT ASSESSMENT REPORT

APPENDIX 7: Air Quality Impact Assessment Report

Appendix 7

AIR QUALITY IMPACT ASSESSMENT OF PROPOSED WASTE POWER STATION IN EAST ROCKINGHAM, WESTERN AUSTRALIA

Prepared for Aurora Environmental

by

ENVALL

Environmental Alliances Pty Ltd

December 2017

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Client: Aurora Environmental

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

New Energy proposes to construct and operate a waste-to-energy (WTE) facility at East Rockingham, approximately 3 km north-east of Rockingham in the Rockingham Industrial Zone.

The nearest residential area (Leda) to the site is approximately 2.3 km away to the east. There is an isolated dwelling located about 1100 m to the north-east - north of Wellard Road.

A previous proposal for a waste-to-energy and materials recovery facility at this site was assessed by the Environmental Protection Authority (EPA) in 2014 and subsequently recommended for approval (EPA 2014).

A detailed description of the revised proposal is described in the Environmental Review Document (ERD) (Aurora Environmental 2017).

The general layout is shown in Figure 1. Office Road abuts the drive-way exiting north.

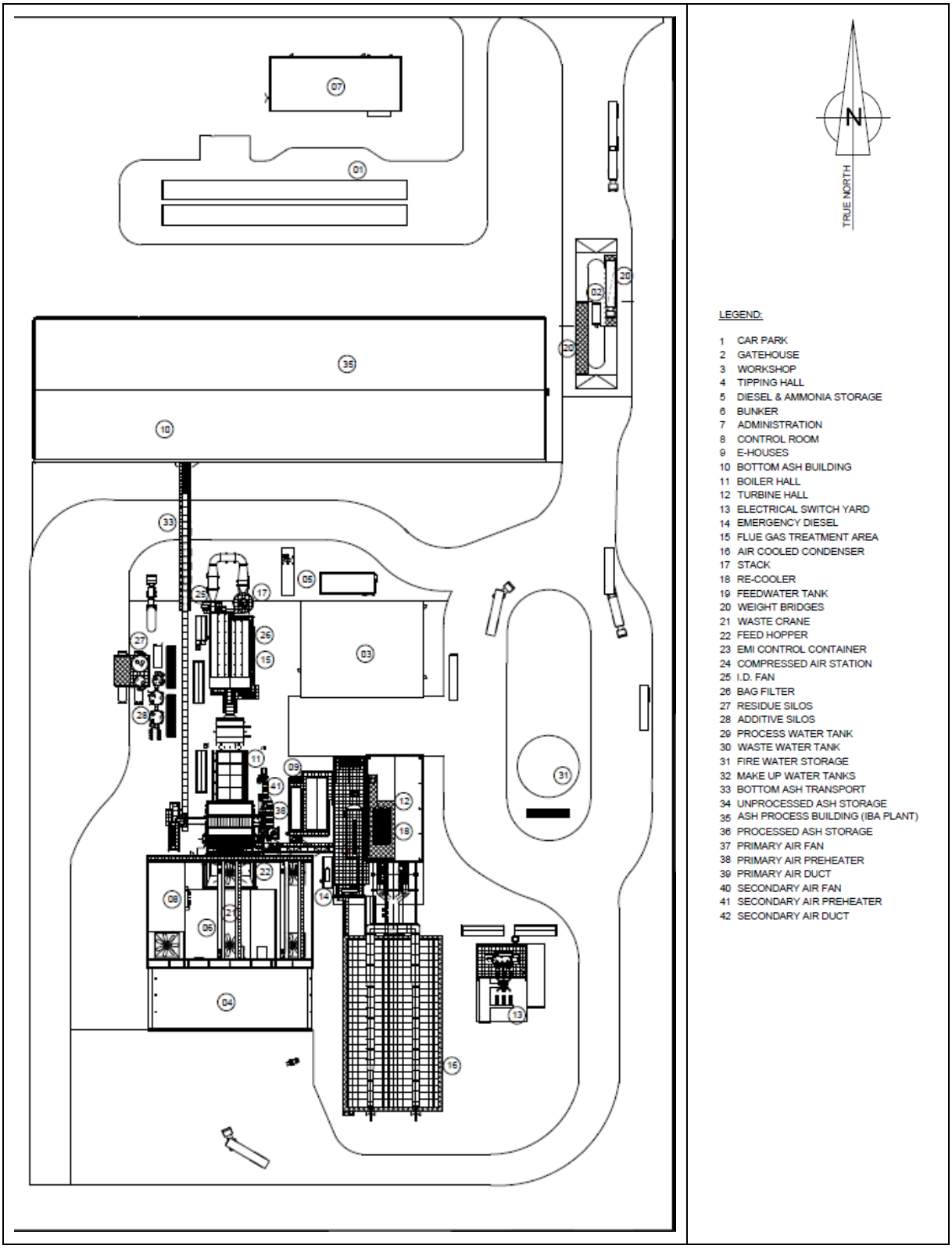

Figure 1 Layout of proposed WTE facility, Office Rd, East Rockingham

Figure 2 shows a conceptual side view of the facility. The elevation is taken from the south-east therefore Office Road abuts the drive-way on the right-hand-side.

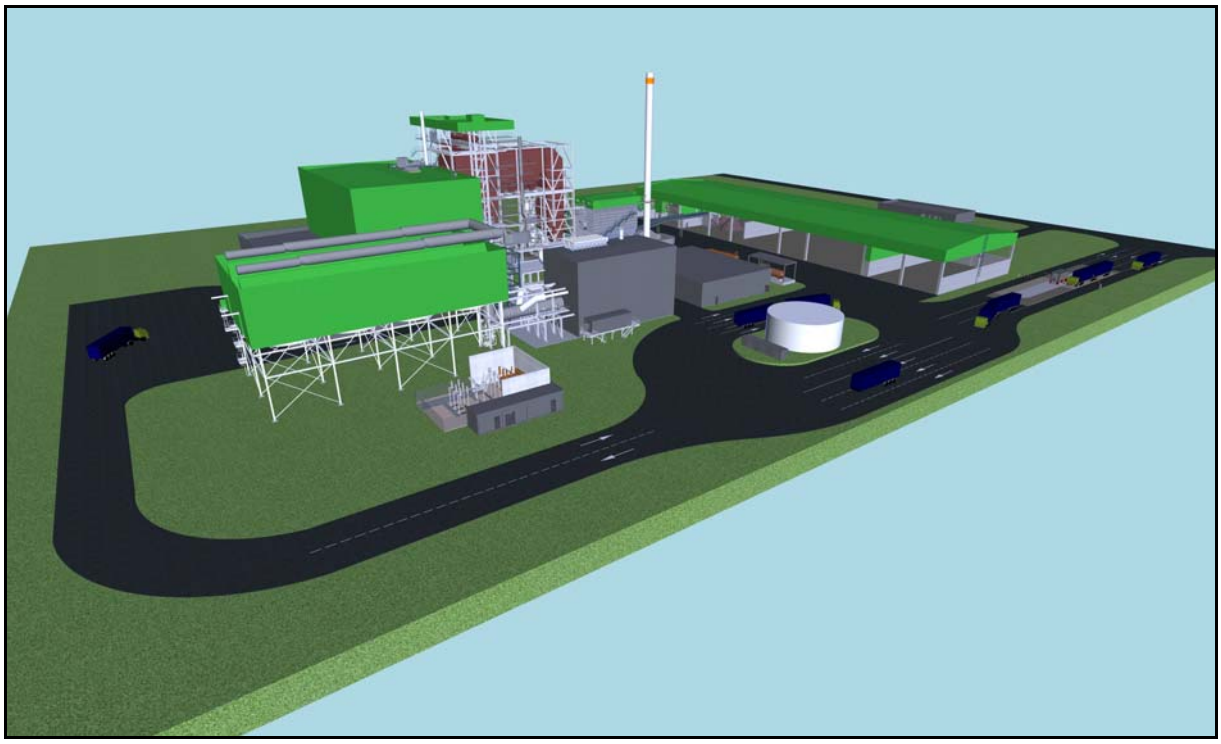

Figure 2 Conceptual side view of proposed WTE facility

The facility is designed for 330,000 tonnes per annum (tpa) of combustible waste (including up to 30,000 tpa of sewerage sludge) from commercial, industrial, construction, demolition and municipal solid waste streams to produce 30.8 MW of electrical energy of which an estimated 27.7 MW will be exported.

The design includes:

- a receival hall/bunker;
- a combustion chamber, boiler and generator; and
- a waste gas treatment system with treated gases from the combustion being discharged through a 60 m stack.

There is also an emergency diesel generator for the safe shut-down in the event of a loss of grid connection.

2. DESCRIPTION OF PROPOSAL

2.1 NATURE OF OPERATIONS

Waste delivery trucks turn around outside of the receival hall, then enter it by reversing from South through fast-acting roller shutter doors. The waste is normally tipped directly into the waste bunker. There is a dedicated door for each tipping bay.

A grab crane fitted with an automatic weighing cell picks up the waste and deposits it at the top of an upwards moving grate. The Hitachi Zosen Inova (HZI) moving grate system consists of five individually driven zones dedicated to each phase of the combustion process - drying, ignition, gasification, combustion of volatiles and char burn-out. The waste cascades downwards over the moving grate as each stage of combustion is completed. The inclination of the grate in combination with its moving grate block rows, guarantees a good mixing of the waste and thus an efficient burn out of the bottom ash.

Feed air for the combustion process will be drawn from within the receival hall/bunker building. This will keep the receival hall/bunker under negative pressure to prevent fugitive odour releases, and oxidise odorous gases.

The combustion process reduces the waste volume received by up to 90%. The burnt-out ash passes through the ash discharger.

The furnace and secondary combustion chamber will comply with the 2-second retention time and 850 °C temperature requirements of the Industrial Emissions Directive 2010/75/EU of the European Union (IED) and be equipped with auxiliary burners. Auxiliary fuel is used only for start-up, therefore the burners are not used for normal operations unless required to ensure compliance with the IED.

The flue gas passes through a water tube boiler to produce superheated steam.

The generated steam is transformed into electrical energy in a turbo-generator set.

Figure 3 illustrates the main features of the waste-to-energy process.

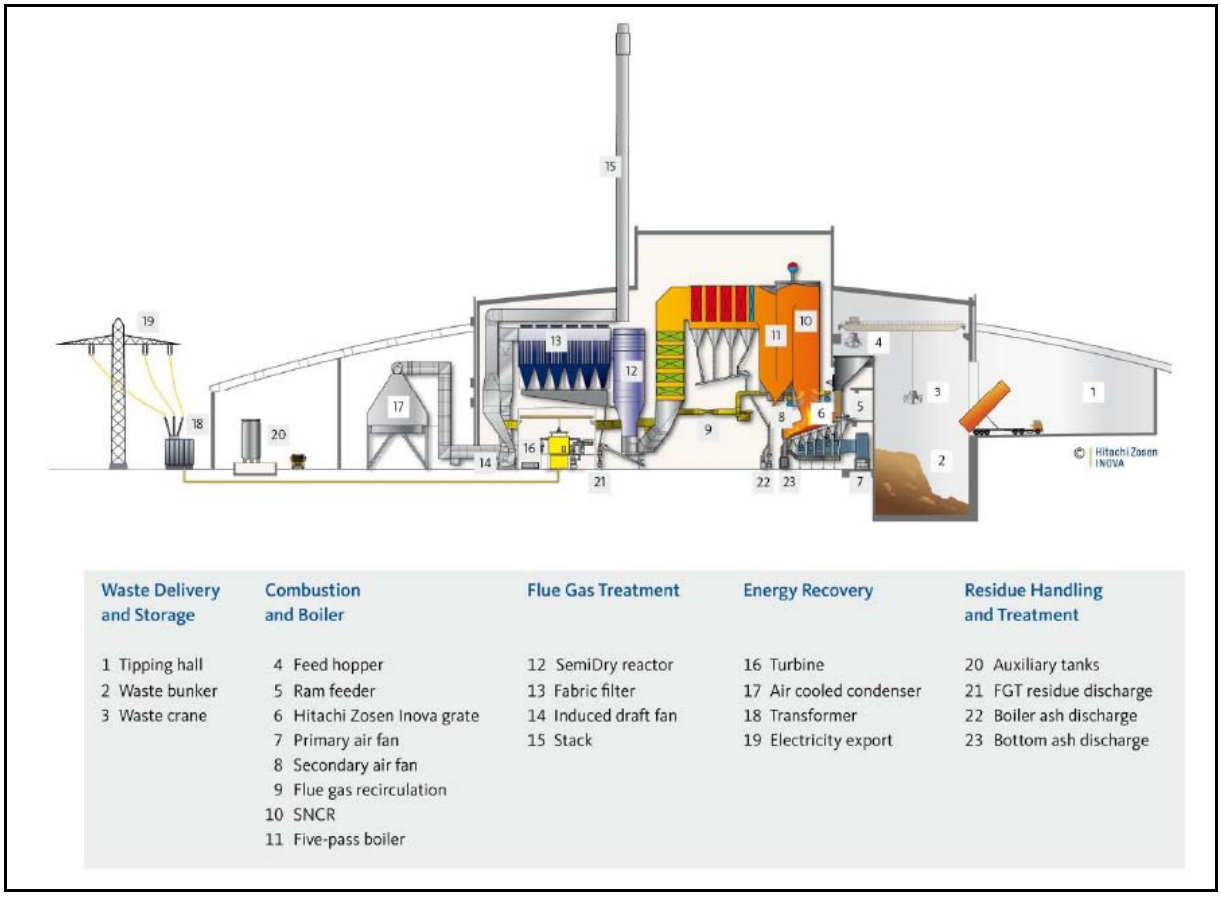

Figure 3 Generic schematic of Waste to Energy plant recently completed by HZI

2.2 FLUE GAS CLEANING

Prior to the boiler, the flue gases are directed through a non-catalytic deNO_x system (SNCR) that uses injection of a reactant, i.e. aqueous ammonia or urea, to convert oxides of nitrogen to nitrogen and water. The required temperature for this conversion is 850 to 950 °C which exists in the secondary combustion chamber of the furnace (the first pass of the boiler).

After the boiler, the flue gases are injected with hydrated lime to neutralise acidic components such as hydrogen chloride, hydrogen fluoride and sulphur dioxide. At the same injection point, activated carbon is added to the flue gas that adsorbs dioxins and furans, gaseous mercury, and other components.

Downstream of the injection of the reactants, the flue gas passes through a fabric filter which traps fine particulates. Periodically, the filters are cleaned by a reverse pulse of air, and the solid residues collected for disposal.

The cleaned flue gases are then monitored using a Continuous Emissions Monitoring System (CEMS).

An induced draught fan maintains the flue gas flow through the process. The final treated flue gases are discharged through a 60 m stack.

An overview of the flue gas process is shown in Figure 4.

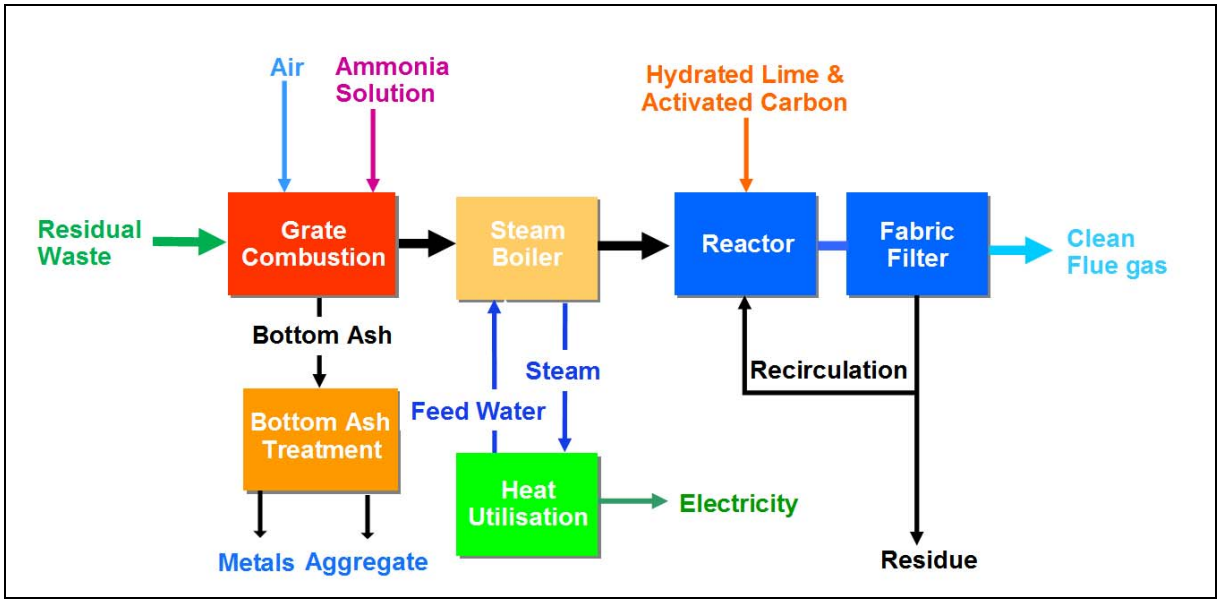

Figure 4 Bloc Flow Diagram of grate-combustion, steam boiler and flue gas cleaning system

The scrubbing system and combustion control will result in emission levels that will be fully compliant with the requirements of the IED. The main stack emissions provided by HZI are shown in Table 1.

Table 1 Air emissions from main stack

Substance	Concentration			Emission rate[(b)]		
	Units[(a)]	Max.	Expected	Units	HZI Max.=IED	HZI Expected
CO	mg/m^3 STP 11% O_2 dry	50	25	g/s	3.7	1.8
NO_x (as NO_2)	mg/m^3 STP 11% O_2 dry	200	190	g/s	14.7	14.0
PM (total)	mg/m^3 STP 11% O_2 dry	10	8	g/s	0.74	0.59
PM10	mg/m^3 STP 11% O_2 dry	10	8	g/s	0.74	0.59
PM2.5	mg/m^3 STP 11% O_2 dry	4.5	3.6	g/s	0.33	0.26
SO_2	mg/m^3 STP 11% O_2 dry	50	40	g/s	3.7	2.9
Chlorine as HCl	mg/m^3 STP 11% O_2 dry	10	8	g/s	0.74	0.59
Fluorine as HF	mg/m^3 STP 11% O_2 dry	1	0.8	g/s	0.074	0.059
TOC	mg/m^3 STP 11% O_2 dry	1.2	0.96	g/s	0.09	0.07
PCDD/F TEQ	ng/m^3 STP 11% O_2 dry	0.1	0.08	ng/s	7.4	5.9
	mg/m^3 O_2					
Sb	mg/m^3 STP 11% O_2 dry	0.055	0.044	mg/s	4.0	3.2
As	mg/m^3 STP 11% O_2 dry	0.005	0.004	mg/s	0.4	0.3
Pb	mg/m^3 STP 11% O_2 dry	0.295	0.236	mg/s	21.7	17.4
Cr	mg/m^3 STP 11% O_2 dry	0.01	0.008	mg/s	0.74	0.59
Co	mg/m^3 STP 11% O_2 dry	0.005	0.004	mg/s	0.37	0.29
Cu	mg/m^3 STP 11% O_2 dry	0.065	0.052	mg/s	4.78	3.82
Mn	mg/m^3 STP 11% O_2 dry	0.055	0.044	mg/s	4.04	3.23
Ni	mg/m^3 STP 11% O_2 dry	0.005	0.004	mg/s	0.37	0.29
V	mg/m^3 STP 11% O_2 dry	0.005	0.004	mg/s	0.37	0.29
Hg	mg/m^3 STP 11% O_2 dry	0.05	0.04	mg/s	3.68	2.94
Cd	mg/m^3 STP 11% O_2 dry	0.00875	0.004	mg/s	0.64	0.29
Tl	mg/m^3 STP 11% O_2 dry	0.00125	0.001	mg/s	0.09	0.07

[(a)] STP = Standard Temperature and Pressure (0 °C, 1 atm).

[(b)] As hourly averages.

The emission rates provided by HZI[1] are conservative estimates based on review of data from:

- the recently commissioned Greatmoor Facility in Buckinghamshire which is of the same capacity and design as the East Rockingham Facility;
- Severnside EfW – 2 lines, each line slightly smaller; and
- Ferrybridge FM1 – 2 lines, each line slightly larger.

All operate using similar feedstocks (MSW and Commercial and Industrial waste).

Based on the data from these EfW plants, HZI expects the emission rates achieved in operation at East Rockingham will be lower but wished to ensure that modelling was conducted on a conservative basis and hence recommend the use of the “maximum” estimates.

[1] Email from Aurora 27/11/2017.

These emission rates will not be exceeded at any time, including during combustor start-ups and shutdowns.

For modelling purposes, the maximum emissions have also been assumed at a constant rate, which will add to the conservativism.

2.3 STACK EMISSIONS MONITORING

As referred to above, emissions from the stack will be monitored using a CEMS for: particulates, carbon monoxide (CO), sulphur dioxide (SO_2), hydrogen chloride (HCl), oxygen (O_2), nitrogen oxides (NO_x) and Volatile Organic Compounds (VOC). The facility will include a dedicated certified duty CEMS for each line and a further hot standby CEMS which will ensure that there is continuous monitoring data available even if there is a problem with the duty CEMS system.

In addition to the continuous monitoring, periodic sampling will be undertaken for nitrous oxide (N_2O), hydrogen fluoride (HF), cadmium (Cd), thallium (Tl), mercury (Hg), antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), vanadium (V), dioxins and furans and dioxin-like polychlorinated biphenyls. The sampling frequency and duration will be confirmed during the assessment process.

3. ODOUR EMISSIONS

3.1 NORMAL OPERATION

3.1.1 Main stack

For normal operation, air is taken from above the bunker at 32.9 kg/s (27.3 m^3/s at 20°C) and used as combustion air. Given the combustion chamber temperature and flue gas residence times, odorants from the waste will be completely destroyed (via oxidisation).

3.1.2 Fugitive odour releases

In the previous odour modelling study for this proposal (TOU 2012), an odour sampling dataset from a large waste transfer station (WTS) in metropolitan New South Wales (NSW) was presented (see Table 2). This WTS accepts up to 400,000 tonnes per annum of municipal solid waste and commercial waste (compared to 330,000 tpa of similar waste for the proposal), with at least 300 tonnes of waste remaining on the WTS floor daily. The waste is stored inside the WTS prior to being out-loaded into semi-trailers for landfill. Given that the NSW WTS tipping floor is under forced extraction, it is reasonable to assume that the odour emissions sampled from this WTS air extraction system would be representative of the proposed New Energy facility.

Table 2 Odour concentrations sampled over 2005 – 2008 from NSW metropolitan Waste Transfer Station (capacity 400,000 tpa of MSW) with forced air extraction

Odour concentrations from 13 samples collected from roof extraction fans (ou)	
395	609
609	892
395	956
512	2400
675	1350
832	320
776	-

Reference: TOU (2012).

From these results, TOU (2012) considered that an internal odour concentration of 2,000 ou in the bunker would be a conservative concentration to use for modelling purposes.

In order to verify that this is a "conservatively realistic" assumption, the total odour from the bunker being extracted to the combustion chamber can be compared to measured total odour from similarly managed waste facilities. Another data set that has been recently used for odour assessments from waste handling are the results from odour emissions testing at the Clyde (waste) Transfer Terminal in NSW in August 2008. This facility handled predominantly putrescible general solid waste with some commercial and industrial waste. Four samples were taken from within the extraction stack for the building, in which 250 tonnes of waste was present on the tipping floor at the time of the sampling. The average odour concentration measured was 320 ou, with a mean stack gas flow rate of 88.7 m^3/s. The total odour emission rate (in this case being discharged untreated into the air via a 21 m stack) was 28,384 $ou.m^3/s$.

For the New Energy internal odour concentration assumption of 2,000 ou and extraction rate of 27.3 m^3/s, the total odour being extracted to the combustion chamber is 54,600 $ou.m^3/s$, which is nearly double that measured as an emission at the Clyde terminal. On this basis, the assumption of an internal odour concentration of 2,000 ou inside the New Energy bunker appears to be appropriately conservative.

It is expected that odours generated from waste in the New Energy bunker, (with a concentration of 2,000 ou as just described), will subsequently mix with air inside the receival hall, following which there will be minor odour emissions from the receival hall doors when open, due to the turbulence of the immediately surrounding external air and a "plunger" effect from ingoing and outgoing trucks. These emissions are very difficult to quantify. In the odour assessment of the NSW Banksmeadow Transfer Terminal, which also incorporated forced extraction (Wilkinson Murray 2014), an estimate of 5% of total odour emissions was considered "a sensible and conservative assumption for fugitive emissions" arising from air lost through the door and small building leaks. This same assumption was also used previously for odour modelling from the Clyde Transfer Terminal, referred to previously.

For the New Energy proposal, 5% of the total odour intake to the combustion chamber is 27.3 m^3/s x 2,000 ou x 0.05 = 2,730 $ou.m^3/s$.

As a comparison, the fugitive odour emissions assumed for the Phoenix Energy 400,000 tpa MSW waste-to-energy plant in Kwinana with a similar internal odour extraction from the waste tipping area and rapid closing door technology to that proposed for New Energy, was 545 $ou.m^3/s$. This was stated in the Environ (2010) report as being based on "data supplied by the client".

Therefore, the assumed fugitive odour emission for the New Energy proposal of 2,730 ou.m^3/s is five times higher than that assumed for Phoenix Energy, and would therefore appear to be a conservative estimate.

3.2 FACILITY DOWN-TIMES

The availability of the WTE facility is expected >8,000 hours per year (91%), with the remaining shutdown time (9%) being due to either planned maintenance or unplanned shut-down.

3.2.1 Fugitive emissions during planned maintenance

In the case of planned maintenance, some waste may still be accepted. Therefore, there will be waste in the bunker during stand-still, and the receival hall door may occasionally be open for truck entry and departure.

In addition, during a prolonged shutdown, the openings in the wall between the bunker and the receival hall (used for trucks tipping) can be closed which will effectively seal the bunker area from exposure to outside air even if the receival hall truck doors are open.

3.2.2 Fugitive emissions during unplanned shut down

In the case of a facility malfunction, waste will continue to be accepted. Hence, in such cases, there will be waste in the bunker during stand-still, and the receival hall door may occasionally be open for truck entry and departure.

3.2.3 Odour emissions during facility down-times

There are likely to be lower fugitive odour emissions during planned maintenance than during an unplanned shutdown, but in either case, the auxiliary forced ventilation system is activated, and the truck doors will be periodically open as waste deliveries continue. Therefore, there will be two sources of odour emissions – the shutdown stack and the receival hall doors.

1. Shutdown stack

As previously described, during all facility down times, an auxiliary forced ventilation system of approximately 10,000 m^3/hr (2.8 m^3/s) capacity will withdraw air from above the bunker and direct it to a dedicated stack of 48 m nominal height positioned at the south-west corner of the boiler room roof.

The odour generation rate from waste within the bunker during facility down-times will most likely actually be lower than during normal operation, as the grabs will be operating less frequently - only to move waste away from the pit area where trucks drop off waste.

Nevertheless, assuming the same internal odour concentration as for normal operation, the shutdown stack odour emission rate will be 2.8 m^3/s x 2,000 ou = 5,600 ou.m^3/s.

2. Reception hall doors

Since the auxiliary mechanical ventilation system extraction rate is much lower than the 27.8 m^3/s extraction rate when the combustor is operating, it is reasonable to expect that the volume of air released when the receival hall doors are opened will be higher than during normal operation (assuming there are no additional measures to restrict air flow from the bunker to the receival hall by shutting some of the tipping bay doors).

The fugitive odour emission rate assumed for modelling is therefore based on the multiple of the shut-down bunker air extraction rate compared to the normal bunker air extraction rate (27.8 m^3/s / 2.78 m^3/s = 10 times) applied to the fugitive odour emission rate for normal operation, that is 10 x 2,730 ou.m^3/s = 27,300 ou.m^3/s.

4. EMISSIONS SOURCE PARAMETERS

4.1 POINT SOURCES

The stacks emission parameters are shown in Table 3.

Table 3 Stacks emission parameters

Parameter	Units [a]	Main Stack			Shutdown Stack[b]
Location Easting	Km	384.580			384.565
Location Northing	Km	6430.979			6430.909
Height	m	60			48
Inner diameter	m	2.5			0.6
		Min	**Max**	**Expected**	
Volumetric flow	m^3/hr STP	123,180	225,830	215,565	-
Actual flow	m^3/hr	181,837	349,912	326,111	10,000
Reference flow	m^3/hr STP 11% O_2 dry			264,662	-
Velocity	m/s	10.3	19.8	18.5	10.3
Temperature	°C	130	150	140	ambient
O_2 content	Vol% O_2 wet			6.1	ambient
Humidity	Vol% H_2O wet			17.6	ambient

[a] STP = Standard Temperature and Pressure (0 °C, 1 atm).

[b] Used only to vent odours from the bunker during combustor shutdowns.

For modelling main stack emissions, the minimum temperature (130 °C) and volume flow (181,837 m^3/hr) were used as this will give the lowest buoyancy and hence plume rise, and conservative predictions of ground level substance concentrations.

The plume rise from both stacks will be affected if there are any buildings/structures up to one-fifth of the stack height within 1.5 times the stack height away. Buildings/structures that were therefore incorporated into modelling are shown in Table 4.

Table 4 Building parameters

Building/structure	Height (m)
Stack	60
Boiler roof	48.2
Bunker (Waste pit)	38
Turbine Hall	18.8
Workshop	7
IBA treatment building	13.4
ACC	26.2
Admin building	4.8
Filter	30
Building	**Volume (m^3)(1)**
Receival Hall	11,100
Bunker (Waste pit)	5,400(2)

(1) Data from Aurora 7/12/2017.

(2) Volume from the base of the bunker to the roof over the footprint of the bunker.

4.2 FUGITIVE SOURCES

For modelling odour emissions from the receival hall doors, the source was configured as a "volume" source with, following the EPAV (2000) guidelines:

- initial sigma y specified as one-quarter of the minimum of the receival hall north-south wall length (30 m) and east-west wall length[2] (4 5 m), vis 0.25 x MIN(30,45) = 7.5 m;
- initial sigma-z specified as one-quarter of the building height (8 m), vis 0.25 x 8 = 2 m; and
- release height specified as one-half of the receival hall building height (8 m), vis 0.5 x 8 = 4 m.

5. OPERATING HOURS

The operational hours for the site will typically be as follows:

Operation	Schedule
Waste Reception (weighbridge)	Continuous (24 hours/day, 7 days/week)
Combustor/Boiler	Continuous (24 hours/day, 7 days/week) except for maintenance and unplanned shutdowns as discussed
Administration	08:30 – 17:00 Mon-Fri

[2] Note: The south facing wall contains the doors.

6. AIR DISPERSION MODELLING

6.1 DISPERSION ISSUES

There are a number of air dispersion models used for regulatory assessments, with the choice of model dependent on the special dispersion issues that may be associated with a particular assessment. For this assessment, the special issues considered to be important in terms of model capability are:

- ability to incorporate the effect of building wakes on dispersion of elevated releases;
- the possible influence of the thermal internal boundary layer (TIBL) during onshore winds, on the dispersion of elevated releases; and
- low level odour releases for which dispersion during low winds speeds is important.

6.2 METEOROLOGICAL DATA

A further issue that has to be considered is the availability of suitable meteorological data.

There are two potential sources of air quality data for use in air dispersion modelling:

- observational data from site considered to adequately represent of the modelling domain; and/or
- data from a prognostic model such as TAPM[3] or WRF[4].

There is no known model-compatible meteorological data set specifically for the East Rockingham site.

In deciding where to source an appropriate meteorological data set, the clearest form of regulatory guidance is in the Victorian Guideline 1550 (EPAV 2013) which states: "Meteorological files constructed using meteorological data generated by prognostic models such as TAPM or MM5 may also be acceptable in situations where there are no measured mandatory data within a 5 km radius of the application site".

Good quality, near-surface wind measurements from the former KIC Alcoa 'A' Lake station for the 2008 year are considered suitable for this proposal (and were used for previous Synergetics (2011) assessment). The Alcoa 'A' Lake site and East Rockingham are similarly located relative to the coast, and are only about 5 km apart hence this data is considered to be suitably representative. The data considered of 1-hour measurements of wind speed and direction at 10 m, temperature and relative humidity. It is understood that winds were measured using air quality grade sensors. The data set was 99.5% complete. Data gaps were filled using TAPM as described in Appendix 1.

Upper air profile wind and temperature data is also required by most models for the dispersion of elevated releases. There are no continuous direct measurements of this for the Kwinana Area, hence the CSIRO's TAPM model was used to generate these data.

TAPM is also a complete prognostic model which means that it can be used independently of any measured meteorological data.

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3 "The Air Pollution Model" developed by CSIRO.

4 "Weather Research and Forecasting Model", an open source model built from collaborative efforts with different U.S.A. and overseas institutions.

6.3 CHOICE OF MODEL

For the dispersion of elevated releases, TAPM model is considered suitable as it has been specifically validated for the dispersion of elevated releases in the Kwinana industrial area. The results of previous validation studies by CSIRO, and TAPM surface wind predictions specific to the New Energy dispersion modelling, is described in Appendix 2.

For low level releases however, TAPM V4 tends to underestimate the frequency of near-calm wind speeds and calms, and hence may under-predict dispersion from low level releases.

Another dispersion model which has the capacity to handle all of the considerations in Section 6.1 is the US EPA's CALPUFF model. CALPUFF (Californian Puff model) is the US regulatory model for "assessing long range transport of pollutants and their impacts and on a case-by-case basis for certain near-field applications involving complex meteorological conditions".

Therefore, for this study:

- TAPM used for elevated releases; and
- CALPUFF used for odour assessment (elevated and low-level releases).

Details of the modelling configurations and the results of model sensitivity testing between TAPM and CALPUFF are described in Appendix 3.

6.4 TREATMENT OF OXIDES OF NITROGEN CONCENTRATIONS

At release from combustion sources, NO_x is predominantly in the form of NO. In general, depending on the characteristics of the source (such as the fuel and combustion technology), approximately 5 to 30% of the NO_x is NO_2. After release into the air, the NO is converted to NO_2 by chemical reactions, primarily involving ozone in the presence of sunlight and to a lesser extent, due to other reactive gases.

For this assessment, ambient NO_2 concentrations were estimated using the Ozone Limiting Method as described in detail in Appendix 4. This method assumes that 10% of the NO_x emitted is NO_2. CEMS NO_x measurements in the emissions of a similar technology WTE facility in the UK[5] show that for normal operations, the average daily NO_2:NO_x from two lines has been 0.75%, with the 97.5% percentile NO_2:NO_x being 2.35%. Therefore, the assumption that 10% of the emitted NO_x is NO_2 used for modelling, should be conservative.

6.5 PARTICULATES

The size of particulates emitted from the main stack after baghouse treatment is expected to be small enough not to be significantly affected by gravitational settling, and hence were assumed to disperse passively.

[5] Memo from HZI "Composition of Nitrogen compounds in WtE Emissions" dated 7 September 2017.

7. AMBIENT AIR QUALITY CRITERIA

7.1 SUBSTANCES

The considerations for environmental impact assessment of air quality are outlined in the Environmental Factor Guideline – Air Quality (EPA 2016). The Guideline does not refer to specific air quality criteria, therefore the applicable criteria for substances assessed were selected on a hierarchical basic of criteria available from:

- the standards specified in the National Environment Protection Measure for Ambient Air Quality (NEPC 2016); and
- for other substances, those recommendations considered to be most applicable to the WA, are as follows:
  - recommendations in "Air Guideline Values for Selected Substances" (Prepared for WA Department of Environment and Conservation) (Toxikos 2010);
  - for HCl and HF only, "Acid Gases – Internal document" (WA DoH 2007);
  - "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales"[6] NSW (2005) since these are referred to in as "Specific Consequence Criteria" in "Risk Assessments - Division 3, Part V, Environmental Protection Act 1986" (DER 2017); and
  - for Cobalt only, as no criteria in any of the above, recommendations in Toxikos (2009).

These are summarised in Table 5.

[6] The NSW guidelines were used as they were referred to in the Department of Environmental Regulation, "Environmental Risk Assessment Framework - Division 3, Part V, Environmental Protection Act 1986", Version: Draft released for consultation, December 2015, before it was withdrawn.

Table 5 Assessment criteria

Substance	Averaging time	Concentration (µg/m^3)[(a)]	Reference[(c)]
CO	8-hour	10000	NEPC (2016)
NO_2	1-hour	246	NEPC (2016)
NO_2	1-year	62	NEPC (2016)
PM10	24-hour	50	NEPC (2016)
PM10	1-year	25	NEPC (2016)
PM2.5	24-hour	25	NEPC (2016)
PM2.5	1-year	8	NEPC (2016)
SO_2	1-hour	570	NEPC (2016)
SO_2	24-hour	228	NEPC (2016)
SO_2	1-year	60	NEPC (2016)
HCl	1-hour	100	WA DoH (2007)
HF	1-hour	100	WA DoH (2007)
TOC(AsBenzene)	1-hour	29	DEC NSW (2005)
DioxinsAndFurans	1-hour	0.000001	Toxikos (2010)
As	1-hour	0.09	DEC NSW (2005)
As	1-year	0.003	Toxikos (2010)
Cd	1-hour	0.018[(b)]	DEC NSW (2005)
Cd	24-hour	0.016[(b)]	Toxikos (2010)
Co	1-year	0.1	Toxikos (2009)
Cr(VI)	1-year	0.0002	Toxikos (2010)
Cr(III)	1-hour	10	Toxikos (2010)
Cu	1-hour	1	Toxikos (2010)
Hg	1-hour	1.8	DEC NSW (2005)
Hg	1-year	1	Toxikos (2010)
Mn	1-hour	18	DEC NSW (2005)
Mn	1-year	0.15	Toxikos (2010)
Ni	1-hour	0.18	DEC NSW (2005)
Ni	1-year	0.003	Toxikos (2010)
Pb	1-year	0.5	NEPC (2016)
Sb	1-hour	9	DEC NSW (2005)
Tl	1-hour	1	Toxikos (2010)
Tl	1-year	0.1	Toxikos (2009)
V	24-hour	1	Toxikos (2010)

[(a)] For criteria originally specified on a volumetric basis, conversions to ug/m^3 are at 0 atm, 25C.

[(b)] With respect to the 1-hour criterion for Cd, Toxikos (2010) did not have a recommended 1-hour criterion but instead recommended a 24-hour average criterion of 0.02 µg/m^3 with footnote that this was a rounded up recommendation from 0.016 µg/m^3. Assuming that 0.016 ug/m^3 was the more precise recommendation, this would be approximately equivalent to a 1-hour average of 0.030 µg/m^3, which is 67% higher than the final DoH 1-hour criterion of 0.018 ug/m^3 used in this assessment.

[(c)] DEC NSW criteria apply to 99.9 percentile of predicted concentration if using local meteorological data for modelling, however, for conservatism, this report uses the maximum (100 percentile) predictions.

7.2 ODOURS

As described in Section 4.1, the dispersion of all of the odour emissions from the proposal will be affected by building wakes.

The criteria currently used by the DER to assess acceptable odour impacts from new proposals[7] for sources other than wake-free stacks, which therefore applies to this proposal, are:

- C99.9,1hr=8ou[8]; and
- C99.5,1hr=2.5ou.

The "Cnn.n" denotes annual percentiles.

"C99.9" is the 99.9th percentile of 1-hour average odour concentrations predictions. The 99.9th percentile is taken to be the 9th highest 1-hourly predicted odour concentration in the year.

"C99.5" is the 99.5th percentile of 1-hour average odour concentrations predictions, taken to be the 44th highest 1-hourly predicted odour concentration in the year.

8. BACKGROUND CONCENTRATIONS

Background concentrations for criteria pollutants were obtained from the DOWER ambient monitoring report for 2016 (DWER 2017). The nearest monitoring station measuring NO_2 and SO_2 were from measurements at the Rockingham air quality monitoring station (AQMS), approximately 3 km south-west of the site. The nearest monitoring station for CO, PM10 and PM2.5 was South Lakes AQMS, approximately 16 km north-north-east of the site.

For 1-hour and 8-hour criteria, the 90th percentile of the daily peak concentrations over 2016 was used. For 24-hour criteria, the 90th percentile of the 24-hour average concentrations was used. For annual average criteria, the 50th percentile of the 24-hour average concentrations was used[9].

Background concentrations are shown in the following section (see Table 6).

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[7] D Griffiths *pers com* 19/10/2012.

[8] Also accepted by Environmental Protection Authority (WA) – see ENVIRON, 2014, "Phoenix Energy Kwinana WTE Project – Air Dispersion Modelling Assessment", 23 May 2014.

[9] Except for NO_2 where neither 24-hour or annual averages were reported, therefore the value of 5 ppb was estimated from the plot for Rockingham in Figure A7.

9. MODELLING RESULTS

9.1 NORMAL OPERATION

9.1.1 Maximum ground level concentrations

The predicted maximum ground level concentrations anywhere from the proposal's air emissions are shown in Table 6.

Table 6 Predicted maximum ground level concentrations

Substance	Averaging time	Criteria conc. ($\mu g/m^3$)[(a)]	Assumed background		Predicted maximum ground level conc. anywhere on modelling grid			
			Conc. ($\mu g/m^3$) [(b)]	% of criteria	From proposal only		From proposal including background	
					Conc. ($\mu g/m^3$)	% of criteria	Conc. ($\mu g/m^3$)	% of criteria
CO	8-hour	10000	815	8.1	2.19E+01	0.2	8.37E+02	8.4
NO_2	1-hour	246	84	34.2	5.38e+01	21.9	1.38E+02	56.1
NO_2	1-year	62	10	15.4	1.00E+00	1.6	1.06E+01	17.0
PM10	24-hour	50	24	48.6	2.17E+00	4.3	2.65E+01	52.9
PM10	1-year	25	15	58.4	7.02E-02	0.3	1.47E+01	58.7
PM2.5	24-hour	25	12	46.4	9.78E-01	3.9	1.26E+01	50.3
PM2.5	1-year	8	7.4	92.5	3.16E-02	0.4	7.43E+00	92.9
SO_2	1-hour	570	35	6.1	3.38E+01	5.9	6.84E+01	12.0
SO_2	24-hour	228	5.3	2.3	1.09E+01	4.8	1.62E+01	7.1
SO_2	1-year	60	2.7	4.4	3.51E-01	0.6	3.01E+00	5.0
HCl	1-hour	100	-	-	6.76E+00	6.8	-	-
HF	1-hour	100	-	-	6.76E-01	0.7	-	-
TOC(AsBenzene)	1-hour	29	-	-	8.11E-01	2.8	-	-
DioxinsAndFurans	1-hour	0.000001	-	-	6.76E-08	6.8	-	-
As	1-hour	0.09	-	-	3.38E-03	3.8	-	-
As	1-year	0.003	-	-	3.51E-05	1.2	-	-
Cd	1-hour	0.018	-	-	5.91E-03	32.9	-	-
Cd	24-hour	0.016	-	-	1.90E-03	11.9	-	-
Co	1-year	0.1	-	-	3.51E-05	0.0	-	-
Cr(VI)	1-year	0.0002	-	-	7.02E-06	3.5	-	-
Cr(III)	1-hour	10	-	-	6.08E-03	0.1	-	-
Cu	1-hour	1	-	-	4.39E-02	4.4	-	-
Hg	1-hour	1.8	-	-	3.38E-02	1.9	-	-

Substance	Averaging time	Criteria conc. (µg/m^3)[(a)]	Assumed background		Predicted maximum ground level conc. anywhere on modelling grid			
			Conc. (µg/m^3) [(b)]	% of criteria	From proposal only		From proposal including background	
					Conc. (µg/m^3)	% of criteria	Conc. (µg/m^3)	% of criteria
Hg	1-year	1	-	-	3.51E-04	0.0	-	-
Mn	1-hour	18	-	-	3.72E-02	0.2	-	-
Mn	1-year	0.15	-	-	3.86E-04	0.3	-	-
Ni	1-hour	0.18	-	-	3.38E-03	1.9	-	-
Ni	1-year	0.003	-	-	3.51E-05	1.2	-	-
Pb	1-year	0.5	-	-	2.07E-03	0.4	-	-
Sb	1-hour	9	-	-	3.72E-02	0.4	-	-
Tl	1-hour	1	-	-	8.45E-04	0.1	-	-
Tl	1-year	0.1	-	-	8.77E-06	0.0	-	-
V	24-hour	1	-	-	1.09E-03	0.1	-	-
Odour	C99.9, 1-hr C99.5, 1-hr	8.0 ou 2.5 ou	-	-	1.8 ou 1.6 ou	22 64	-	-

[(a)] For criteria originally specified on a volumetric basis, conversions to ug/m^3 are at 0 atm, 20 °C. Odour concentrations are in ou.

[(b)] Background concentrations from nearest available DWER air quality monitoring station – see Section 8.

The maximum predicted concentration anywhere including background relative to its criterion is annual average PM2.5 at 92.9%. The incremental contribution from the proposal only is, however, just 0.4%, with 92.5% of the criterion being from background. The relatively high annual average PM2.5 background concentration is partly due to the method by which DWER measure PM2.5[10].

The second highest maximum predicted concentration anywhere including background relative to its criterion is annual average PM10 at 58.7%. The incremental contribution from the proposal only is, however, just 0.3%, with 58.4% of the criterion being from background.

A similar outcome is for 24-hour PM10. The maximum predicted concentration anywhere including background is 52.9% of the criterion, with the incremental contribution from the proposal only being 4.3%, and 48.6% of the criterion being from background.

For 1-hour NO_2, the maximum predicted concentration anywhere including background is 56.1% of the criterion, with background already comprising 36.7% of the criterion.

For 1-hour Cd the maximum predicted incremental concentration anywhere from the proposal only is 32.9% of the criterion. As noted in Table 5, the criterion adopted here is more stringent than proposed in Toxikos (2010).

The incremental predicted ground level concentrations of all other substances emitted from the main stack is less than 10% of their criterion.

9.1.2 Sulfur dioxide emissions and the Kwinana EPP

Heavy industries in Kwinana are the only significant sources of sulfur dioxide in the Perth/Kwinana/Rockingham region.

The "Kwinana EPP" (*Environmental Protection Act 1986* in concert with the *Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1999*) was implemented in the late 1990s to ensure that sulfur dioxide emissions did not cause ambient Limits and Standards set by the EPP, to be exceeded.

Concentrations of sulfur dioxide have since reduced due to the conversion from high to low sulfur fuels and the installation of sulfur dioxide control technologies.

A "screening" assessment of the impact of the New Energy sulfur dioxide emissions in the Kwinana EPP context is described in Appendix 5.

9.1.3 Contour plots

Nitrogen dioxide

The predicted maximum 1-hour average NO_2 concentrations from the proposal only are shown in Figure 5. The highest concentrations tend to be towards the south-west of the facility. These impacts are determined by the stack location relative to the buildings/structures on site and consequent plume downwash under certain meteorological conditions.

[10] DWER add 3 µg/m^3 to the TEOM measurement.

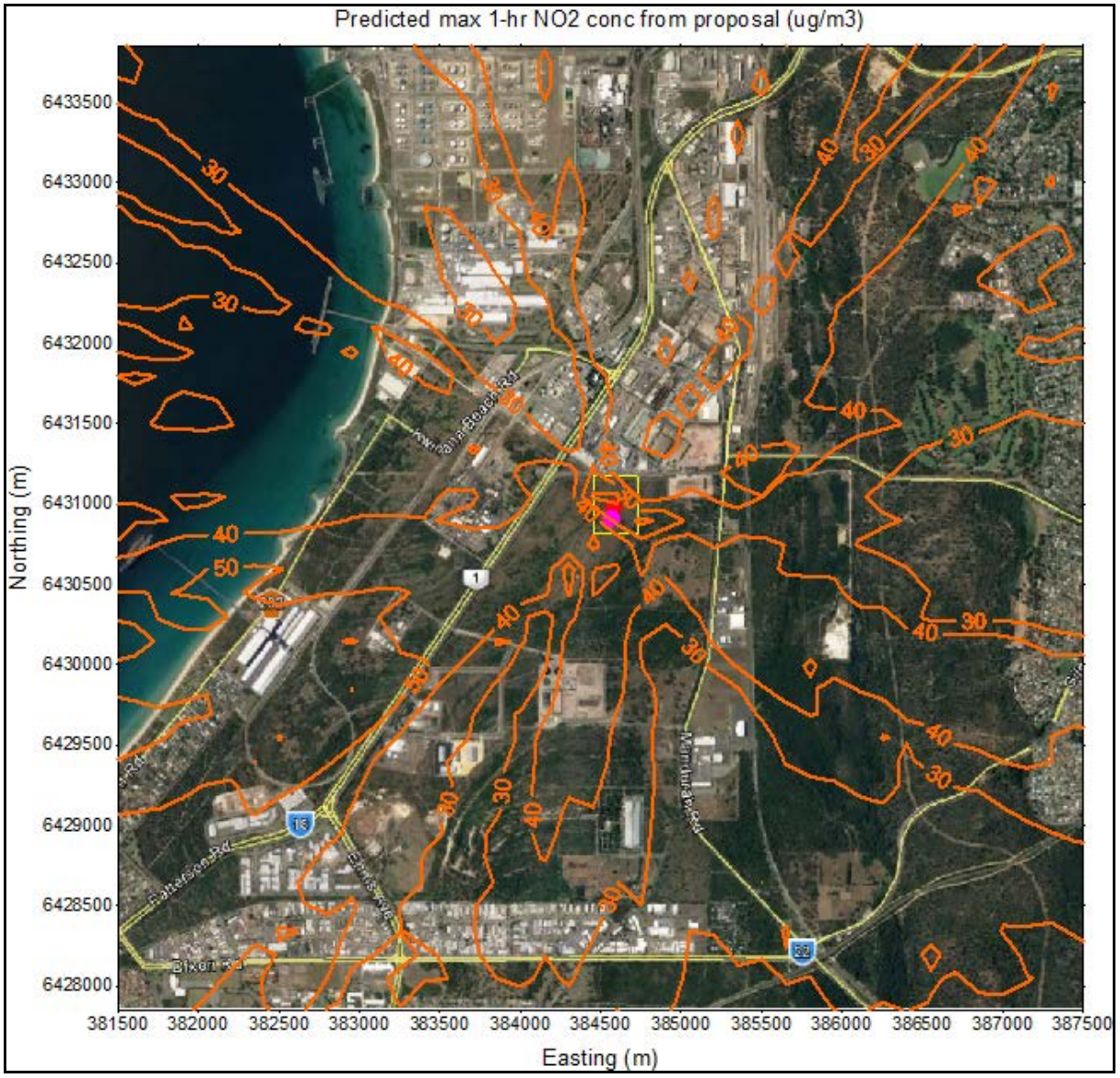

Figure 5 Predicted maximum 1-hour NO_2 concentrations from proposal

Note: Maximum NO_2 is 54 ug/m^3. Background NO_2 not included but otherwise as using Equation 1.

Figure 6 Predicted maximum 1-hour NO_2 concentrations from proposal including background

Note: Maximum NO_2 is 138 µg/m^3. Background of 84 µg/m^3 included. Criterion of 246 µg/m^3 is not exceeded.

Cadmium

The predicted maximum 1-hour average Cd concentrations from the proposal only are shown in Figure 7. The highest concentrations tend to be approximately 1 km south-west of the facility. These impacts are determined by the stack location relative to the buildings/structures on site and consequent plume downwash under certain meteorological conditions.

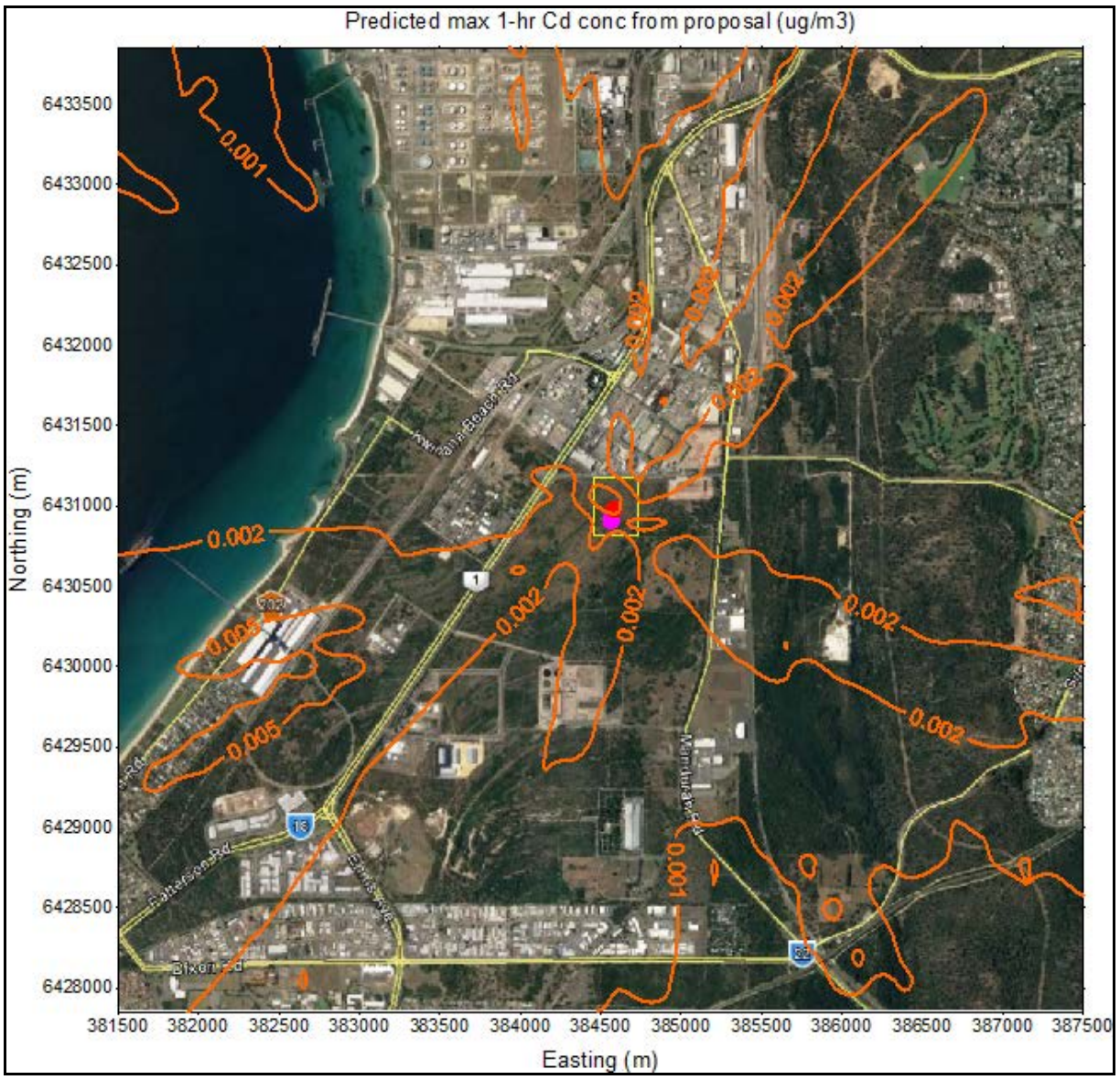

Figure 7 Predicted maximum 1-hour Cd concentrations from proposal

Note: Maximum Cd is 0.0059 µg/m^3. Criterion of 0.018 µg/m^3 is not exceeded.

Odour – normal operations

The predicted odour concentrations for normal operations are shown in Figure 8.

The C99.9,1-hr=8 ou residential criterion for odours is not predicted to be exceeded outside the site anywhere at ground level. The yellow contour shows one-tenth of this criterion.

The C99.5,1-hr=2.5 ou residential criterion for odours is not predicted to be exceeded outside the site anywhere at ground level. The orange contour shows one-tenth of this criterion.

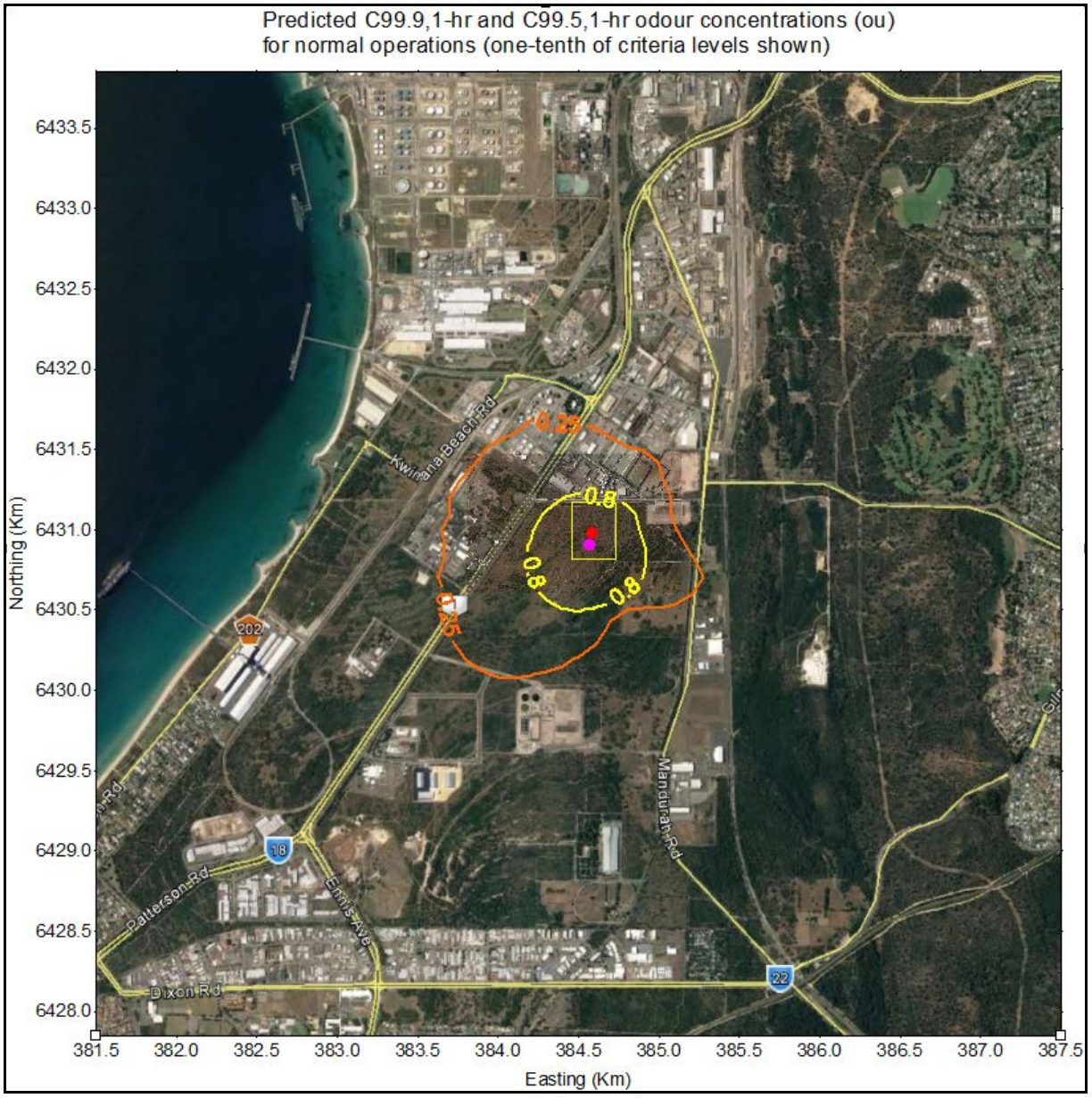

Figure 8 Predicted odour concentrations during normal operation

Odour criterion C99.9,1-hr=8 ou in yellow not exceeded anywhere outside the site boundary. The maximum C99.9,1-hr odour concentration outside the site boundary is 1.8 ou on the south side.

Odour criterion C99.5,1-hr in orange. The maximum C99.5,1-hr odour concentration outside the site boundary is 1.6 ou on the south side.

9.2 ODOUR – COMBUSTOR SHUTDOWNS

The highest odour emissions will occur during planned and unplanned maintenance when the auxiliary fan is discharging untreated air from the bunker at 48m and the facility is continuing to receive waste.

The predicted C99.9,1-hr=8ou and C99.5,1-hr=2.5ou criterion odour concentrations assuming continuous unplanned shutdown emissions over full year are shown in Figure 9. This is very conservative as this scenario is only expected to occur for less than 9% of the time.

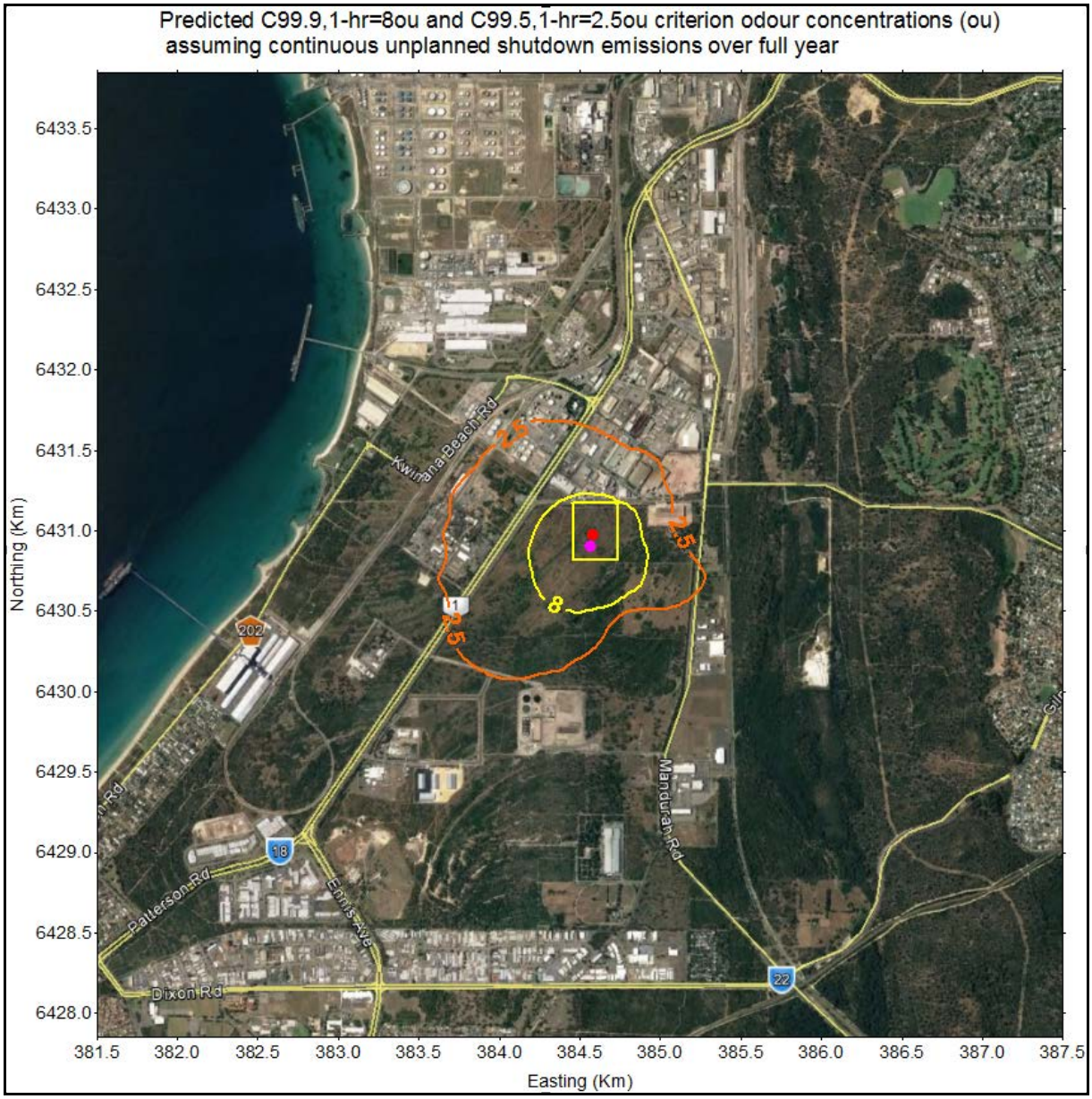

Figure 9 Predicted C99.9,1-hr=8ou and C99.5,1-hr=2.5ou criterion odour concentrations (ou) assuming continuous unplanned shutdown emissions over full year

Notes: Modelling based on continuous emissions 24/7, 366 days whereas unplanned shutdown emissions expected for only 9% of the year.

Odour criterion C99.9,1-hr=8ou in yellow. The maximum C99.9,1-hr odour concentration outside the site boundary is 18 ou on the south side.

Odour criterion C99.5,1-hr=2.5ou in orange. The maximum C99.5,1-hr odour concentration outside the site boundary is 16 ou on the south side.

From Figure 9, the criteria concentrations extend approximately 748 m (on average) from the site as these arise from odour emissions through the (low level) doors, however the criteria are still easily met at the nearest residential areas.

10. SUMMARY AND RECOMMENDATIONS

This report described the predicted air quality impacts from a proposed waste to energy facility on Office Road, East Rockingham.

Three sources of air emissions are considered; the main 60 m high stack discharging treated combustion gases, a 48 m high shutdown stack used to vent internal odours from the bunkers when the combustor is not operating, and odours release from the receival hall truck doors during truck entry and departure.

The TAPM model was used to predict ground level concentrations of emissions from the main stack. The CALPUFF model was used to predict ground level concentrations from odour emissions from the shutdown stack and receival hall truck doors.

The main stack emission rates were based on worst case estimates provided by the HZI.

For emissions from the main stack:

- The maximum predicted concentration anywhere including background relative to its criterion is annual average PM2.5 at 92.9%. The incremental contribution from the proposal only is, however, just 0.4%, with 92.5% of the criterion being from background. The relatively high annual average PM2.5 background concentration is partly due to the method by which DWER measure PM2.5[11].
- The second highest maximum predicted concentration anywhere including background relative to its criterion is annual average PM10 at 58.7%. The incremental contribution from the proposal only is, however, just 0.3%, with 58.4% of the criterion being from background.
- A similar outcome is for 24-hour PM10. The maximum predicted concentration anywhere including background is 52.9% of the criterion, with the incremental contribution from the proposal only being 4.3%, and 48.6% of the criterion being from background.
- For 1-hour NO_2, the maximum predicted concentration anywhere including background is 56.1% of the criterion, with background already comprising 36.7% of the criterion.
- For 1-hour Cd the maximum predicted incremental concentration anywhere from the proposal only is 32.9% of the criterion. As noted in Table 5, the criterion adopted here is more stringent than proposed in Toxikos (2010).
- The incremental predicted ground level concentrations of all other substances emitted from the main stack is less than 10% of their criterion.

For odour emissions during normal operations when the facility is operating:

- The C99.9,1-hr=8 ou residential criterion for odours is not predicted to be exceeded outside the site anywhere at ground level.
- The C99.5,1-hr=2.5ou residential criterion for odours is not predicted to be exceeded outside the site anywhere at ground level.

For odour emissions when the combustor is not operating, the predicted odour levels assuming a very conservative modelling scenario in which the facility continued to receive waste continuously for a full year, exceeded the residential criteria about 748 m (on average) from the site, however did not exceed the residential criteria at any actual residential areas (2.3 km away).

[11] DWER add 3 µg/m^3 to TEOM measurement.

Modelling results should always be qualified in that atmospheric dispersion models represent a simplification of the many complex processes involved in determining ground level concentrations of pollutants. Model uncertainty is composed of model chemistry/physics uncertainties, data uncertainties, and stochastic uncertainties. In addition, there is inherent uncertainty in the behaviour of the atmosphere, especially on shorter time scales due to the effects of random turbulence. The major cause of poor modelling predictions is, however, emissions data uncertainties. This report has endeavoured to balance these uncertainties through the use of conservative assumptions in the application of applicable criteria.

For this proposal, emissions of particulates, carbon monoxide, sulphur dioxide, hydrogen chloride, nitrogen oxides and Volatile Organic Compounds from the main stack will be continuously monitored. It is assumed that the emission rates modelled for this assessment will not be exceeded at any time, including during combustor start-ups and shutdowns.

For the prediction of odour impacts, a key assumption is that the bunker building and receival hall are air-tight except for the truck entry and departure doors in the receival hall.

It is recommended that immediately following commencement of stable operations, field odour assessments outside the site boundary are undertaken to verify the effectiveness of the odour control measures and predicted odour levels. Should odour levels exceed those predicted, options for odour mitigation include:

- installing an atomizer system to suppress odour (and dust) inside the bunker during combustor shutdowns;
- constructing a semi-porous wind fence along the southern boundary engineered (based on distance to the receival hall doors) to provide an effective wind barrier during south-westerly wind, with supplementary landscape plantings on the fence line with quick growing species;
- testing the bunker building and receival hall for air-tightness using internal smoke flares during moderate-strong winds (i.e. static test with doors closed);
- similarly, investigating the effectiveness of the air extraction systems to restrict odour releases from the truck doors when opened for truck movements during operation, with internal smoke flares (during normal operations and combustor shutdowns with waste continuing to be received);
- upgrading the capacity of the shutdown air extraction system; and
- re-positioning the air extraction intake vents in the bunker.

11. GLOSSARY OF TERMS

"BoM" means Bureau of Meteorology.

"DEC" means Department of Environment and Conservation (WA).

"EPA" means Environmental Protection Authority (WA).

"hr" means hour.

"Kg" means kilograms.

"km" means kilometres.

"m/s" means metres per second.

"m" means metres.

"m^2" means square metres.

"m^3/s" means cubic metres per second.

"m^3" means cubic metres.

"min" means minute.

"^oC" means degrees Celsius.

"OER" means odour emission rate with units of ou/s.

"$ou.m^3$" means odour units multiplied by the associated volumetric flow with units of m^3. When used as the emissions term in a dispersion model, the predicted ambient concentrations per cubic metre cause the volume units to cancel out to give odour units (the dimensionless ratio of the odour concentration to the odour threshold concentration).

"ou/s" means odour units per second.

"ou" means odour units. An odour unit is a dimensionless ratio defined as the volume which an odorous sample would occupy when diluted to the odour detection threshold, divided by the volume of the odorous sample.

"Percentile" means the division of a distribution into 100 groups having equal frequencies.

"s" means seconds.

"SOER" means odour emission rate (SOER) being the unit area odour emission rate from a surface for the prevailing wind or sweep air conditions, and having units of $ou.m^3/m^2/s$.

"t/hr" means tonnes per hour.

"t" means tonnes.

"TAPM" refers to "The Air Pollution Model", a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research.

"tpa" means tonnes per annum.

"US EPA" means United States Environmental Protection Agency.

Table 7 Substance abbreviations

Abbreviation	Description
As	Arsenic
Cd	Cadmium
CO	Carbon Monoxide
Co	Cobalt
Cr	Chromium
Cu	Copper
HCl	Hydrochloric acid
HF	Hydrogen Fluoride
Hg	Mercury
Mn	Manganese
Ni	Nickel
NO_x (as NO_2)	Nitrogen Oxides as Nitrogen Dioxide
Pb	Lead
PCDD/F I-TEQ	Polychlorobenzodioxins (PCDDs) and Polychlorodibenzofurans (PCDFs) expressed in "International Toxic Equivalents" or I-TEQ. .PCDDs comprise 75 congeners and PCDFs comprise 135 congeners. I-TEQ or "toxic equivalency" system (TEQ) expresses the relative toxicity of each less toxic compound as a fraction of the toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) . A "Toxic Equivalency Factor" (TEF) is assigned to each compound. This weighting coefficient indicates the degree of toxicity compared to 2,3,7,8-TCDD, which has the reference value 1. To calculate the overall toxic equivalency of a combination of dioxins compared to 2,3,7,8-TCDD, the quantities of each toxic compound are multiplied by their respective TEFs, which are then added together
PM (total)	Particulate Matter
PM_{10}	Particles having an equivalent aerodynamic diameter of less than 10 micrometres
$PM_{2.5}$	Particles having an equivalent aerodynamic diameter of less than 2.5 micrometres
Sb	Antimony
SO_2	Sulfur Dioxide
Tl	Thallium
TOC	Total Organic Carbon
V	Vanadium

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Appendix 1 Brief description of TAPM model

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research. Briefly, TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components, eliminating the need to have site-specific meteorological observations. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

TAPM incorporates the following databases for input to its computations:

- Gridded database of terrain heights on a longitude/latitude grid of 30 second grid spacing, (approximately 1 km). This default dataset was supplemented by finer resolution data at 90 m spacing for this study.
- Australian vegetation and soil type data at 3 minute grid spacing, (approximately 5 km).
- Rand's global long term monthly mean sea-surface temperatures on a longitude/latitude grid at 1 degree grid spacing, (approximately 100 km).
- Six-hourly synoptic scale analyses on a longitude/latitude grid at 0.75-degree grid spacing, (approximately 75 km), derived from the Local Analysis and Prediction System (LAPS) data from the Bureau of Meteorology.

Prognostically derived surface and upper air meteorological data (from TAPM) are increasingly being used in dispersion modelling where no observational meteorological data exists or where the network is sparse. This method of coupling derived meteorological with observational data has been used in modelling the dispersion of pollutants for this study.

The TAPM setups for this study were:

- meteorological grid domain of 25 x 25 cells nested at 30 km, 10 km, 3 km, 1 km and 300 m;
- pollution grid at 150 m;
- otherwise all other settings were defaults including no incorporation of any surface wind observations.

Appendix 2 TAPM validations for Kwinana

The most recent verification of the TAPM model for use at Kwinana is described in Hurley et al (2009). The paper described the results of TAPM wind and surface temperature predictions against hourly averaged surface winds (10 m) and temperatures at the Department of Environment (now DWER) air quality monitoring site at Hope Valley.

The statistics used for the comparison were those used earlier in Hurley (2000) and summarised below[12]:

- Means and Standard Deviations of the modelled and observed data.
- Root Mean Square Error (RMSE). Low RMSE values indicate that the model is explaining most of the variation in the observations. Tesche et al (2002) considers that for wind data, RMSE $\leq$ 2.0 represents acceptable model performance.
- Index of Agreement (IOA). This determines the degree to which the magnitudes and signs of the observed deviation about the mean observed value are related to the predicted deviation about the mean observed value (0 = no agreement, 1 = perfect agreement). Teschke (2002) considers that for wind data, IOA $\geq$ 0.6 and for temperatures IOA $\geq$ 0.8, represents acceptable model performance.

The Hurley et al (2009) study used TAPM V2, V3 and V4 (current version as used for New Energy modelling) at a horizontal final nested resolution of 1 km in the Kwinana region to simulate annual meteorology for 1997, and compared the hourly averaged results to the Hope Valley measurements. Table 3a in Hurley et al (2009) shown below, provides statistics for wind speed (WS), wind components (U and V) and temperature (T) at an observation height of 10 m above the ground.

Table 3a. Hope Valley Results at 10 m for TAPM V2.

	OBS AVG	MOD AVG	OBS STD	MOD STD	RMSE	IOA
WS	4.0	5.2	1.7	2.0	1.84	0.77
U	-0.2	-0.3	3.2	4.4	2.25	0.91
V	1.1	0.7	2.8	3.4	1.88	0.90
T	18.2	18.1	5.2	6.0	2.50	0.95

Table 3b. Hope Valley Results at 10 m for TAPM V3.

	OBS AVG	MOD AVG	OBS STD	MOD STD	RMSE	IOA
WS	4.0	4.6	1.7	1.8	1.40	0.83
U	-0.2	-0.2	3.2	3.9	1.94	0.92
V	1.1	0.6	2.8	3.0	1.70	0.91
T	18.2	18.0	5.2	6.2	2.63	0.94

Table 3c. Hope Valley Results at 10 m for TAPM V4.

	OBS AVG	MOD AVG	OBS STD	MOD STD	RMSE	IOA
WS	4.0	3.7	1.7	1.7	1.29	0.84
U	-0.2	-0.5	3.2	3.1	1.64	0.93
V	1.1	0.5	2.8	2.5	1.63	0.90
T	18.2	18.2	5.2	5.0	1.79	0.97

The results show that all versions have predicted temperature very well, with V4 showing little mean bias, a low RMSE of 1.79 °C and a high IOA of 0.97.

The results for TAPM V4 for winds show that:

[12] A complete description of the statistics is given in the Appendix of Hurley et al (2008).

- wind speeds are predicted well, with little mean bias, low RMSE of 1.29 m/s and high IOA of 0.84.

  It is notable the wind speed predictions have improved over successive versions of TAPM, and that the tendency of the original V2 to over-predict wind speeds has been reduced such that V4 mean wind speed is lower than observed.

- wind components (which also take into account wind directions) also have high IOA values of 0.93 and 0.90 respectively, again indicating very good predictions.

In summary, the most recent validation study of TAPM V4 for use at Kwinana demonstrated very good performance for the key parameters used in dispersion modelling.

The same analysis for the New Energy modelling was undertaken by comparing the TAPM V4 wind and temperature predictions against the observed hourly averaged surface winds (10 m) and temperature, at the Alcoa 'A' Lake monitoring site at Hope Valley[13]. The results are shown in Table 8.

Table 8 Statistical Measures of TAPM Performance for 2008 at Alcoa 'A' Lake site (New Energy)

Parameter	N	OBS AVG	MOD AVG	OBS STD	MOD STD	RMSE	IOA
Acceptance level	-	-	-	-	-	Winds ≤ 2.0	Winds ≥ 0.6 Temperature ≥ 0.8
WS	8738	3.2	3.6	1.6	1.7	1.31	0.82
U	8738	-0.4	-0.6	2.5	3.0	1.44	0.93
V	8738	1.0	1.1	2.3	2.2	1.31	0.91
T	8751	18.5	17.6	5.7	4.8	2.12	0.96

Notes:

1) N is number of data pairs, OBS AVG is mean of observations (in measurement units), MOD AVG is mean of modelled predictions (in measurement units), STD AVG is standard deviation of observations (in measurement units), STD AVG is standard deviation of modelled predictions (in measurement units), RMSE is root mean square error (in measurement units), IOA is index of agreement.

2) WS is wind speed (m/s), U and V are wind components (m/s) and T is ambient surface temperature (°C).

The results for TAPM V4 for 2008 at the Alcoa site show that:

- wind speed predictions are marginally poorer than for 1997 meteorology, with a mean bias of 0.4 m/s (compared to 0.3 m/s), RMSE of 1.31 m/s (compared to 1.29 m/s) and IOA of 0.82 (compared to 0.84).

  It is interesting that the TAPM-predicted 10 m mean wind for 2008 is slightly higher than the mean observed wind speed. It is suggested that the contrasting 1997 V4 result (in Hurley 2009) is due to the exposure of for the DWER Hope Valley site, and its location on a small hill, which would not be well resolved by the 1 km grid size used, and this outcome for the Alcoa site (i.e. TAPM-predicted mean wind speed slightly higher than observed) would be more typical for TAPM usage at most locations.

[13] A minor difference is that for New Energy, TAPM was nested down to 300 m whereas in Hurley (2009) TAPM was nested to 1km.

- wind directions (from the components) are practically the same as for 1997 with IOA values of 0.93 (same as before) and 0.91 (compared to 0.90) respectively, indicating very good predictions.
- temperature agreement is practically the same as for 1997 with IOA values of 0.96 (compared to 0.97).

In summary, the performance of TAPM V4 key parameter predictions for the New Energy study easily meet the reference acceptance levels, and are very similar to the results for 1997 in Hurley (2009).

Appendix 3 Sensitivity analysis of CALPUFF dispersion modelling options

The CALPUFF model, used in this study for odour dispersion modelling from elevated and low-level sources, allows for numerous user-configuration options. In order to determine appropriate settings for this work – and particularly to ensure that the CALPUFF results for odour emissions from the shutdown stack would be consistent with TAPM modelling results for other substances from the main stack, some sensitivity testing was undertaken. Predictions from TAPM configuration used for modelling the main stack emissions were compared to two CALPUFF modelling options, with the following set-ups common to all options:

- Meteorology for 2008 year;
- Stack emission 50 m (an arbitrary initial preliminary value);
- Nominal emission rate of 1 g/s;
- Zero buoyancy (selected for simulation of odour emission parameters during unplanned shutdown); and
- Incorporation of building wake effects using PRIME algorithm.

Modelling Option 1 (MO1) – TAPM using default settings

Objective: TAPM using default settings as used for Kwinana verification studies.

1 day spin up.

Default settings (see below).

Modelling Option 2 (MO2) – CALPUFF_A

Objective: CALMET/CALPUFF using same (as close as possible) meteorological input data as TAPM.

Geophysical file from TAPM default land use data base.

3D meteorological data from TAPM as above via CalTAPM to convert to MM5 compatible data.

CALMET with MM5 data used for initial Guess field and default Step 1 modifications only (NOOBS=2). The Step 1 modifications in this instance are expected to be minimal.

CALPUFF with TIBL sub-grid and COASTLN.DAT coastline coordinates.

Modelling Option 3 (MO3) – CALPUFF_B

Objective: CALMET/CALPUFF using same input data as TAPM for upper air parameters and incorporating Alcoa Motoplex site surface wind measurements.

As for MO2 except CALMET with MM5 data used for Initial Guess field, default Step 1 modifications (NOOBS=3) and Step 2 merging of surface winds with the selections below:

Pseudo site of Alcoa A observation data at the New Energy site.

RMAX1 = 4 km – Observational data merged with step 1 winds to a maximum for 4 km in layer 1.

R1 = 2 km – Observational data merging in layer 1 weighted equally with step 1 winds at 2 km.

RMAX2 = 8 km – Observational data merged with step 1 winds to a maximum for 8 km in upper layers.

R2 = 4 km – Observational data merging in upper layers 1 weighted equally with step 1 winds at 4 km.

Layer heights (m) = 0.,20.,40.,80.,160.,300.,600.,1000.,1500.,2200.,3000. Biases = -1 , -1 , -.75 , -.5 , -.25 , 0 , .25 , .5 , .75 , 1.

The above settings to emphasis uniformity of winds in the lowest few layers in the immediate vicinity of the site.

The advantages of this option compared to MO2 is that observational winds are used near the surface where TAPM-predicted winds are a little high, which is important for modelling dispersion of low level releases. The disadvantaging is that the merging of the observational winds can possibly lead to artificial wind shears being created where the observational winds are very different to the prognostic winds at the observational location, hence artificially enhancing dispersion.

Results

The maximum predicted 1-hour average ground level concentration is generally the limiting criteria for most air pollutants. Therefore, the comparison using this statistic is shown below.

Using the 5 ug/m^3 contour as an indicator of the distance where predictions at sensitive receptors are most important (i.e about 2 km from the site), Figure 10 shows:

- the CALPUFF options MO2 and MO3 are fairly similar which indicates that the incorporation of observation winds has made only little difference; and
- the TAPM predictions compared to CALPUFF MO2/MO3 are also similar for most bearings except to the south-east where CALPUFF predictions are more than two times higher, and to the south-west where TAPM predictions are about two times higher.

It is considered that given the inherent difficulty for different models to predict “extreme” i.e. 1-hour maximum, concentrations, the choice of modelling option does not make a material difference to predicted ground level concentrations at the nearest residential areas.

These results are consistent with a review of previous modelling of emissions from elevated point sources at Kwinana using TAPM and CALPUFF, in which it was concluded… “the Report shows that CALPUFF (and TAPM) are suitable for modelling odour emissions from the Kwinana refinery…” (Physick 2004).

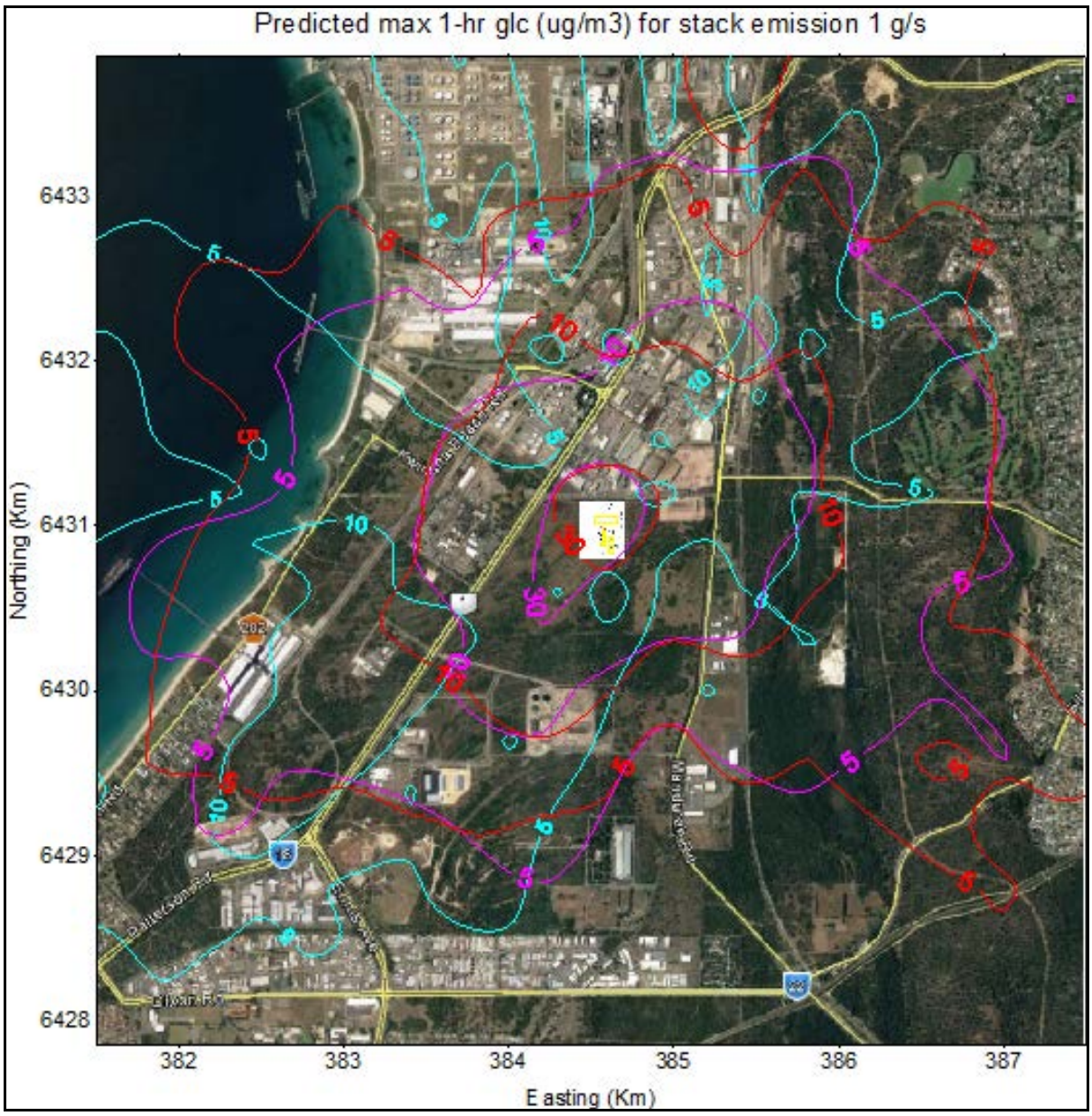

Figure 10 Comparison of modelling options

Contour intervals selected for illustration/comparison purposes are 5, 10 and 30 ug/m^3.

Blue contours are from MO1 – TAPM

Pink contours are from MO2 – CALPUFF using complete TAPM meteorological data

Red contours are from MO3 – CALPUFF using Alcoa site measured surface winds and TAPM upper air meteorological data

Conclusion

It was concluded that the use of CALPUFF, which is important for predicting dispersion from low-level releases (i.e. odours from the receival hall doors), with the Option B settings incorporating the measured surface winds, would give results that were consistent with TAPM for elevated releases, and was therefore appropriate for modelling odour emissions from the combination of elevated and near-ground level sources.

Appendix 4 Treatment of nitrogen oxides concentrations

At release from combustion sources, NO_x is predominantly in the form of NO with between 5 to 30% as NO_2 dependent on the source. After release, the NO is converted to NO_2 by chemical reactions, primarily involving ozone in the presence of sunlight and to a lesser extent, due to other reactive gases.

For this study, rather than predicting the conversion on an hourly basis, which requires hourly ozone concentration data, ambient NO2 concentrations were estimated using the Ozone Limiting Method (OLM) (NSW EPA 2005). The OLM is based on the assumption that approximately 10% (a conservative value for most combustion sources) of the NO_x emissions in the exhaust are generated as NO_2. If the ozone concentration is greater than 90% of the predicted NO_x concentrations, all the NO_x is assumed to have been converted to NO_2. Otherwise, the NO_2 concentration is calculated assuming total conversion of the ozone and adding the 10% of the NO_x that was emitted as NO_2.

The predicted ambient NO2 concentration is calculated from:

$$[NO_2]_{total} = \{0.1 \times [NO_X]_{pred}\} + MIN\{0.9 \times [NO_X]_{pred}, or(46/48) \times [O_3]_{bkgd}\} + [NO_2]_{bkgd}$$

Equation 1

Where-

$[NO_2]_{total}$ is the predicted concentration of NO_2 (vol/vol).

$[NO_x]_{pred}$ is the dispersion model prediction of the ground-level concentration of NO_x (vol/vol).

MIN means the minimum of the two quantities within the braces.

$[O_3]_{bkgd}$ is the background ambient O_3 concentration (vol/vol).

(46/48) is the molecular weight of NO_2 divided by the molecular weight of O_3.

$[NO_2]_{bkgd}$ is the background ambient NO_2 concentration (vol/vol).

For the calculation of 1-hour NO_2 for this study, background ozone and NO_2 levels were taken from the 90th percentile of daily peak concentrations from the DWER's ambient air monitoring at East Rockingham over 2016. These were 0.022 ppm (44 µg/m^3) and 0.044 ppm (84 µg/m^3) respectively. This is conservative in that the high (90th percentile) concentrations of NO_2 and ozone are unlikely to occur simultaneously, and at the same time as the predicted maximum concentrations from the proposal. This gives the relationship between predicted NO_x and estimated NO_2 as shown in Figure 11.

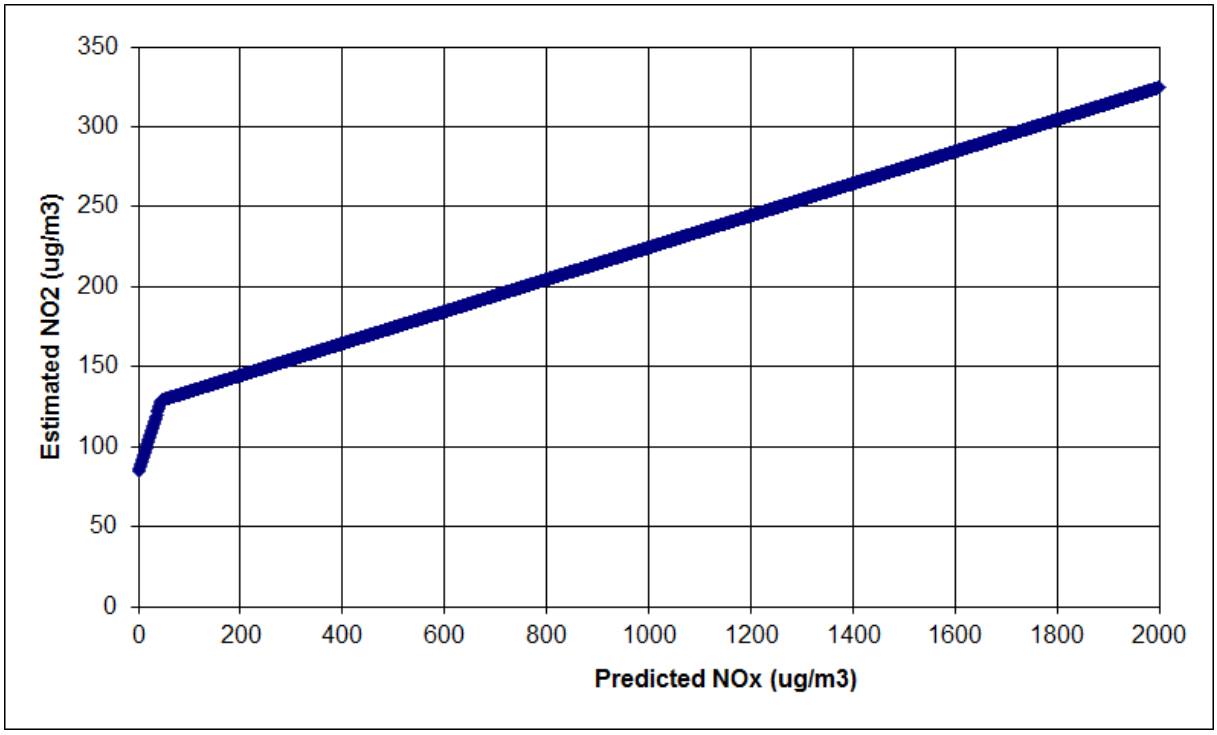

Figure 11 Relationship between predicted 1-hour average NO_x concentration and NO_2 concentration estimated using OLM and 90th percentile NO_2 and ozone concentrations

Notes:

Assumed ozone (O_3) background is 0.022 ppm.

Assumed nitrogen dioxide (NO_2) background is 0.044 ppm.

For the annual average NO2 concentrations, the value of 22 ppb (44 µg/m^3) for ozone and 5 ppb (9.6 µg/m^3) for NO_2 were estimated from DEWR (2017) Figure A7 for Rockingham.

Appendix 5 "Screening" assessment of the impact of the New Energy SO_2 emissions in the Kwinana EPP context

Sulfur dioxide (SO_2) levels in the Kwinana region are controlled through emissions limits for significant industries in the Kwinana Heavy Industrial Area, set through conditions of licences issued by DWER under Part V of the *Environmental Protection Act 1986*, in concert with the Environmental *Protection (Kwinana) (Atmospheric Wastes) Policy 1999* (EPP).

A "screening" assessment of the impact of the New Energy SO_2 emissions in the EPP context is undertaken as follows:

- The results of DISPMOD modelling for the current industry maximum emissions under the EPP is described in ENVIRON (2014). Whilst a number of meteorological years are presented, the results for the Full Modelling Domain using DISPMOD 2005, and the 1996 meteorological year, gives the most conservative results and hence are used for this screening assessment.

  EPP Limit

- The maximum predicted 1-hour SO_2 concentration from the New Energy proposal "anywhere"[14], is 35 µg/m^3 (See ENVALL 2017 Table 6).

  This maximum prediction is added to the maximum predicted concentrations "anywhere" in each of the Kwinana EPP Areas, and the sum compared to the EPP Limit.

  EPP Standard

- The maximum predicted 99.9 percentile 1-hour SO_2 concentration from the New Energy proposal "anywhere", is 19.5 µg/m^3 (subsequently extracted from the New Energy modelling results).

  This maximum prediction is added to the maximum predicted 99.9 percentile 1-hour concentrations "anywhere" in each of the Kwinana EPP Areas, and the sum compared to the EPP Standard.

This assessment methodology is a very conservative because:

- The DISPMOD modelling results are based on the current industry emitting at their maximum levels continuously over a year, which is extremely unlikely.
- The predicted maximum concentrations from New Energy will never occur at the same time and place as the predicted maximum statistics from the existing industries.
- The New Energy modelling prediction is based on the worst case SO_2 emission continuously over a year, which is extremely unlikely.

The results of the screening assessment are shown in Table 9 below.

[14] Note that "anywhere" in this context means at any modelled grid point.

Table 9 Results of screening assessment of incremental New Energy SO_2 concentrations with DISPMOD predictions

Statistic	EPP Criteria		Max. DISPMOD prediction anywhere*		Incremental contribution from New Energy anywhere		Screening assessment cumulative max. 1-hour conc.	
	Area	Limit (µg/m^3)	(µg/m^3)	% of criteria	(µg/m^3)	% of criteria	(µg/m^3)	% of criteria
EPP Limit: Max. 1-hour conc.	A	1400	1084	77	35	3	1119	80
	B	1000	450	45	35	4	485	49
	C	700	339	48	35	5	374	53
Statistic	**EPP Criteria**		**Max. DISPMOD prediction anywhere***		**Incremental contribution from New Energy anywhere**		**Screening assessment cumulative max. 1-hour conc.**	
	Area	**Standard (µg/m^3)**	**(µg/m^3)**	**% of criteria**	**(µg/m^3)**	**% of criteria**	**(µg/m^3)**	**% of criteria**
EPP Standard: 99.9 %ile 1-hour conc.	A	700	869	124	20	3	889	127
	B	500	362	72	20	4	382	76
	C	350	258	74	20	6	278	79

* DISPMOD 2005 - 1996 meteorological year (ENVIRON 2014).

From the Table:

- The incremental New Energy SO_2 contribution is only 3 to 6% of the EPP criteria at the various Areas.
- Except for the EPP Standard at Area A, the cumulative SO_2 is 49 to 80% of the EPP criteria at the various Areas, and hence below the criteria.
- For the EPP Standard at Area A, the predicted existing SO_2 is 124% of the EPP criteria. This is due to the inherent conservativism in the DISPMOD modelling case used. The incremental contribution from New Energy is only 3% of the criteria.

Concentrations of SO_2 in the Kwinana region have reduced markedly since the late 1970s due to the conversion from high to low sulfur fuels and the installation of sulfur dioxide control technologies. Ambient sulfur dioxide monitoring by DWER has shown that since the initiation of the Kwinana EPP, the EPP limits and standards have never been seriously threatened (see DWER 2016). The incremental SO_2 contribution from New Energy will make no significant difference to existing levels.