PROJECT REPORT

PT. Domas Agrointi Prima > Kuala Tanjung, Indonesia

Dispersion Modelling Report

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June 2017

Project 174801.0047

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1. INTRODUCTION

The company PT. Domas Agrointi Prima (DAP), an Indonesian producer of oleochemical products derived from palm oil, owns an oleochemical plant in the industrial estate of Kuala Tanjung, approximately 120 km southeast from the city of Medan, in North Sumatra. Since 2011, DAP is part of PT Bakrie Sumatera Plantation Tbk (BSP), a large Indonesian plantation conglomerate and a vertically integrated palm fruit plantation and processing operation.

DAP's oleochemical complex (the Project), located on a land area of approximately 114 hectare, is currently mothballed and only maintenance work is currently being done. The Project has an annual combined capacity of approximately 200,000 metric tons of fatty acid and fatty alcohol. It also has kernel crushing capabilities of approximately 160,000 metric tons per annum and refining capacity of approximately 500,000 metric tons per annum. The Project involves the restart of operations of DAP's Plant and the expansion of its facilities and production capacity. Once finished, the Plant will include two lines for fatty acid and fatty alcohol processing (Lines 1 and 2), a kernel crushing plant and a refinery. Supporting Project facilities will include a 2.7 km jetty and a 16MW natural gas power station.

The Overseas Private Investment Corporation (OPIC), as international lender of the Project, has identified the need to "Assess potential impacts to ambient air emissions, including a scenario where the Project builds and operates its own gas-fired power plant using internationally recognized air dispersion modelling methods." Under request from Pacific Harbor Group (PHG), Trinity Consultants Inc. (Trinity) performed an air dispersion modelling analysis as part of the assessment to determine the likelihood of compliance of the Project's future operations with international standards, in particular International Finance Corporation's (IFC's) Environmental, Health, and Safety (EHS) Guidelines for Ambient Air Quality.[1]

This report documents the modelling methodology for the air dispersion modelling analysis and presents the results from the analysis. Pollutants modelled include sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter with aerodynamic size smaller than 10 micron (PM_{10}) and particulte matter with aerodynamic size smaller than 2.5 micron ($PM_{2.5}$).

[1] IFC's General EHS Guidelines: Environmental; Air Emissions and Ambient Air Quality. Available at: https://www.ifc.org/wps/wcm/connect/532ff4804886583ab4d6f66a6515bb18/1-1%2BAir%2BEmissions%2Band%2BAmbient%2BAir%2BQuality.pdf?MOD=AJPERES.

2. MODELLING METHODOLOGY

2.1. DISPERSION MODEL SELECTION

The AERMOD dispersion model is selected for this dispersion modelling analysis, because AERMOD is an internationally recognized air dispersion model as listed in the IFC's Environmental, Health, and Safety Guidelines for Ambient Air Quality. AERMOD is a steady-state plume model that includes a state-of-the-science downwash algorithm and predicts concentrations at particular receptor locations over different hours and meteorological conditions. The most recent AERMOD dispersion model version 16126r was used.

Additionally, the terrain near the Project site is relatively flat and the domain size is less than 50 kilometers; therefore, a non-steady-state, long-range model such as CALPUFF is not warranted.

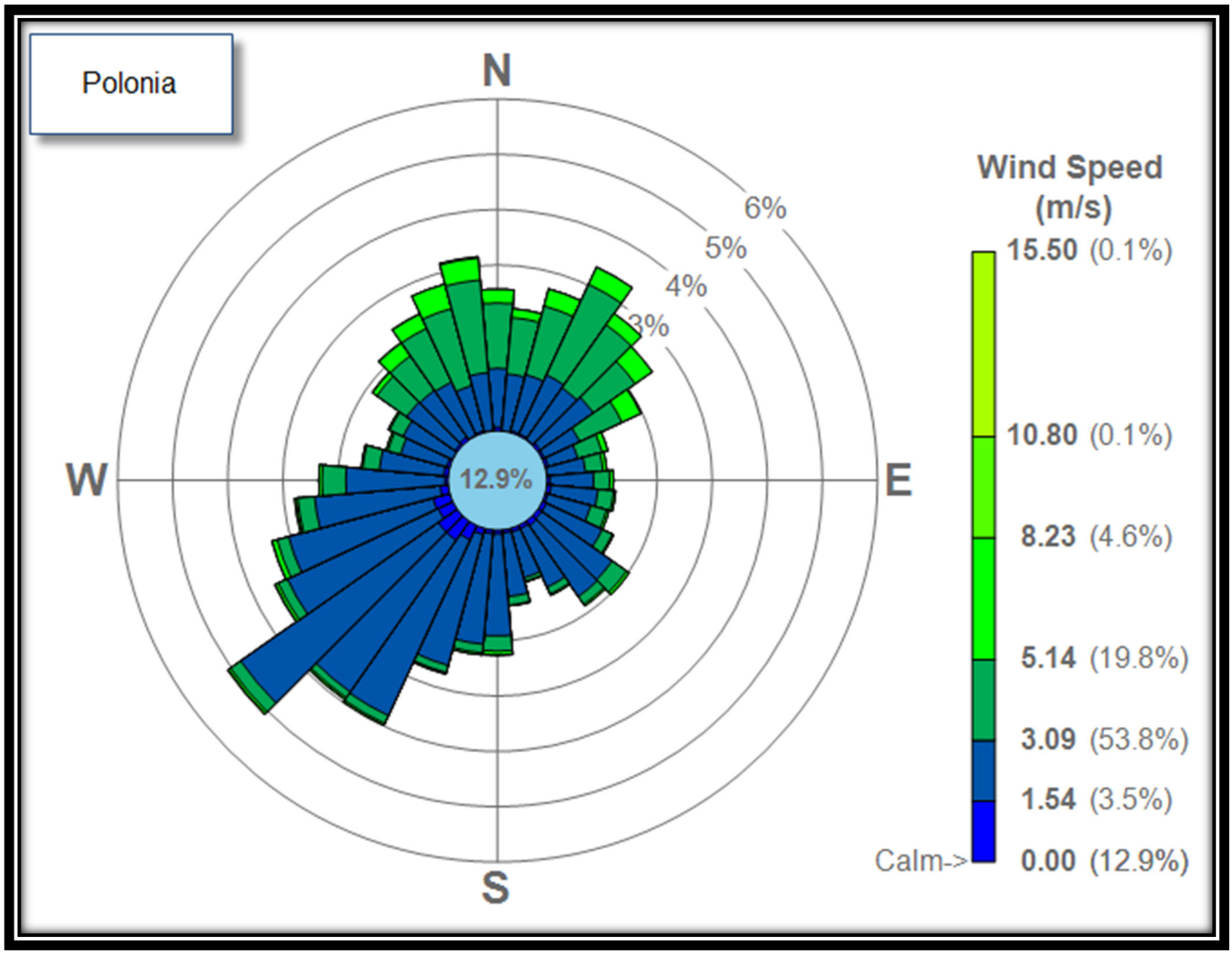
2.2. METEOROLOGICAL DATA

This modelling analysis is being performed using five years of representative meteorological data (January 1, 2012 to December 31, 2016) for the AERMOD dispersion model. Surface meteorological data are taken from the nearest meteorological surface station with complete data at the WIMM station at the Polonia International Airport in Medan, Indonesia, located at latitude 3.57 N and longitude 98.68 E. Upper air data are from the nearest upper air station at the Kualnamu International Airport. This dataset uses AERMOD meteorological preprocessor, AERMET (Version 16126).

Figure 1 below shows the wind rose at the WIMM surface station for the most recent year (2016).

Note that winds at the Project site on the coast may be stronger than those at this selected station. However, lower wind speeds result in higher concentrations; therefore use of this meteorological dataset is expected to be conservative. For future dispersion modelling efforts, generation of mesoscale meteorological data using a model such as the Weather Research Forecasting mesoscale model (WRF) to create a pseudo surface station on the Project site would yield more representative results.

Figure 2-1 WIMM Surface Station Wind Rose



2.3. TERRAIN ELEVATIONS

Terrain elevations for receptors, buildings, and sources are determined using the Shuttle Radar Topography Mission (SRTM) Version 2.1, SRTM3.[2] The SRTM3 provides elevations based on three arc-second (approximately 90 meters) grid spacing. Elevations are converted from the SRTM grid spacing to the air dispersion model spacing using the AERMOD preprocessor, AERMAP version 11103. All data obtained from the SRTM files are checked for completeness and spot-checked for accuracy.

2.4. COORDINATE SYSTEM

The location of emission sources, structures, and receptors is represented in the Universal Transverse Mercator (UTM) coordinate system using the World Geodetic System 1984 (WGS84) projection. The UTM grid divides the world into coordinates that are measured in north meters (measured from the equator) and east meters (measured from the central meridian of a particular zone, which is set at 500 km). UTM coordinates for this

[2] Downloaded from https://dds.cr.usgs.gov/srtm/version2_1/SRTM3/Eurasia/. June 13, 2017.

analysis will be based on UTM Zone 47 North. The location of the Project is approximately 547,910 m Northing and 373,000 m Easting.

2.5. RECEPTOR GRIDS

Receptors are placed in all areas directly surrounding the facility considered to be ambient air. Receptors are not placed on the water since it is not expected that exposure will occur continuously in the ocean. This modelling analysis uses three Cartesian receptor grids extending 1,000, 10,000, and 40,000 meters from the facility's fenceline. Receptors nearest the facility have a fine grid spacing and become coarse on the edge of the grid. This ensures the maximum model concentration is obtained and allows confirmation that concentrations are reducing at the outer boundary of the modeling domain (edge of receptor grid). In respective order, the receptor spacing for each tier is 100, 250, and 1,000 meters.

Boundary receptors spaced 25 meters from one another circumscribe the facility at the ambient air boundary. The ambient air boundary is determined to be the property boundary, as shown in Figure 2-2. Figure 2-3 shows the modelled receptors.

Figure 2-2. Modelled Ambient Air Boundary

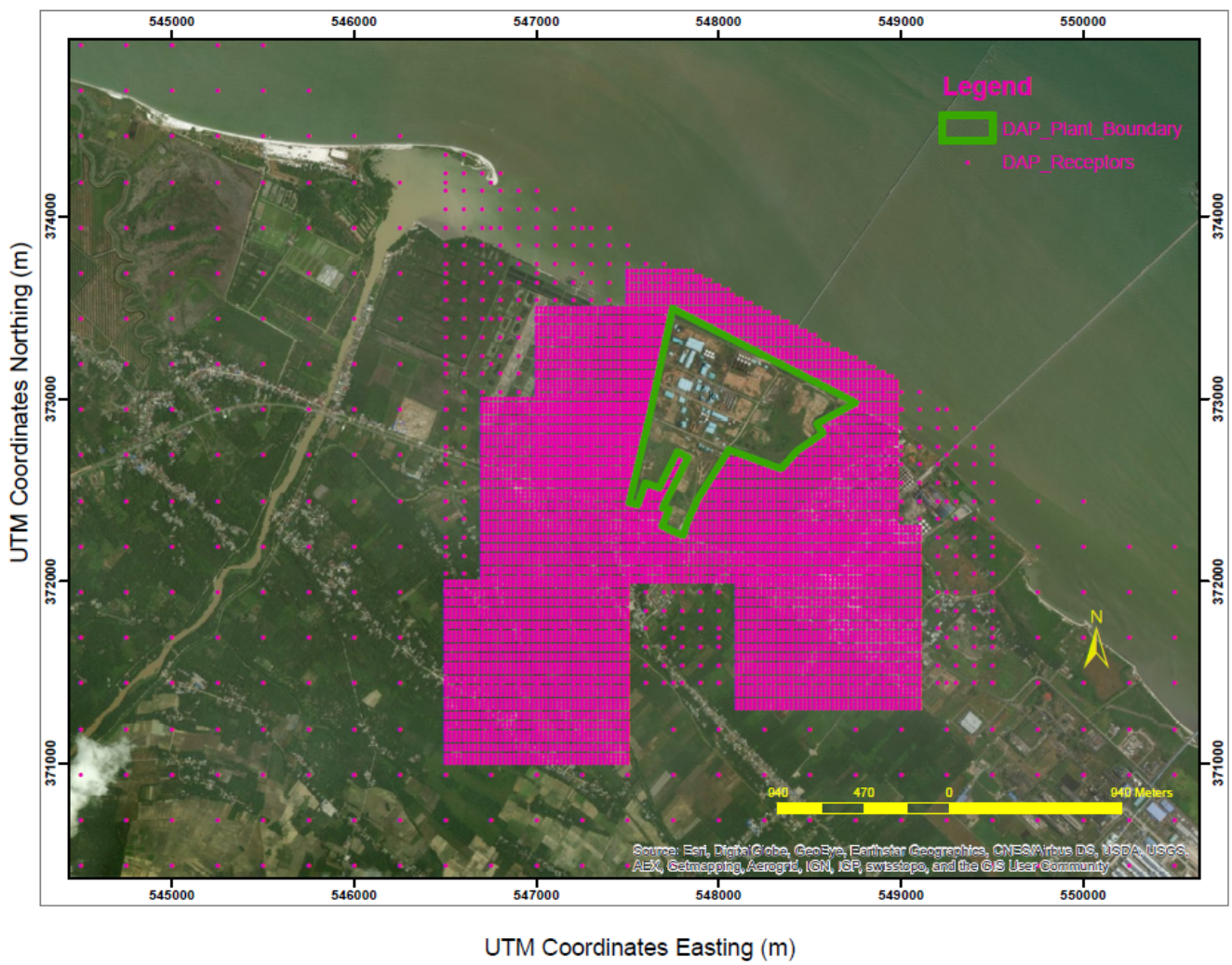
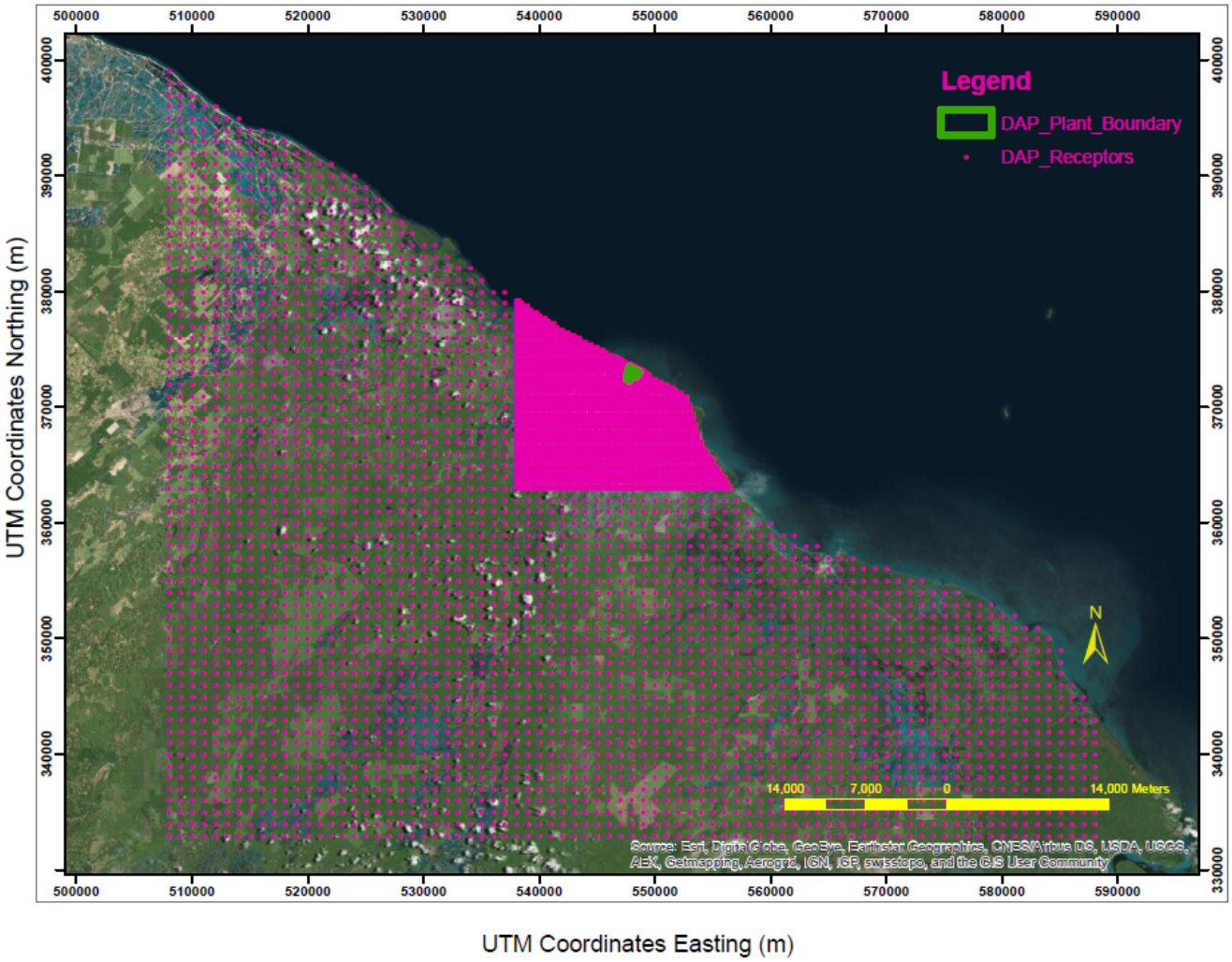


Figure 2-3. Modelled Receptors



2.6. BUILDING DOWNWASH

Building downwash effects are included to determine if emission discharges become caught in the turbulent wakes of nearby structures. Direction-specific building dimensions and the dominant downwash structure parameters (mainly the new dryer building and warehouse) used as inputs to the dispersion model are determined using the *BREEZE-WAKE/BPIP* software, developed by Trinity. This software incorporates the algorithms of the Building Profile Input Program with PRIME enhancement (BPIP-PRIME), version 04274. BPIP is designed to incorporate the concepts and procedures expressed in the GEP Technical Support document, the Building Downwash Guidance document, and other related documents.

Table 2-1 presents the list of buildings that may have downwash effects on the emission source exhaust stacks. The buildings are also shown in Figure 2-2.

Table 2-1. Building Description and Heights

Building ID	Description	UTM East (m)	UTM North (m)	Elevation (m)	Height (m)
KCP1	Kernel Crushing Plant 1	547804.70	373273.90	8.33	14
SILO	KPC Silos	547817.90	373228.30	8.75	14
KCP2	Kernel Crushing Plant 2	547844.80	373262.10	8.47	14
REFN	Refinery	547908.90	373191.70	8.76	35.2
WAREH	Warehouse	547786.40	373115.40	15.34	13.93
ALCOHOL1	Alcohol 1	547910.30	373074.10	11.78	36.3
HYDPLANT	Hydrogen Plant	547894.70	373013.20	14.93	34
ACID1	Acid 1	547952.90	373035.70	15.77	61.15
ALCOHOL2	Alcohol 2	547776.7	372882.1	10.6	49.5
ACID2	Acid 2	547886.50	372762.20	10.55	53.6
BOILER	Boiler Building	547940.50	372871.90	19.09	16.73
POWERGEN	Existing Backup Generator Power House	547959.1	372927.1	19.65	15.7
PHBOILER	New Power House Boiler	548072.73	372928.38	17.56	7.5
ENGCLS	New Power House Eng CLS	548083.03	372952.48	17.56	9
RAD1	New Power House Radiator 1	548087.43	372948.18	17.56	12
RAD2	New Power House Radiator 2	548092.93	372945.58	17.56	12
RAD3	New Power House Radiator 3	548098.33	372943.28	17.56	12
RAD4	New Power House Radiator 4	548103.93	372941.18	17.56	12
RAD5	New Power House Radiator 5	548109.33	372938.48	17.56	12
PANEL	New Power House Panel	548087.03	372961.78	17.56	4.5
INTAK1	New Power House Intake 1	548095.93	372953.98	17.56	7.5
INTK2	New Power House Intake 2	548101.53	372951.58	17.56	7.5
INTK3	New Power House Intake 3	548107.13	372949.38	17.56	7.5
INTAK4	New Power House Intake 4	548113.23	372947.08	17.56	7.5
INTK5	New Power House Intake 5	548090.23	372956.58	17.56	7.5
PHCLT	Existing Power House Cooling Tower	547990.9	372884	17.52	9.14
ACCLT1	Acid1 Cooling Tower	547949.6	373068.3	13.91	9.14
ACCLT2	Acid 2 Cooling Tower	547924.0	373001.6	17.61	9.14
REFCLT1	Refinery Cooling Tower 1	547895.5	373218.5	8.52	9.14
REFCLT2	Refinery Cooling Tower 2	547885.3	373194.1	9.86	9.14
REFCLT3	Refinery Cooling Tower 3	547921.1	373221.9	7.99	9.14

[a] Note that lattice structures are input at an adjusted height of 50% of the structure height, based on wind tunnel studies demonstrating these structures have some effect on downwash, but not the same as solid structures. Acid1: 61.15m, Alcohol2, 49.5m, Acid2: 53.6 m, Alcohol1:36.3m, refinery: 35.2m, changed to Acid1: 42.8m, Alcohol2, 34.65m, Acid2: 37.52 m, Alcohol1:25.41m, refinery: 24.64m. http://www.cppwind.com/wp-content/uploads/2016/10/Using-Physical-Modeling-to-Refine-Downwash-Inputs-to-AERMOD_EMMag-Oct-16_PetersenGuerra.pdf

2.7. EMISSION SOURCE PARAMETERS

2.7.1. Identification of Emission Sources

The Project could operate under two scenarios: one without the natural gas power plant in which all existing sources operate at maximum capacity (Without Power plant Scenario; WOPP Scenario), and a second scenario with the natural gas power plant in which the power plant offsets the steam demand from the high pressure boiler and this boiler does not operate (With Power Plant Scenario; WPP Scenario). The Power Plant will include five identical natural gas-fired engines with one of the engines being a backup unit. DAP currently owns three boilers to provide steam with various pressures, which will all be operated under the WOPP Scenario. Installation of the Power Plant will offset the boiler providing high pressure steam; thus, the WPP Scenario includes operation of four gas engines and two boilers.

In addition to the combustion sources providing steam, there are two hot oil heaters that provide heat for Lines 1 and 2. There are also six (6) cooling tower sets that are currently operated as part of the normal operations. The locations of these sources are identified with the information provided by PHG and aerial imagery available from Google Earth. Table 2-2 presents the locations of these emission sources. Figure 2-4 shows the locations of these emission sources and the relative locations to the building structures.

Fugitive emissions from equipment leaks (e.g., volatile organic compound (VOC) emissions from valves, flanges, pumps, etc.) and tailpipe emissions and road dust from vehicle traffic are not included in this assessment. These types of air emissions are difficult to characterize and are generally not accurately represented in dispersion models. VOC emissions are also typically not assessed because there is no internationally recognized ambient threshold for VOC. [3] While this ambient air modelling analysis does not include VOC, qualitative assessment based on proximity of residential areas indicates IFC guidelines related to VOC emissions from equipment leaks should be followed. In particular, for any volatile streams, IFC recommends *implementing a leak detection and repair (LDAR) program that controls fugitive emissions by regularly monitoring to detect leaks, and implementing repairs within a predefined time period*.

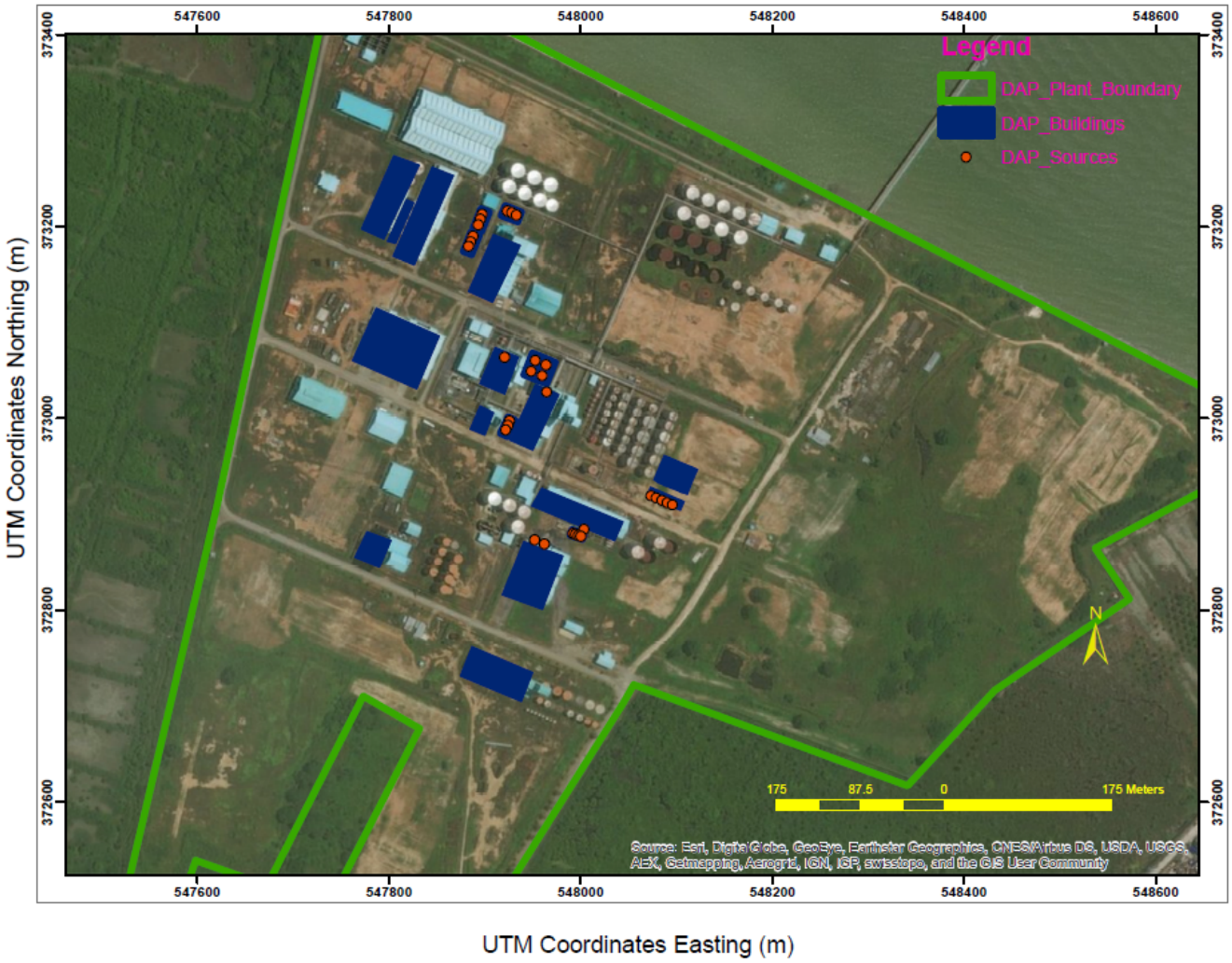
[3] VOC reacts in the atmosphere and can contribute to formation of ozone which does have ambient thresholds; however these complex chemical reactions are not modelled for projects, but rather, for entire regions or countries using complex photochemical models capturing all industrial and natural sources of all ozone precursor emissions.

Table 2-2. Modelled Point Source Locations

Source ID	Description	Source Type	UTM East (m)	UTM North (m)	Elevation (m)
BO_HP [1]	High Pressure Boiler	POINT	548003.7	372884.1	15.50
BO_MP	Medium Pressure Boiler	POINT	547952.0	372873.0	19.40
BO_LP	Low Pressure Boiler	POINT	547962.0	372869.0	18.22
HOH1	Hot Oil Heater 1	POINT	547964.5	373027.3	16.29
HOH2	Hot Oil Heater 2	POINT	547920.6	373063.6	12.69
Cogen1 [2]	Gas Engine 1	POINT	548073.6	372918.9	17.56
Cogen2 [2]	Gas Engine 2	POINT	548079.2	371916.5	17.56
Cogen3 [2]	Gas Engine 3	POINT	548084.8	372914.1	17.56
Cogen4 [2]	Gas Engine 4	POINT	548090.3	372911.8	17.56
Cogen5 [2]	Gas Engine 5	POINT	548095.9	372909.3	17.56

1. The High Pressure Boiler is only modelled in Scenario 1 without the Power Plant.
2. The gas engines are only modelled in Scenario 2 with full installation of the Power Plant.

Figure 2-4. Source Locations



2.7.2. Emission Calculations

An emission inventory is also developed as part of the modelling analysis. The modelled emission rates are summarized in Table 2-3 and Table 2-4.

Table 2-3. Emission Summary (WOPP Scenario)

Pollutant	Hot Oil Heater 1 (kg/hr)	Hot Oil Heater 2 (kg/hr)	High Pressure Boiler (kg/hr)	Medium Pressure Boiler (kg/hr)	Low Pressure Boiler (kg/hr)	Cooling Towers (kg/hr)	Total Emissions [1] (kg/hr)	Total Emissions [1] (metric tonne/yr)
SO_2	2.75	3.19	0.62	0.08	1.32	--	7.97	63.13
NO_X	1.55	1.80	0.35	1.64	25.96	--	31.29	247.81
PM_{10}	0.26	0.30	0.06	1.26	19.97	0.36	22.20	175.80
$PM_{2.5}$	0.26	0.30	0.06	1.09	17.32	0.04	19.06	150.97

1. Annual emissions are based on 330 days of operation.

Table 2-4. Emission Summary (WPP Scenario)

Pollutant	Gas Engines [1] (kg/hr)	Hot Oil Heater 1 (kg/hr)	Hot Oil Heater 2 (kg/hr)	Medium Pressure Boiler (kg/hr)	Low Pressure Boiler (kg/hr)	Cooling Towers (kg/hr)	Total Emissions [2] (kg/hr)	(metric tonne/yr)
SO_2	0.19	2.75	3.19	0.08	1.32	--	7.54	59.71
NO_X	15.91	1.55	1.80	1.64	25.96	--	46.85	371.07
PM_{10}	0.37	0.26	0.30	1.26	19.97	0.36	22.51	178.24
$PM_{2.5}$	0.37	0.26	0.30	1.09	17.32	0.04	19.37	153.41

1. There will be four gas engines that could be operated at the same time during normal operation when gas engines are installed. There will be a fifth gas engine serving as backup. The steam generated by the gas engines will serve the process units that would have operated with steam from the High Pressure Boiler.
2. Annual emissions are based on 330 days of operation.

The two Hot Oil Heaters and the High Pressure Boiler are fired on diesel only. Emission factors are obtained from AP-42[4], Tables 1.3-1 and 1.3-2 for uncontrolled distillate oil-fired boilers less than 100 million British thermal unit per hour (MMBtu/hr). SO_2 emissions are calculated based on the sulfur content in the fuel. In this analysis, the diesel fuel fired at the heaters and the boiler are assumed to be the sources from the same supplies as vehicle diesel. SO2 emissions conservatively assume the sulfur content of 2500 ppm, which is the sulfur limit for diesel fuel with cetane number 48 according to SK 978/2013 rule (versus 500 ppm for diesel with cetain number of 51 or above). The particulate matter emission factor is the sum of filterable PM factor for distillate oil-fired boilers and condensable PM factor for No.2 oil-fired boilers. It is assumed that all PM have sizes smaller than 2.5 µm. The heat inputs of the Hot Oil Heaters and the High Pressure Boiler are estimated based on steam demand provided by PHG during normal operations.

The Medium Pressure Boiler and the Low Pressure Boiler will primarily fire on palm kernel shells. Palm kernel shells are assumed to have similar properties as the wood residue since palm kernel shells specific emission factors are not available. Generally, palm kernel shells contain low moisture content (less than 20%) than other agricultural biomass.[5,6] Therefore, the emission factors for uncontrolled dry wood firing from AP-42 Tables 1.6-1 and 1.6-2 are used. Sum of filterable $PM_{10}/PM_{2.5}$ emission factors and condensable PM emission factors are used here. Additionally, the Medium Pressure Boiler and the Low Pressure Boiler will fire approximately 1 liter diesel fuel each time for startup. It is conservatively assumed that the startup will occur daily. For modelling purposes, the hourly emission rates assume that diesel firing is evenly distributed over a day. Sum of the emissions from diesel firing and palm kernel shells firing is used to determine the emission rate for modelling.

Only PM_{10} and $PM_{2.5}$ emissions are expected from cooling towers. According to AP-42 Chapter 13.4, the PM emissions from cooling towers are determined by water flow rate, drift loss, and total dissolving solids (TDS) in the water. Water flow rates are provided by PHG. Drift loss is assumed to be 0.02% and the TDS is assumed to be 20,600 ppm for induced-draft cooling towers per Table 13.4-2 of AP-42. The PM_{10} and $PM_{2.5}$ emissions are then determined based on a particle size distribution study, which suggests that approximately 1.8% of the PM emitted from the cooling towers is PM_{10} and 0.2% is $PM_{2.5}$.

[4] AP-42: *Compilation of Air Emission Factors,* by U.S. Environmental Protection Agency (EPA), Fifth Edition. Available at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors.
[5] M. Kavalek et. al., *Oil Palm Shell Use as Alternative Biofuel,* Agronomy Research 11(1), 183-188, 2013.
[6] B. Jagustyn et. al., *Evaluation of Physicochemical Properties of Palm Kernel Shell as Agro Biomass Used in the Energy Industry*, CHEMIK 2013, 67, 6, 552-229.

The engines will fire natural gas only under the WPP Scenario for cogeneration of electricity and thermal energy for the production process. PM_{10}, $PM_{2.5}$ and SO_2 emissions are calculated based on emission factors from AP-42 Tables 3.1-1 and 3.1-2 for uncontrolled natural gas-fired engines. NO_X emissions are estimated based on 250 milligram per standard cubic meter (mg/Nm^3) according to manufacturer's information. The heat input for each engine is determined for 4000 kilowatt (kW) electrical output based on the demand, which approximately corresponds to 91% load. Based on the manufacturer's information on the electrical efficiency and overall load, the engines are expected to be operated at approximately natural gas heat input 31 MMBtu/hr on average.

Detailed emission calculations are provided in Appendix B.

2.7.3. Source Parameters

Point sources for this Project include boilers, heaters, engines, and cooling towers. Modelled point sources require exhaust information to properly characterize the emitting plume. The information required for each source includes stack location, stack height, stack diameter, exhaust velocity, exhaust temperature, and emission rates.

The stack locations of the existing combustion sources, including the boilers and heaters, and cooling towers, are determined based on the aerial imagery and identification provided by PHG. Each set of cooling tower is consist of multiple cells; therefore, there are multiple stacks for each cooling tower. The power house where the engines will be housed, will be located east of the Acid Plant and northeast of the existing building where the High Pressure Boiler is located. Engineering schematics for the locations of the engines inside the power house are included in Appendix A.

The stack heights for the existing combustion sources are the physical heights provided by PHG. The stack height for the Low Pressure Boiler is modelled at an increased height, which will be modified as part of the Project. For the engines, the stack height is determined based on the design, which are provided in the engineering schematics in Appendix A. The exhaust point for the cooling towers is assumed to be 1 meter higher than the cooling tower main structure,

The exit velocity is determined based on the exhaust flow rate and the stack diameter for engines and cooling towers. For gas engines, the exhaust flow rate is estimated based on the manufacturer's specifications for operations at 91% load, and the stack diameter is based on the design (see Appendix A). For the cooling towers, the air flow rate is calculated based on the water flow rate for each cooling tower set and amount of air required to cool water from 98 °F to 88 °F. The air flow is evenly distributed among the number of stacks representing the same set of cooling tower. The exit velocity is then calculated based on the stack diameter estimated based aerial imagery and the flow rate for the each stack.

For the existing combustion sources, the flow rate is estimated based on combustion air requirement per Perry's Handbook[7], which assumes 20% excess air for combustion. The exit velocity for these sources is assumed to be 20 meter per second (m/s), and the stack diameter is back-calculated based on the flow rate and exit velocity.

The exhaust temperatures for the existing combustion sources are the default values from Perry's Handbook depending on the fuel type: 450 °F for diesel-fired units (High Pressure Boiler and two Hot Oil Heaters) and 475 °F for biomass-fired units (Low Pressure Boiler and Medium Pressure Boiler). For engines, the exhaust temperature of 120 °C is obtained from manufacturer's specifications. It is assumed that the cooling towers will emit at a temperature 5 °F higher than ambient.

[7] Perry's Chemical Engineer's Handbook (2007), 8th Edition.

The modelled parameters for all the sources are provided in Appendix C.

2.8. NO_2 TO NO_X CONVERSION

NO_X is formed when nitrogen in ambient air is exposed to high temperatures during the combustion process. At these temperatures, some nitrogen is converted to NO and NO_2 (collectively referred to as NO_X). This Project includes NO_X emitted from combustion sources. Emissions are calculated for NO_X, while the modelling analysis is performed for NO_2. In order to estimate the amount of NO_2 concentration from the amount of emitted NO_X, the Plume Volume Molar Ratio Method (PVMRM) is used for this modelling analysis. PVMRM is an embedded module in AERMOD and determines the amount of NO converting to NO_2 based on the amount of ozone (O_3) entrained in the plume from each source to each receptor.

PVMRM requires in-stack ratio of NO_2 to NO_X for each NO_X emitting source and O_3 concentration in the ambient air. Default in-stack ratio of 0.1 is used for the existing combustion sources.[8] For engines, the in-stack ratio of 0.3 is used according to manufacturer information. For O_3 concentrations, seasonal hour-of-day concentrations derived from monitoring data is included.[9] There are 4 sets of 24 values representing 24 hours in a day, and each set of values represents a season in a year.

2.9. BACKGROUND CONCENTRATIONS

The area where the Project is located already has a certain amount of pollution due to other industrial sites, vehicle traffic, residential pollution, and/or naturally occurring air emissions. Background concentrations, representing the existing level of pollution in the area, are added to the modelled concentrations to determine the post-project air quality.

Environmental studies have been performed and air quality baseline data have been collected as part of the effort. For this analysis, "Ambient air quality laboratory results" for the November 2016 observed concentrations are used as the background concentrations. Site AQ-1, which is located immediately offsite of the boundary of the Project and closest to maximum modelled impacts, is determined to be representative of the baseline air quality for the Project. The modelled averaging periods are different than the observations; therefore, the observations are scaled following U.S. EPA's guidance[10] to determine the appropriate background concentrations for the modelling analysis. The background concentrations are summarized in Table 2-5.

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[8] Hanrahan, P.L (1999a). *The Plume Volume Molar Ratio Method for Determining NO_2/NO_X Ratios in Modelling – Part I: Methodology*. J. Air & Waste Mange. Assoc., 1324-1338.

[9] Ozone monitoring data obtained from one day of study of diurnal variation in Padang City. While one day and location are not ideal, ozone concentration in Padang City are expected to be considerably higher than in the more rural coastal area of the Project site.
Vera Surtia Bachtiar, Slamet Raharjo, Yenni Ruslinda, Fitra Hayati, Desi Ratna Komala, Mapping of Ozone Gas (O) Concentrations in Padang City, Procedia Engineering, Volume 125, 2015, Pages 291-297, ISSN 1877-7058, http://dx.doi.org/10.1016/j.proeng.2015.11.046 .
(http://www.sciencedirect.com/science/article/pii/S1877705815033639)

[10] Scaling ratios are obtained from AERSCREEN User's Guide, available at https://www3.epa.gov/scram001/models/screen/aerscreen_userguide.pdf.

Table 2-5. Observations and Background Concentrations

Pollutants Observed	Averaging Periods in the Observations	Observed Concentrations [1] (µg/m³)	Modelled Pollutants (µg/m³)	Averaging Period in the Observations	Average Period Scaling Ratios	Background Concentration (µg/m³)
NO_2	24-hour	<5	NO_2	1-hour	1.7	4.3
			NO_2	Annual	0.2	0.4
$PM_{2.5}$	24-hour	10.8	$PM_{2.5}$	24-hour	NA	10.8
PM_{10}			$PM_{2.5}$	Annual	0.2	1.8
PM_{10}	24-hour	19.6	PM_{10}	24-hour	NA	19.6
PM_{10}			PM_{10}	Annual	0.2	3.3
SO_2	24-hour	<20	SO_2	1-hour	1.7	17.0
			SO_2	24-hour	1.0	10.0

1. The air concentrations measured during the November 2016 baseline air quality study of NO_2 and SO_2 were below detection levels; therefore, the concentration applied in this assessment is set to half the detection level. For example, the SO_2 baseline measurement listed as "<20" results in an estimated background concentration set at half the detection level (10 µg/m³) applied in this assessment.

3. MODELLING RESULTS

The modelling analysis is performed for the two scenarios as discussed in Section 2.7.1: one without the natural gas power plant in which all existing sources operate at maximum capacity (WOPP Scenario), and a second scenario with the natural gas power plant in which the power plant offsets the steam demand from the high pressure boiler and this boiler does not operate (WPP Scenario). The modelled concentrations, plus the applicable background concentrations, are compared to the corresponding IFC General EHS Guidelines for Ambient Air Quality[1], which reference the World Health Organization (WHO) Ambient Air Quality Guidelines. The total concentrations are also compared to the Indonesian thresholds[11]. The results are summarized in Table 3-1 and Table 3-2, and presented graphically in Figures 3-1 through 3-16.

Table 3-1. Model Results for Without Power Plant Scenario

Pollutant	Averaging Period	Modelled Year	UTM Coordinate East (m)	UTM Coordinate North (m)	Concentration (µg/m³) Modelled[1]	Concentration (µg/m³) Background	Concentration (µg/m³) Total	WHO Standards (µg/m³)[2]	Indonesian Threshold (µg/m³)
NO_2	1-hour	2014	548,000	372,600	56.2	4.3	60.4	200	400
NO_2	Annual	2012	547,775	372,709	2.5	0.4	3.0	40	100
SO_2	1-hour	2016	548,100	372,625	70.1	17.0	87.1	263	900
SO_2	24-hour	2015	547,658	373,086	16.8	10.0	26.8	20	365
PM_{10}	24-hour	2014	547,669	373,134	16.7	19.6	36.3	50	--
PM_{10}	Annual	2012	547,576	372,720	5.2	3.3	8.5	20	--
$PM_{2.5}$	24-hour	2014	547,669	373,134	13.3	10.8	24.1	25	150
$PM_{2.5}$	Annual	2012	547,576	372,720	4.3	1.8	6.1	10	--

1. The form of the WHO guideline for 24-hour PM_{10} and $PM_{2.5}$ is the 99th percentile. This equals for 4th highest daily average result from the modelled output. All other model output is the highest hour or day of the five years modelled at the maximum offsite location.
2. The WHO guideline for short term SO_2 is 500 µg/m³ on a 10-minute averaging period. A 1.9 factor is used to adjust the 10 minutes average to 1 hour average value for comparison to 1 hour average SO_2 modelled concentrations.

[11] Government Regulation No. 41/1999 on Air Pollution Control.

Table 3-2. Model Results for With Power Plant Scenario

Pollutant	Averaging Period	Modelled Year	UTM Coordinate East (m)	UTM Coordinate North (m)	Concentration (µg/m³) Modelled[1]	Concentration (µg/m³) Background	Concentration (µg/m³) Total	WHO Standards (µg/m³)[2]	Indonesian Threshold (µg/m³)
NO_2	1-hour	2016	548,450	372,575	130.6	4.3	134.8	200	400
NO_2	Annual	2015	548,392	373,165	5.4	0.4	5.8	40	100
SO_2	1-hour	2014	548,027	372,676	68.6	17.0	85.6	263	900
SO_2	24-hour	2015	547,700	373,281	16.1	10.0	26.1	20	365
PM_{10}	24-hour	2014	547,669	373,134	16.8	19.6	36.4	50	--
PM_{10}	Annual	2012	547,773	372,711	5.3	3.3	8.6	20	--
$PM_{2.5}$	24-hour	2014	547,669	373,134	13.4	10.8	24.2	25	150
$PM_{2.5}$	Annual	2012	547,576	372,720	4.3	1.8	6.1	10	--

1. The form of the WHO guideline for 24-hour PM_{10} and $PM_{2.5}$ is the 99th percentile. This equals for 4th highest daily average result from the modelled output. All other model output is the highest hour or day of the five years modelled at the maximum offsite location.
2. The WHO guideline for short term SO_2 is 500 µg/m³ on a 10-minute averaging period. A 1.9 factor is used to adjust the 10 minutes average to 1 hour average value for comparison to 1 hour average SO_2 modelled concentrations.

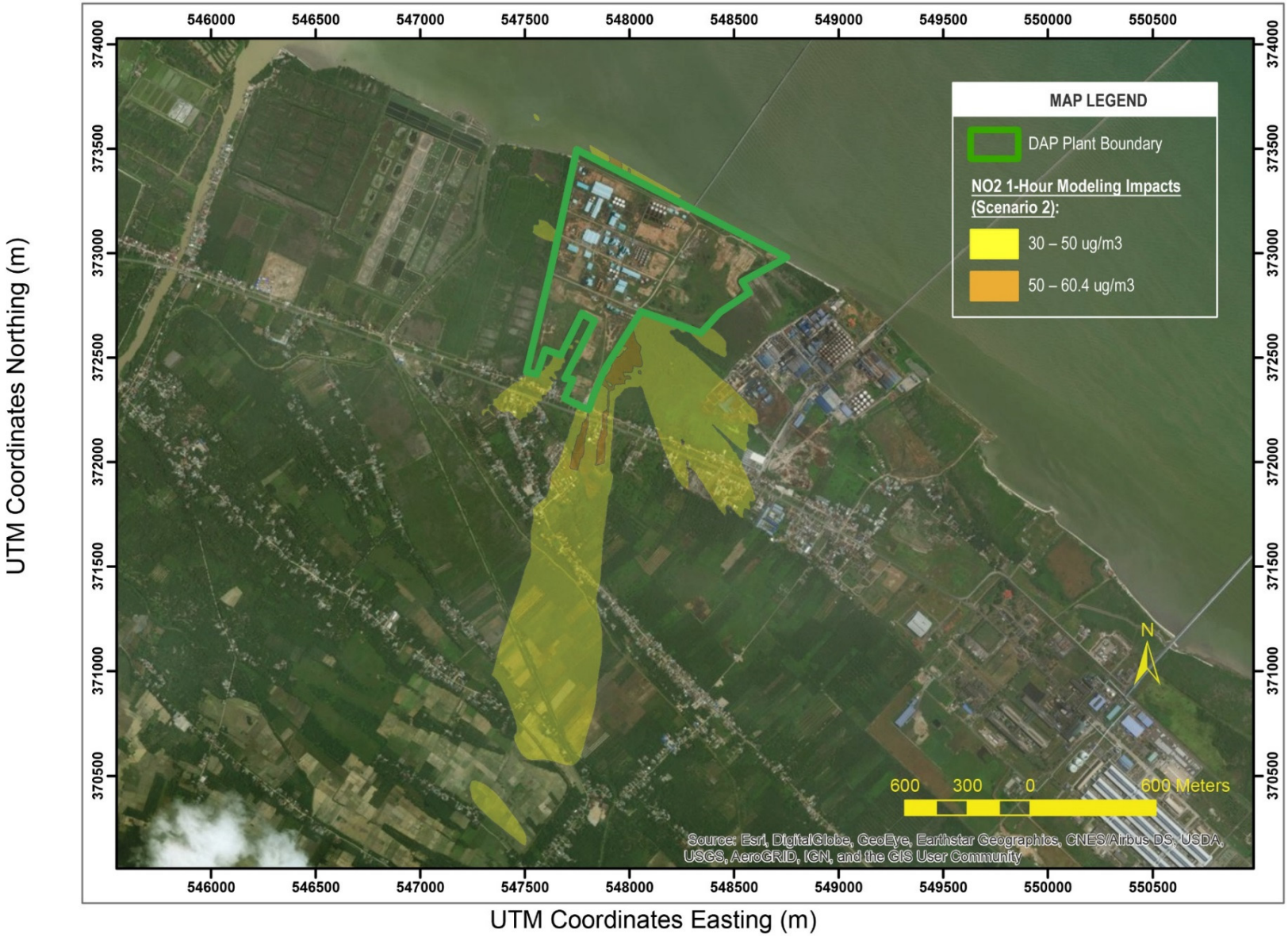
As shown in the Table 3-1 and Table 3-2, all model results show predicted ambient air concentrations below the established ambient air quality thresholds, with the exception of the 24-hour WHO guideline for SO_2. While the predicted concentrations under both scenarios do exceed the 24-hour WHO guideline, the model results from the Project itself are below the guideline (16.1 or 16.8 µg/m³ versus 20 µg/m³), and the estimated background concentration representing non-project emissions of 10 µg/m³ may result in an over-prediction of cumulative impacts, because this value is known only to be less than 20 µg/m³ (24-hour average) based on ambient sampling results below the detection level. Additionally, the predicted SO_2 ambient concentrations are well below the Indonesian thresholds, and also well below other internationally recognized thresholds such as the US EPA NAAQS (87 µg/m³ versus 196 µg/m³ (1-hour)).

The model result closest to its associated guideline value is for $PM_{2.5}$ 24-hour (24.1 µg/m³ and 24.2 µg/m³ predicted for the WOPP and WPP scenarios respectively versus the guideline of 25 µg/m³). All other results are well below their respective thresholds. The palm-shell fired boilers contribute most to the predicted $PM_{2.5}$ concentration. However, the emission estimates are based on source tests of biomass boilers firing dry wood. Since these estimates do not do not precisely represent the palm-shell fired boilers, stack testing of the particulate matter emissions in the boiler exhaust may be warranted. This information could then be used to determine whether other mitigation measures (e.g., installing add-on control technology such as a baghouse or electrostatic precipitator) would be appropriate.

The With Power Plant scenario results in notably higher predicted NO_2 concentrations, and similar concentrations for all other pollutants[12]. While the model predicts the power plant will cause an increase in NO_2 concentrations, these concentrations remain below the associated ambient thresholds. The potential impact to air quality under the WPP scenario is mitigated through selection of clean burning natural gas engines using low NOx combustion technology with half the NO_X emission levels compared to the standard option (250 mg/Nm³ versus 500 mg/Nm³).

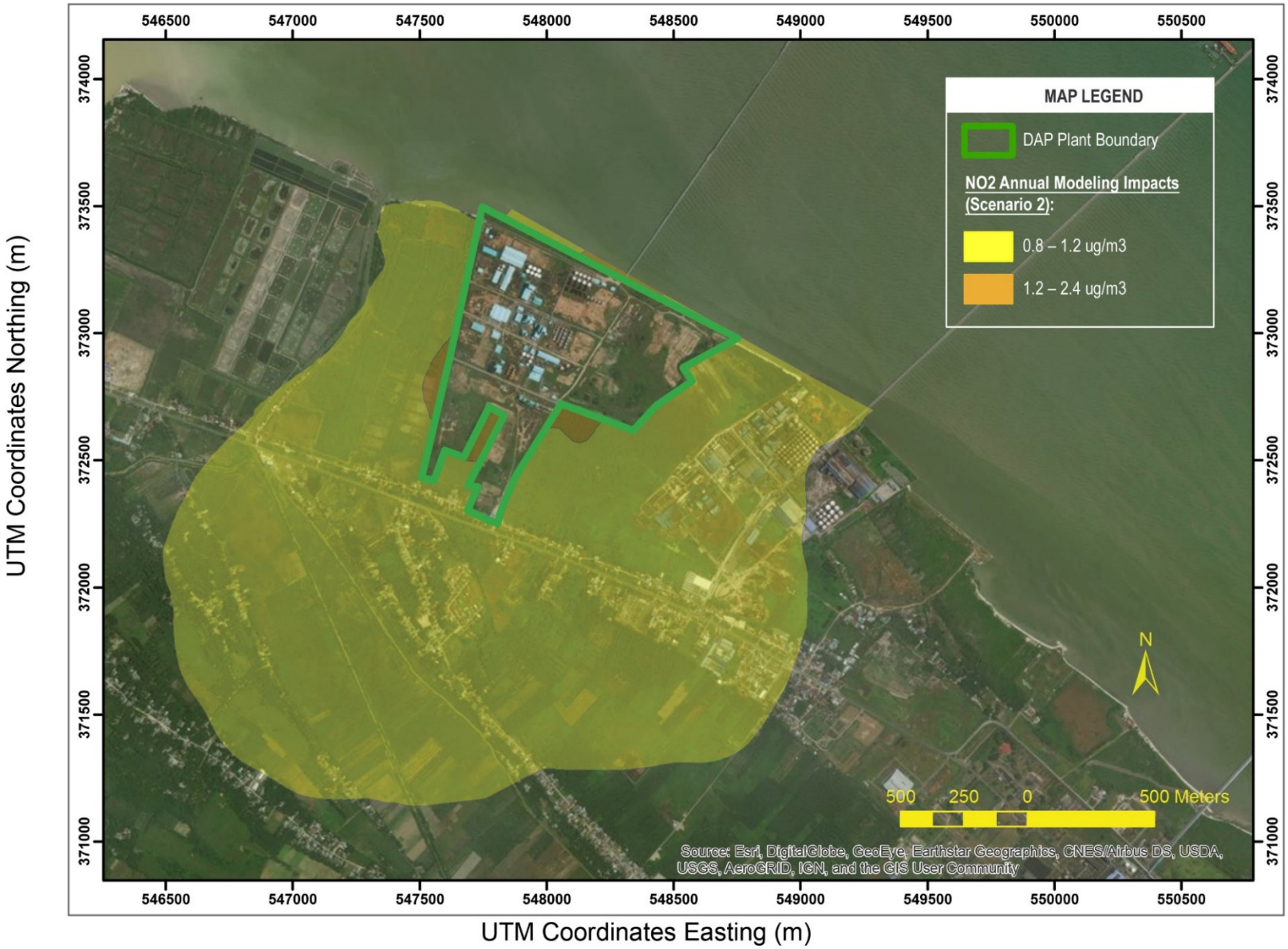
[12] Predicted concentrations of SO_2 are slightly lower under the power plant scenario, because the steam from the power plant would offset steam generated from the diesel-fired high pressure boiler.

Figure 3-1. WOPP Scenario Modelled NO_2 Concentrations - 1-hour averaging period



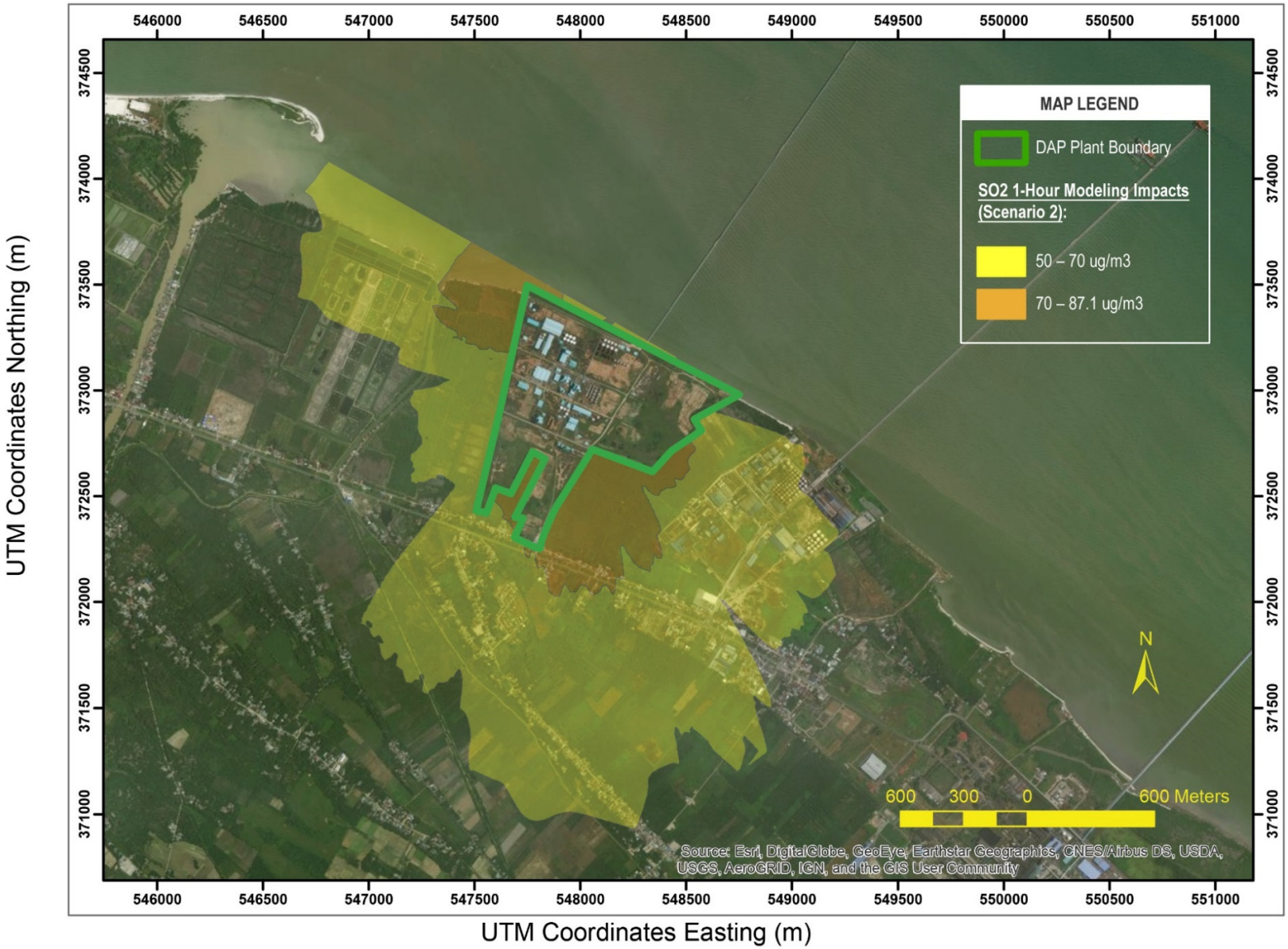
Note: Background concentration (of 4.3 ug/m3) has been added to the modeling impacts.

Figure 3-2. WOPP Scenario Modelled NO_2 Concentrations - Annual averaging period



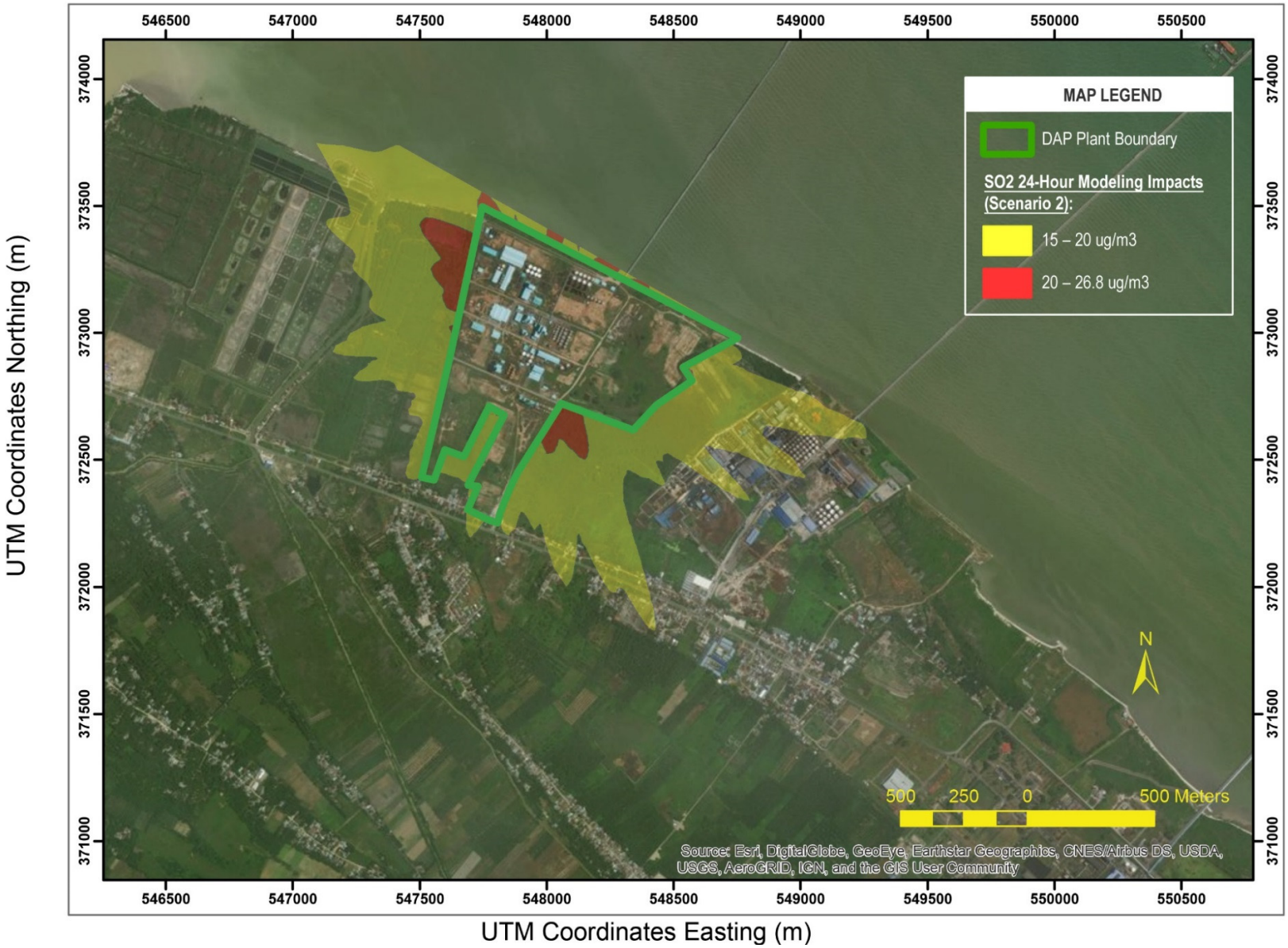
Note: Background concentration (of 0.4 ug/m3) has been added to the modeling impacts. Isopleth plot is based on 5-year average modeling runs.

Figure 3-3. WOPP Scenario Modelled SO2 Concentrations – 1-hour Averaging Period



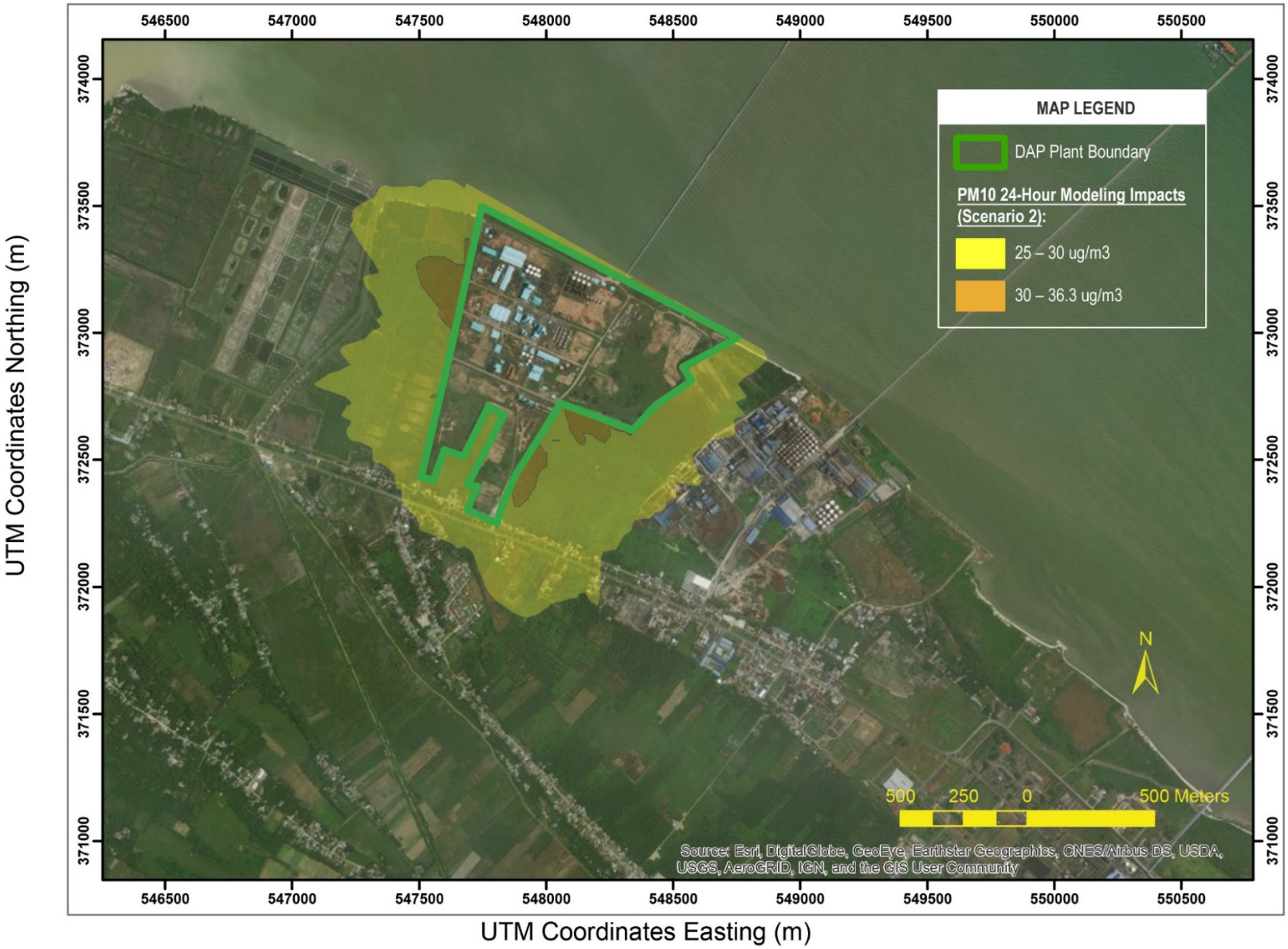
Note: Background concentration (of 17 ug/m3) has been added to the modeling impacts.

Figure 3-4. WOPP Scenario Modelled SO2 Concentrations – 24-hour Averaging Period



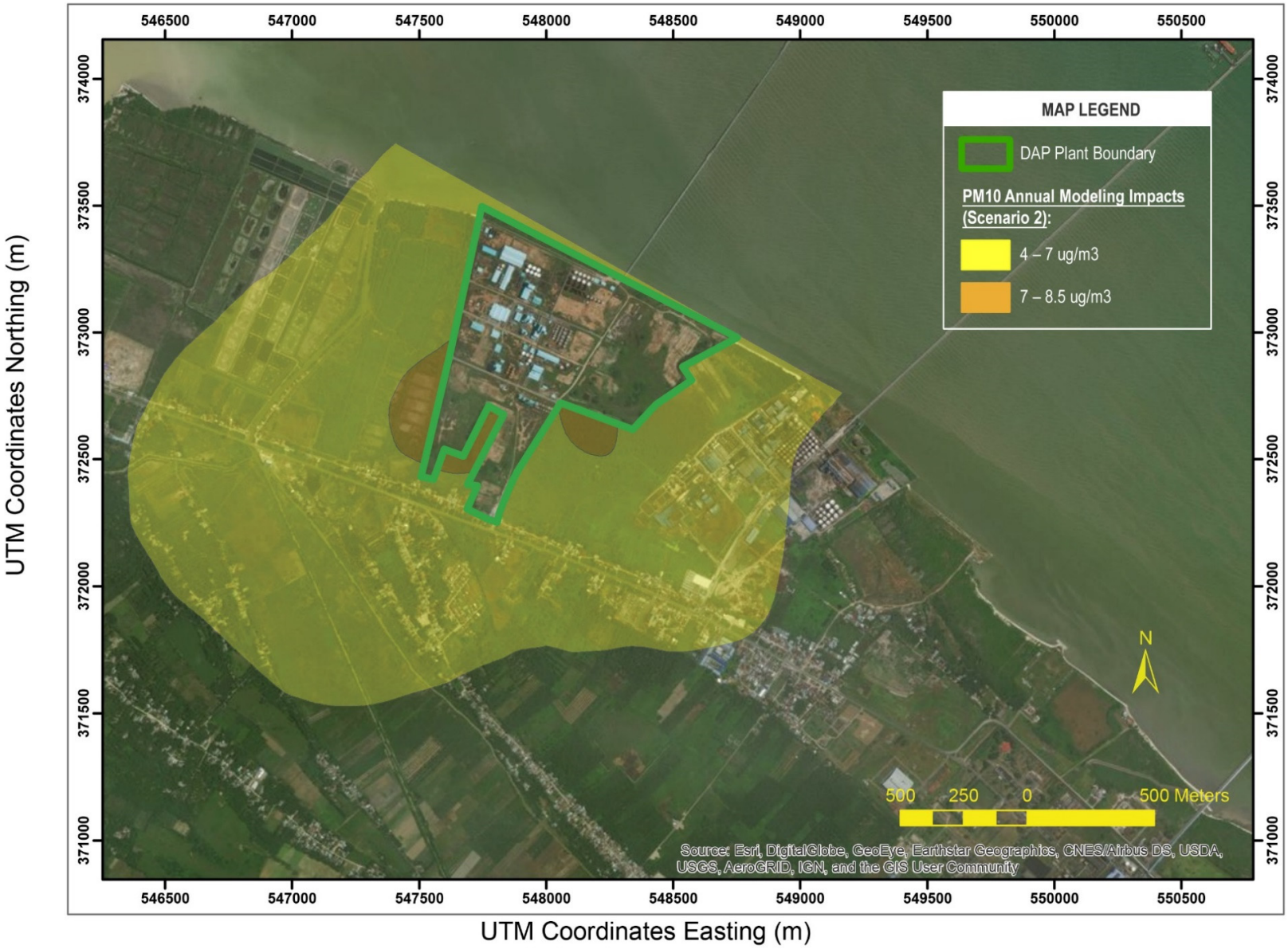
Note: Background concentration (of 10 ug/m3) has been added to the modeling impacts.

Figure 3-5. WOPP Scenario Modelled PM_{10} Concentrations - 24-hour averaging period



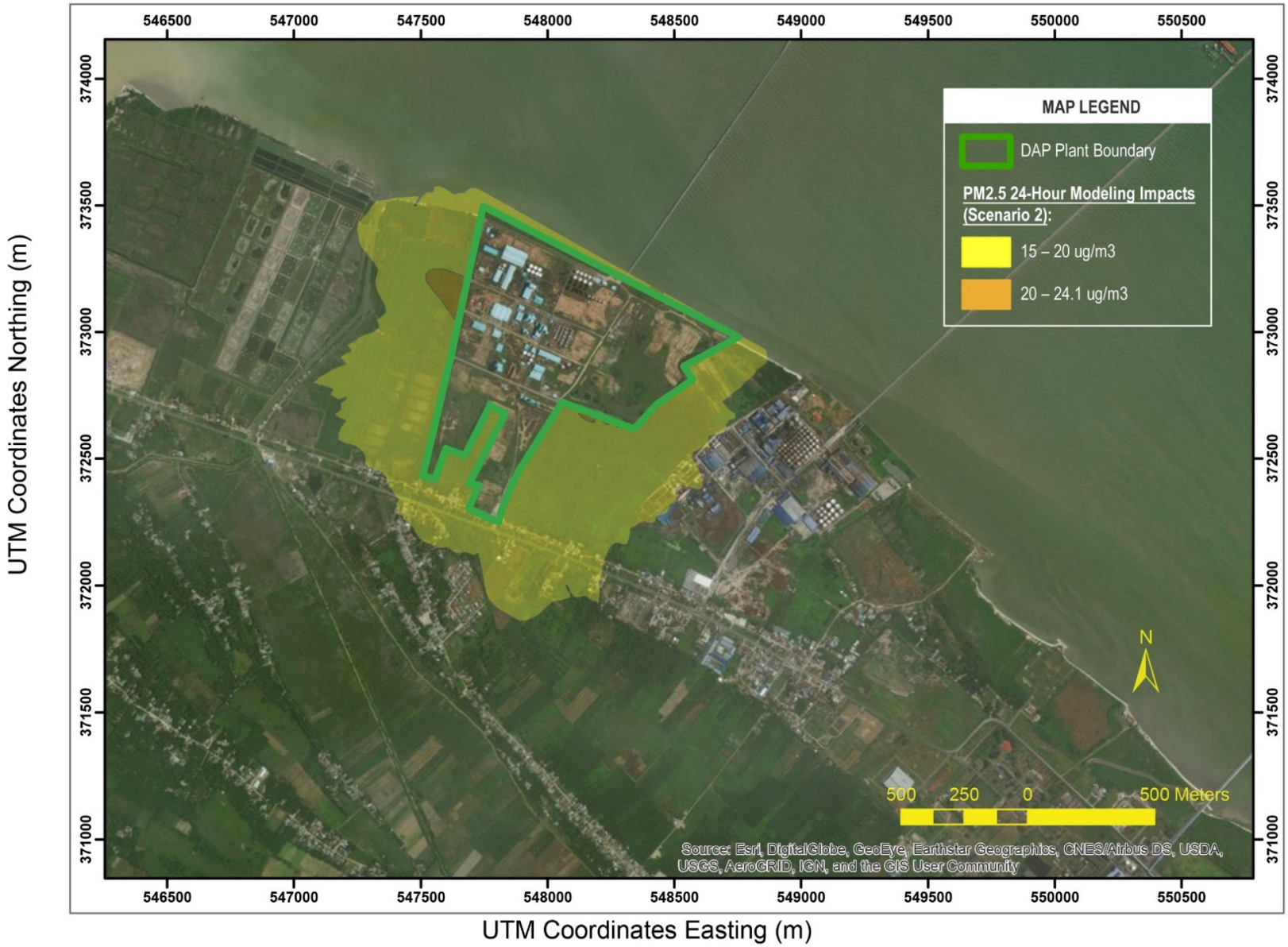
Note: Background concentration (of 19.6 ug/m3) has been added to the modeling impacts.

Figure 3-6. WOPP Scenario Modelled PM_{10} Concentrations - Annual Averaging Period



Note: Background concentration (of 3.3 ug/m3) has been added to the modeling impacts.

Figure 3-7. WOPP Scenario Modelled $PM_{2.5}$ Concentrations – 24-hour Averaging Period



Note: Background concentration (of 10.8 ug/m3) has been added to the modeling impacts.

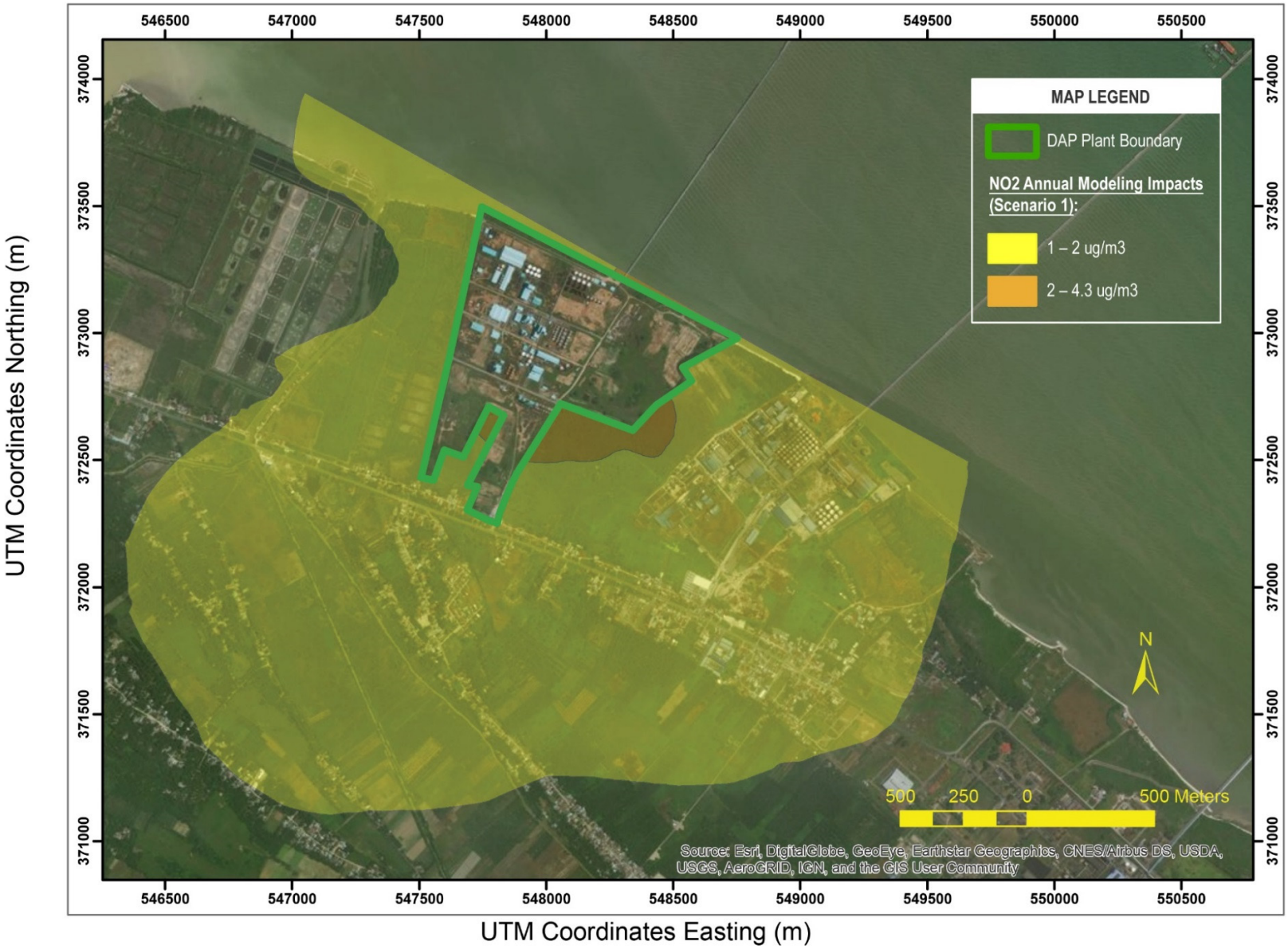
Figure 3-8. WOPP Scenario Modelled PM2.5 Concentrations - Annual Averaging Period

Note: Background concentration (of 1.8 ug/m3) has been added to the modeling impacts.

Figure 3-9. WPP Scenario Modelled NO_2 Concentrations – 1-hour Averaging Period

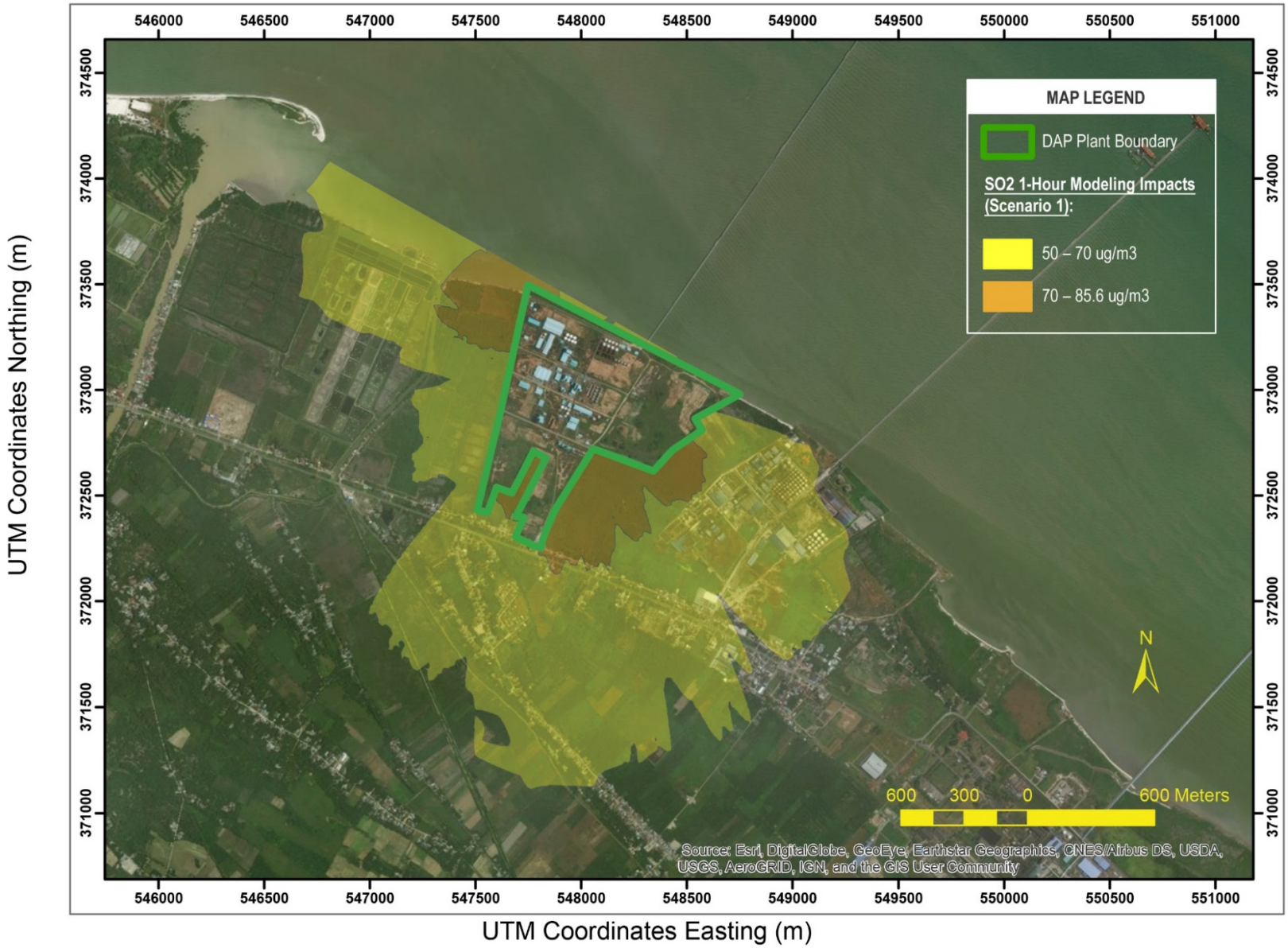
Note: Background concentration (of 4.3 ug/m3) has been added to the modeling impacts.

Figure 3-10. WPP Scenario Modelled NO2 Concentrations – Annual Averaging Period



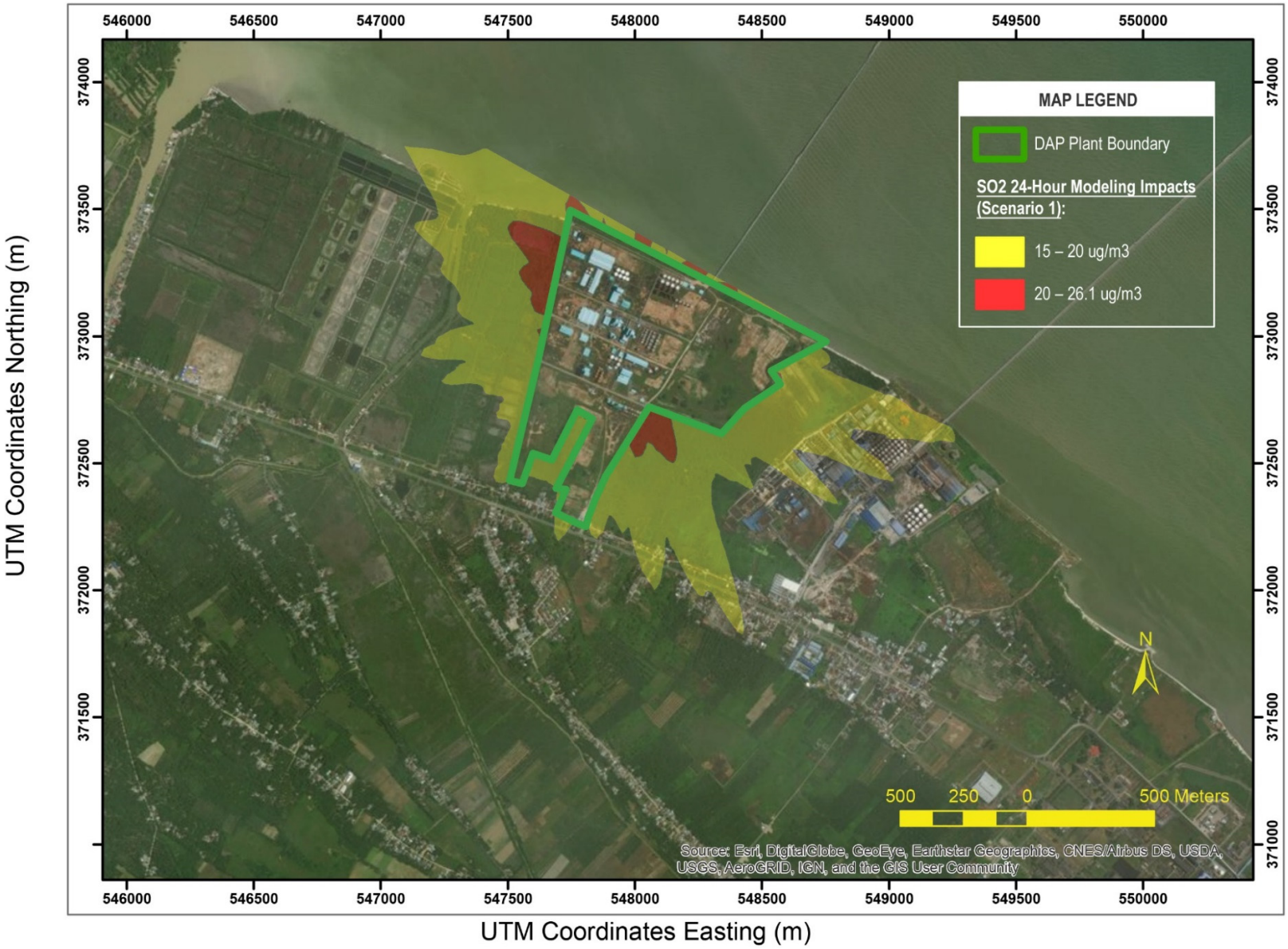
Note: Background concentration (of 0.4 ug/m3) has been added to the modeling impacts. Isopleth plot is based on 5-year average modeling runs.

Figure 3-11. WPP Scenario Modelled SO2 Concentrations – 1-hour Averaging Period



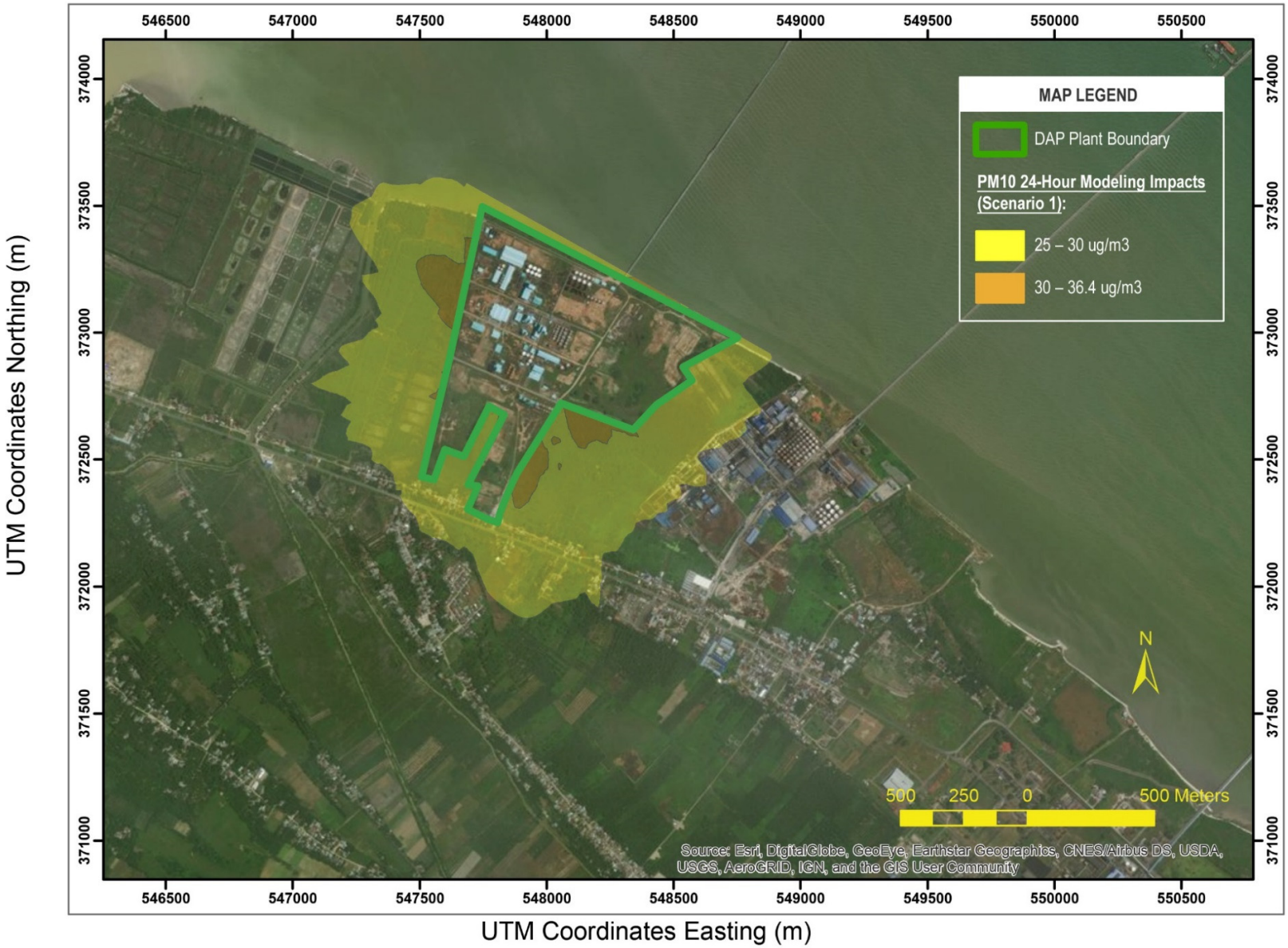
Note: Background concentration (of 17.0 ug/m3) has been added to the modeling impacts.

Figure 3-12. WPP Scenario Modelled SO2 Concentrations – 24-hour Averaging Period



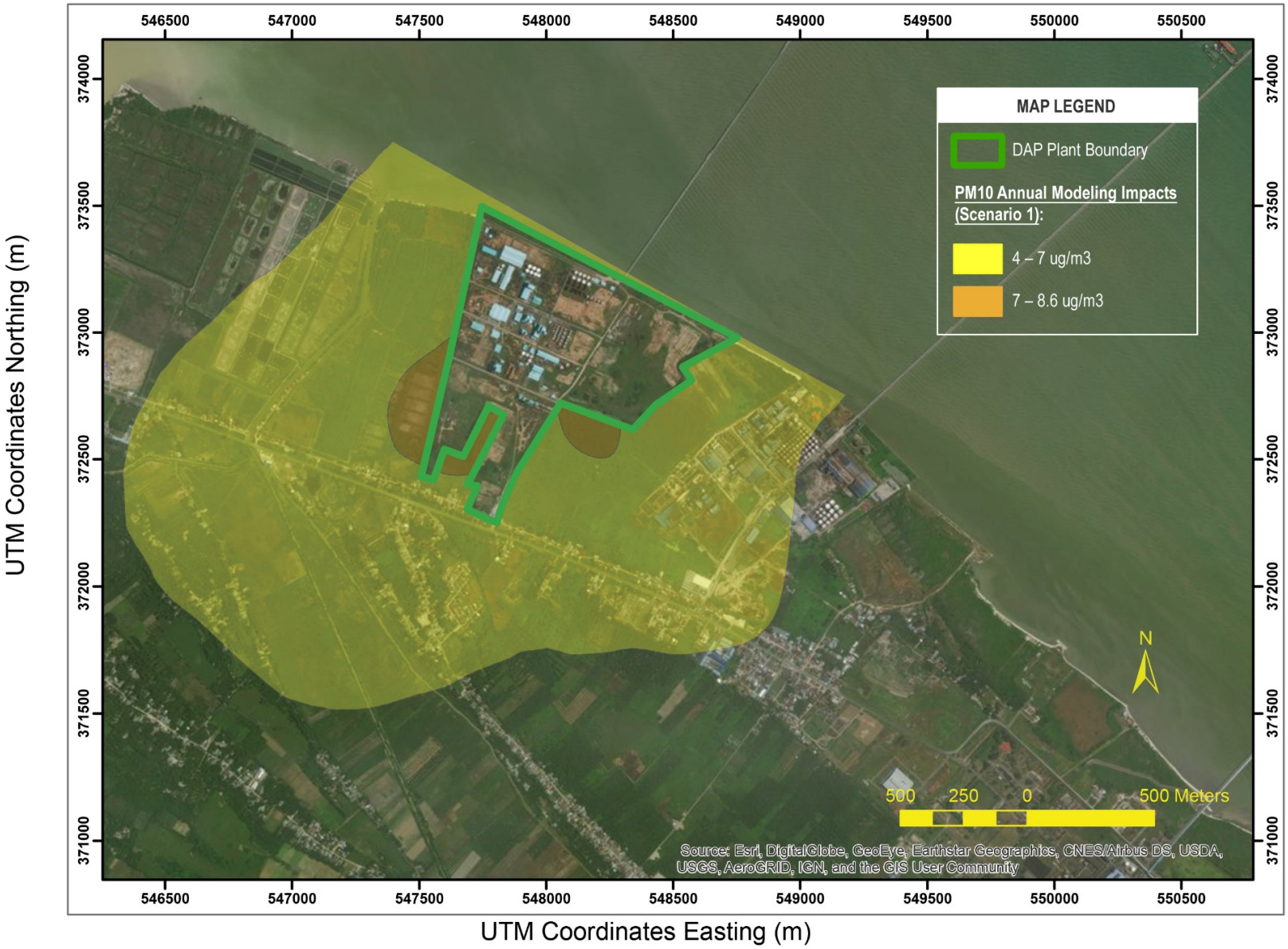
Note: Background concentration (of 10 ug/m3) has been added to the modeling impacts.

Figure 3-13. WPP Scenario Modelled PM_{10} Concentrations – 24-hour Averaging Period



Note: Background concentration (of 19.6 ug/m3) has been added to the modeling impacts.

Figure 3-14. WPP Scenario Modelled PM_{10} Concentrations – Annual Averaging Period



Note: Background concentration (of 3.3 ug/m3) has been added to the modeling impacts.

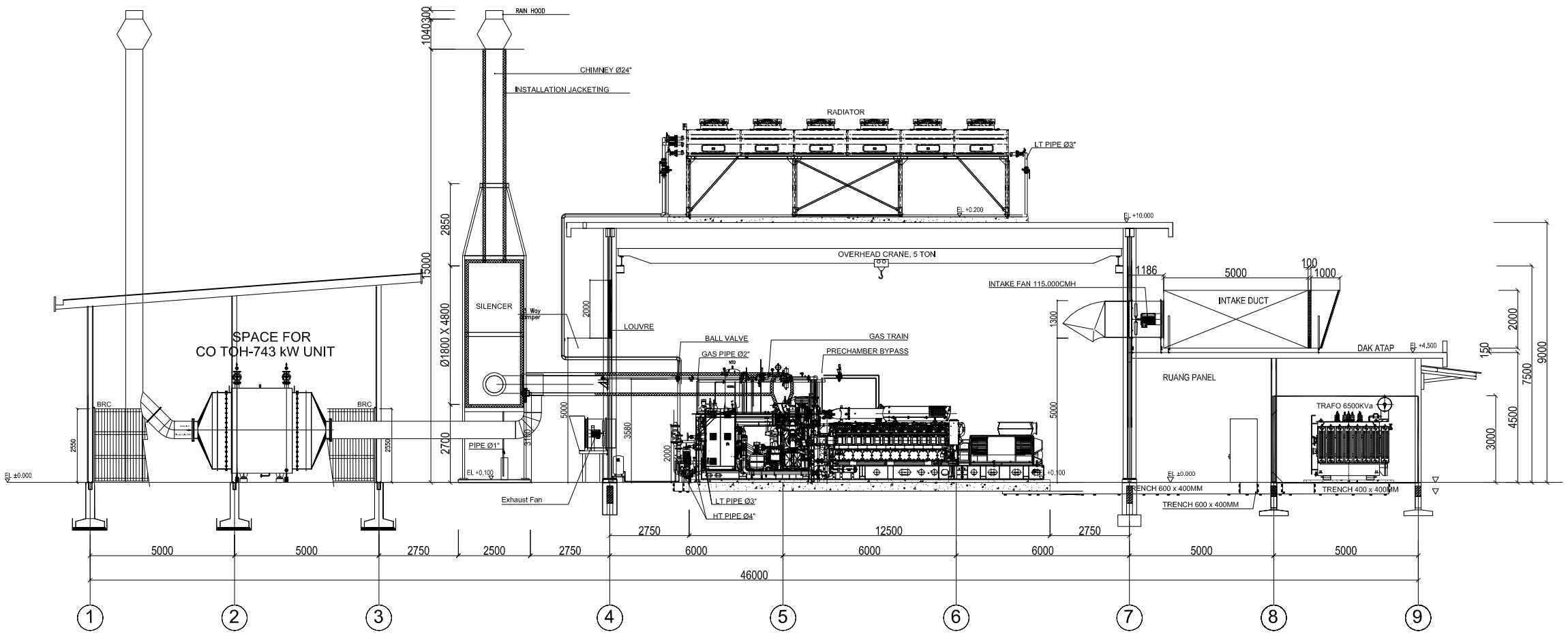
Figure 3-15. WPP Scenario Modelled PM2.5 Concentrations – 24-hour Averaging Period

Note: Background concentration (of 10.8 ug/m3) has been added to the modeling impacts.

Figure 3-16. WPP Scenario Modelled PM2.5 Concentrations – Annual Averaging Period

Note: Background concentration (of 1.8 ug/m3) has been added to the modeling impacts.

APPENDIX A. POWER PLANT SCHEMATICS AND ENGINE SPECIFICATIONS



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A	16-03-2016	FOR INFORMATION	A.S	ABY	NILS

NAVIGAT energy

	NAME	DATE	SIGN
DRAWN	A.S	16-03-2016	
CHECKED	ABY	16-03-2016	
APPROVED	NILS	16-03-2016	

PROJECT: STANDART LAYOUT POWER HOUSE 05 x JMS 624 GS NL

COSTUMER: -

DRAWING TITLE : SECTIONAL VIEW

CONTRACT NO.	DRAWING NO.	SIZE	SCALE	SHEET
–	NEI-STD-01-624-05-LA-03	A3	1:125	3/3

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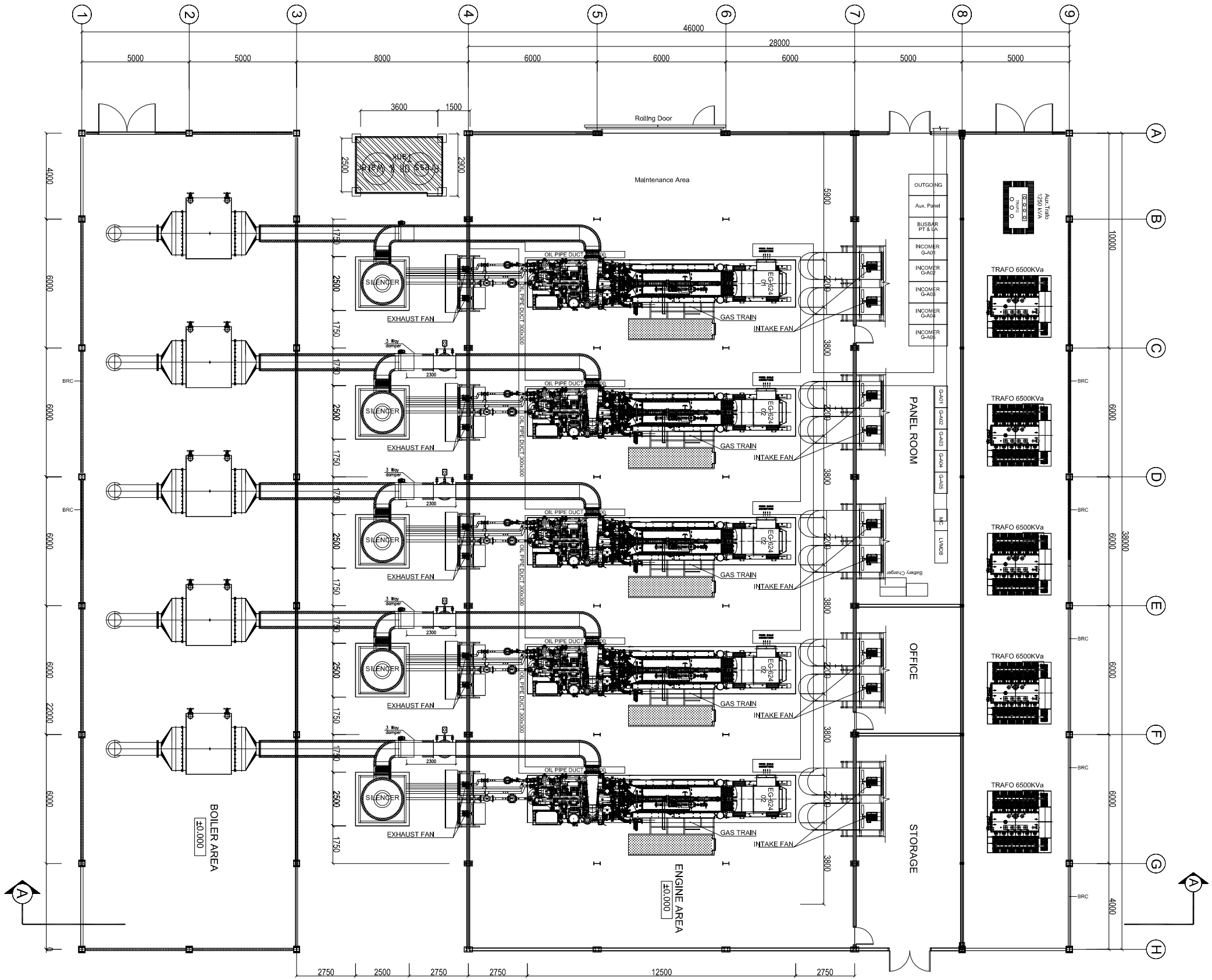

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NAVIGAT energy

	NAME	DATE	SIGN
DRAWN	A.S	16-03-2016	
CHECKED	ABY	16-03-2016	
APPROVED	NILS	16-03-2016	

PROJECT: STANDART LAYOUT POWER HOUSE 05 x JMS 624 GS NL

COSTUMER: -

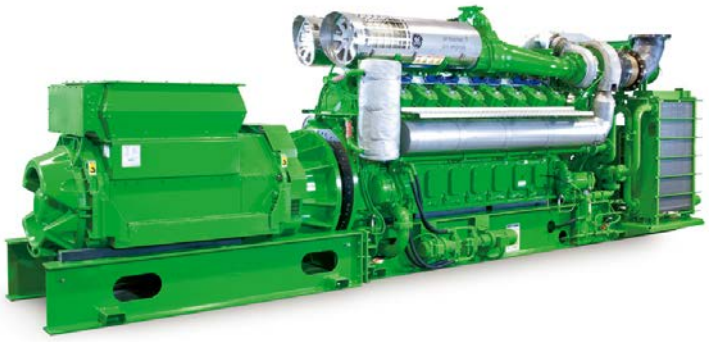
DRAWING TITLE : PLAN VIEW LAYOUT

CONTRACT NO.	DRAWING NO.	SIZE	SCALE	SHEET
–	NEI-STD-01-624-05-LA-01	A3	1:125	1/3

A3

GE Power & Water
Distributed Power

Jenbacher type 6



cutting-edge technology

Continuously refined based on our extensive experience, the Jenbacher type 6 engines are reliable, advanced products serving the 1.5 to 4.4 MW power range. Its 1,500 rpm engine speed results in a high power density and low installation costs. The type 6 pre-combustion chamber achieves high efficiency with low emissions. Proven design and enhanced components enable a service life of 60,000 operating hours before the first major overhaul. The new J624 model is available with the new technology of 2-stage turbocharging, which offers high electrical efficiency combined with improved flexibility regarding ambient conditions.

reference installations

model, plant	key technical data	description	
J612 **Beretta, industry; Gardone, Italy**	Fuel ..... Natural gas Engine type ..... 1 x J612 Electrical output ..... 1,457 kW Thermal output ..... 1,536 kW Commissioning ..... December 1998	The generated electricity covers the entire electricity requirement of the Beretta factory, while the heat is used for the production process. By using our cogeneration system, Beretta was able to reduce the energy supply costs for the factory by 30%.	
J616 **Mussafah Industrial City, residential area; Abu Dhabi, UAE**	Fuel ..... Natural gas Engine type ..... 3 x J616 Electrical output ..... 6,018 kW Commissioning ..... June 2003	Three Jenbacher generator sets supply power generation for continuous operation of compressor chillers to provide chilled water for cooling to a residential area that incorporates apartments, shopping centres, mosques, a police station, and a cinema complex.	
J620 **Wijnen Paprika; Egchel, The Netherlands**	Fuel ..... Natural gas Engine type ..... 3 x J620 Electrical output ..... 9,123 kW Thermal output ..... 10,773 kW Commissioning ..... June 2006 (1st, 2nd engine), March 2007 (3rd engine)	The Jenbacher cogeneration systems provide power, heat and CO_2 to increase the Wijnen greenhouse paprika production. The CO_2 produced from the exhaust gas of the engines is cleaned and used for fertilization in the greenhouse.	
J624 2-stage turbocharged **Serres Vinet greenhouse, Forclum Machecoul, France**	Fuel ..... Natural gas Engine type ..... 2 x J624 2-stage turbocharged Electrical output ..... 8,800 kW Thermal output ..... 8,024 kW Commissioning ..... January 2011	At this greenhouse facility, two Jenbacher J624 2-stage turbocharged gas engines enable French grower Serres Vinet to generate all of the hot water and electricity required for its extensive tomato and lettuce greenhouse operations. These are the first 2-stage turbocharged gas engines in France and give Serres Vinet the flexibility to switch among electrical energy, thermal energy and fuel sources as economics dictate.	
J620 **Barakatullah Electro Dynamics Ltd. (BEDL), Fenchuganj, Bangladesh**	Fuel ..... Natural gas Engine type ..... 19 x J620 Electrical output ..... 51 MW Commissioning ..... October 2009	The plant in the town of Fenchuganj is the first of several emergency "rental" power plants that the Bangladesh government installed to help end widespread chronic energy shortages occurring throughout the Southeast Asian nation. The plant features 19 of GE's low-emission, J620 Jenbacher gas engine generator sets that run on natural gas. The electricity produced by the power plant, which was commissioned in October 2009, is sold to the national grid.	

GE imagination at work

technical features

feature	description	advantages
Four-valve cylinder head	Centrally located purged pre-combustion chamber, developed using advanced calculation and simulation methods (CFD)	Reduced charge-exchange losses, highly efficient and stable combustion, optimal ignition conditions
Heat recovery	Flexible arrangement of heat exchanger, two stage oil plate heat exchanger on demand	High thermal efficiency, even at high and fluctuating return temperatures
Air/fuel mixture charging	Fuel gas and combustion air are mixed at low pressure before entering the turbocharger	Main gas supply with low gas pressure, mixture homogenized in the turbocharger
Pre-combustion chamber	The ignition energy of the spark plug is amplified in the pre-combustion chamber	High efficiency, lowest NOx emission values, stable and reliable combustion
Gas dosing valve	Electronically controlled gas dosing valve with high degree of control accuracy (for natural gas)	Very quick response time, rapid adjustment of air/gas ratio, large adjustable calorific value range
2-stage turbocharging	Next generation turbocharging technology concept (for J624 only)	Improved performance in terms of output and efficiency, increased flexibility regarding ambient conditions

technical data

Configuration	V 60°
Bore (mm)	190
Stroke (mm)	220
Displacement/cylinder (lit)	6.24
Speed (rpm)	1,500 (50 Hz); 1,500 with gearbox (60 Hz)
Mean piston speed (m/s)	11 (1,500 1/min)
Scope of supply	Generator set, cogeneration system, containerized package
Applicable gas types	Natural gas, flare gas, biogas, landfill gas, sewage gas. Special gases (e.g., coal mine gas, coke gas, wood gas, pyrolysis gas)

Engine type	J612	J616	J620	J624*
No. of cylinders	12	16	20	24
Total displacement (lit)	74.9	99.8	124.8	149.7

Dimensions l x w x h (mm)[1]

Containerized package	J612 - J620	12,000/15,000 x 3,000/6,000 x 8,100
	J624	17,000 x 6,000 x 8,400
Generator set	J612	7,600 x 2,200 x 2,800
	J616	8,300 x 2,200 x 2,800
	J620	8,900 x 2,200 x 2,800
	J624*	12,800 x 2,500 x 2,900
Cogeneration system	J612	7,600 x 2,200 x 2,800
	J616	8,300 x 2,200 x 2,800
	J620	8,900 x 2,200 x 2,800
	J624*	12,800 x 2,500 x 2,900

Weights empty (kg)[1]

	J612	J616	J620	J624*
Generator set	22,700	28,100	32,000	44,900
Cogeneration system	23,200	28,600	32,700	45,500

1) Dimensions and weights are valid for 50 Hz applications.
*J624 with 2-stage turbocharging

outputs and efficiencies

Natural Gas

		1,500 rpm | 50 Hz					1,500 rpm | 60 Hz				
NOx <	**Type**	**Pel (kW)[1]**	**ηel (%)[1]**	**Pth (kW)[2]**	**ηth (%)[2]**	**ηtot (%)**	**Pel (kW)[1]**	**ηel (%)[1]**	**Pth (kW)[2]**	**ηth (%)[2]**	**ηtot (%)**
500 mg/m³$_N$[3]	J612	2,000	44.7	1,949	43.5	88.2	1,979	44.2	1,960	43.8	88.0
	J616	2,679	44.9	2,598	43.5	88.4	2,654	44.5	2,612	43.8	88.2
	J620	3,356	45.0	3,229	43.3	88.2	3,332	44.7	3,243	43.5	88.1
	J624*	4,401	46.3	4,087	43.0	89.3	4,374	46.0	4,088	43.0	89.0
250 mg/m³$_N$[3]	J612	2,000	43.4	1,986	43.1	86.6	1,979	43.0	1,997	43.4	86.4
	J616	2,679	43.6	2,647	43.1	86.8	2,654	43.2	2,661	43.3	86.6
	J620	3,356	43.7	3,302	43.0	86.8	3,332	43.4	3,316	43.2	86.6
	J624*	4,401	45.2	4,207	43.2	88.4	4,374	44.9	4,127	42.4	87.3

Biogas

		1,500 rpm | 50 Hz					1,500 rpm | 60 Hz				
NOx <	**Type**	**Pel (kW)[1]**	**ηel (%)[1]**	**Pth (kW)[2]**	**ηth (%)[2]**	**ηtot (%)**	**Pel (kW)[1]**	**ηel (%)[1]**	**Pth (kW)[2]**	**ηth (%)[2]**	**ηtot (%)**
500 mg/m³$_N$	J612	1,817	43.9	1,668	40.3	84.1	1,794	43.3	1,770	42.7	86.0
	J616	2,433	44.0	2,225	40.3	84.3	2,405	43.5	2,359	42.7	86.3
	J620	3,044	44.1	2,782	40.3	84.4	3,020	43.7	2,947	42.7	86.4
250mg/m³$_N$	J612	1,818	43.0	1,717	40.6	83.6	1,794	42.4	1,780	42.1	84.5
	J616	2,433	43.1	2,292	40.6	83.8	2,405	42.6	2,373	42.1	84.7
	J620	3,044	43.2	2,863	40.6	83.8	3,020	42.8	2,965	42.1	84.9

*J624 with 2-stage turbocharging

1) Technical data according to ISO 3046
2) Total heat output with a tolerance of +/- 8%, exhaust gas outlet temperature 120°C, for biogas exhaust gas outlet temperature 180°C

All data according to full load and subject to technical development and modification.

Further engines versions available on request.

GEA-13691A

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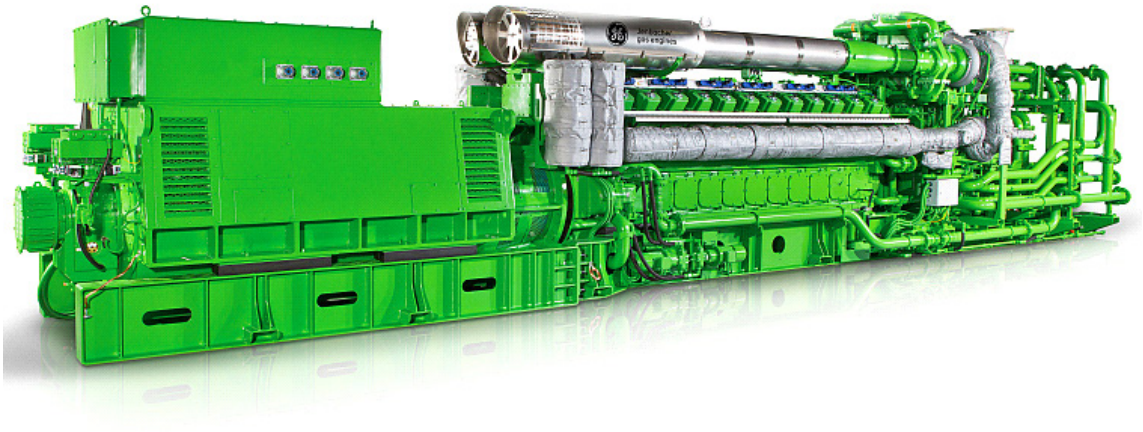
Technical Description
Cogeneration Unit

JMS 624 GS-N.L

with Island Operation
no special Grid Code

Navigat



Electrical output	**4405 kW el.**
Thermal output	**2626 kW**

Emission values
NOx < 250 mg/Nm³ (5% O2)

0.01 Technical Data (at module) 3
Main dimensions and weights (at module) 4
Connections 4
Output / fuel consumption 4
0.02 Technical data of engine 5
Thermal energy balance 5
Exhaust gas data 5
Combustion air data 5
Sound pressure level 6
Sound power level 6
0.03 Technical data of generator 7
Reactance and time constants (saturated) 7
0.04 Technical data of heat recovery 8
General data - Hot water circuit 8
General data - Cooling water circuit 8
connection variant H2-i 9
0.10 Technical parameters 10

0.01 Technical Data (at module)

Fuel gas LHV		kWh/Nm³		9,5		
				100%	**75%**	**50%**
Energy input		kW	[2]	9.805	7.507	5.209
Gas volume		Nm³/h	*)	1.032	790	548
Mechanical output		kW	[1]	4.491	3.368	2.246
Electrical output		kW el.	[4]	4.405	3.299	2.190
Recoverable thermal output						
~ Intercooler 1st stage		kW	[9]	1.524	987	415
~ Lube oil		kW		418	382	376
~ Jacket water		kW		684	608	570
~ Exhaust gas cooled to 359 °C		kW		~	~	~
Total recoverable thermal output		kW	[5]	2.626	1.977	1.361
Total output generated		kW total		7.031	5.277	3.551
Heat to be dissipated						
~ Intercooler 2nd stage		kW		221	86	35
~ Lube oil		kW		~	~	~
~ Surface heat	ca.	kW	[7]	217	~	~
Spec. fuel consumption of engine electric		kWh/kWel.h	[2]	2,23	2,28	2,38
Spec. fuel consumption of engine		kWh/kWh	[2]	2,18	2,23	2,32
Lube oil consumption	ca.	kg/h	[3]	0,90	~	~
Electrical efficiency		%		44,9%	43,9%	42,0%
Thermal efficiency		%		26,8%	26,3%	26,1%
Total efficiency		%	[6]	71,7%	70,3%	68,2%
Hot water circuit:						
Forward temperature		°C		90,0	85,1	80,4
Return temperature		°C		70,0	70,0	70,0
Hot water flow rate		m³/h		113,8	113,8	113,8

*) approximate value for pipework dimensioning
[_] Explanations: see 0.10 - Technical parameters

All heat data is based on standard conditions according to attachment 0.10. Deviations from the standard conditions can result in a change of values within the heat balance, and must be taken into consideration in the layout of the cooling circuit/equipment (intercooler; emergency cooling; ...). In the specifications in addition to the general tolerance of ±8 % on the thermal output a further reserve of +5 % is recommended for the dimensioning of the cooling requirements.

Main dimensions and weights (at module)

Length	mm	~ 13.800
Width	mm	~ 2.500
Height	mm	~ 2.900
Weight empty	kg	~ 54.300
Weight filled	kg	~ 55.500

Connections

Hot water inlet and outlet [A/B]	DN/PN	100/10
Exhaust gas outlet [D]	DN/PN	600/10
Fuel Gas (at module)	DN/PN	100/16
Water drain ISO 228	G	½"
Condensate drain	DN/PN	50/10
Safety valve - jacket water ISO 228	DN/PN	80/16
Safety valve - hot water	DN/PN	100/10
Lube oil replenishing (pipe)	mm	28
Lube oil drain (pipe)	mm	28
Jacket water - filling (flex pipe)	mm	13
Intercooler water-Inlet/Outlet 1st stage	DN/PN	150/16
Intercooler water-Inlet/Outlet 2nd stage	DN/PN	100/16

Output / fuel consumption

ISO standard fuel stop power ICFN	kW	4.491
Mean effe. press. at stand. power and nom. speed	bar	24,00
Fuel gas type		Natural gas
Based on methane number | Min. methane number	MZ d)	70 | 70
Compression ratio	Epsilon	11,5
Min. fuel gas pressure for the pre chamber	bar	6,03
Min./Max. fuel gas pressure at inlet to gas train	bar	6 - 8 c)
Allowed Fluctuation of fuel gas pressure	%	± 10
Max. rate of gas pressure fluctuation	mbar/sec	10
Maximum Intercooler 2nd stage inlet water temperature	°C	60
Spec. fuel consumption of engine	kWh/kWh	2,18
Specific lube oil consumption	g/kWh	0,20
Max. Oil temperature	°C	80
Jacket-water temperature max.	°C	95
Filling capacity lube oil (refill)	lit	~ 1000

c) Lower gas pressures upon inquiry
d) based on methane number calculation software AVL 3.2 (calculated without N2 and CO2)

0.02 Technical data of engine

Manufacturer		GE Jenbacher
Engine type		J 624 GS-H112
Working principle		4-Stroke
Configuration		V 60°
No. of cylinders		24
Bore	mm	190
Stroke	mm	220
Piston displacement	lit	149,70
Nominal speed	rpm	1.500
Mean piston speed	m/s	11,00
Length	mm	9.533
Width	mm	2.111
Height	mm	2.564
Weight dry	kg	17.100
Weight filled	kg	18.100
Moment of inertia	kgm²	92,70
Direction of rotation (from flywheel view)		left
Radio interference level to VDE 0875		N
Starter motor output	kW	20
Starter motor voltage	V	24

Thermal energy balance

Energy input	kW	9.805
Intercooler	kW	1.745
Lube oil	kW	418
Jacket water	kW	684
Exhaust gas cooled to 180 °C	kW	1.337
Exhaust gas cooled to 100 °C	kW	1.917
Surface heat	kW	101

Exhaust gas data

Exhaust gas temperature at full load	°C [8]	359
Exhaust gas temperature at bmep= 18 [bar]	°C	~ 401
Exhaust gas temperature at bmep= 12 [bar]	°C	~ 450
Exhaust gas mass flow rate, wet	kg/h	24.371
Exhaust gas mass flow rate, dry	kg/h	22.904
Exhaust gas volume, wet	Nm³/h	19.238
Exhaust gas volume, dry	Nm³/h	17.414
Max.admissible exhaust back pressure after y-pipe	mbar	50

Combustion air data

Combustion air mass flow rate	kg/h	23.663
Combustion air volume	Nm³/h	18.311
Max. admissible pressure drop at air-intake filter	mbar	10

Sound pressure level

Aggregate a)	dB(A) re 20µPa	103
31,5 Hz	dB	90
63 Hz	dB	97
125 Hz	dB	103
250 Hz	dB	101
500 Hz	dB	96
1000 Hz	dB	95
2000 Hz	dB	94
4000 Hz	dB	96
8000 Hz	dB	97
Exhaust gas b)	dB(A) re 20µPa	123
31,5 Hz	dB	109
63 Hz	dB	111
125 Hz	dB	121
250 Hz	dB	116
500 Hz	dB	117
1000 Hz	dB	113
2000 Hz	dB	113
4000 Hz	dB	120
8000 Hz	dB	103

Sound power level

Aggregate	dB(A) re 1pW	126
Measurement surface	m²	194
Exhaust gas	dB(A) re 1pW	131
Measurement surface	m²	6,28

a) average sound pressure level on measurement surface in a distance of 1m (converted to free field) according to DIN 45635, precision class 3.
b) average sound pressure level on measurement surface in a distance of 1m according to DIN 45635, precision class 2.
The spectra are valid for aggregates up to bmep=24 bar. (for higher bmep add safety margin of 1dB to all values per increase of 1 bar pressure).
Engine tolerance ± 3 dB

0.03 Technical data of generator

Manufacturer		TDPS e)
Type		TD125-F2K9 e)
Type rating	kVA	6.360
Driving power	kW	4.491
Ratings at p.f. = 1,0	kW	4.405
Ratings at p.f. = 0,8	kW	4.375
Rated output at p.f. = 0,8	kVA	5.469
Rated reactive power at p.f. = 0,8	kVar	3.281
Rated current at p.f. = 0,8	A	287
Frequency	Hz	50
Voltage	kV	11
Speed	rpm	1.500
Permissible overspeed	rpm	1.800
Power factor (lagging - leading)		0,8 - 1,0
Efficiency at p.f. = 1,0	%	98,1%
Efficiency at p.f. = 0,8	%	97,4%
Moment of inertia	kgm²	443,75
Mass	kg	18.800
Radio interference level to EN 55011 Class A (EN 61000-6-4)		N
Ik'' Initial symmetrical short-circuit current	kA	1,49
Is Peak current	kA	3,80
Insulation class		F
Temperature (rise at driving power)		F
Maximum ambient temperature	°C	40

Reactance and time constants (saturated)

xd direct axis synchronous reactance	p.u.	1,92
xd' direct axis transient reactance	p.u.	0,25
xd'' direct axis sub transient reactance	p.u.	0,19
x2 negative sequence reactance	p.u.	0,29
Td'' sub transient reactance time constant	ms	35
Ta Time constant direct-current	ms	170
Tdo' open circuit field time constant	s	2,83

e) GE Jenbacher reserves the right to change the generator supplier and the generator type. The contractual data of the generator may thereby change slightly. The contractual produced electrical power will not change.

0.04 Technical data of heat recovery

General data - Hot water circuit

Total recoverable thermal output	kW	2.626
Return temperature	°C	70,0
Forward temperature	°C	90,0
Hot water flow rate	m³/h	113,8
Nominal pressure of hot water	PN	10
min. operating pressure	bar	6,0
max. operating pressure	bar	9,0
Pressure drop hot water circuit	bar	1,70
Maximum Variation in return temperature	°C	+0/-5
Max. rate of return temperature fluctuation	°C/min	10

General data - Cooling water circuit

Heat to be dissipated	kW	221
Return temperature	°C	60
Cooling water flow rate	m³/h	50
Nominal pressure of cooling water	PN	10
min. operating pressure	bar	0,5
max. operating pressure	bar	5,0
Loss of nominal pressure of cooling water	bar	~
Maximum Variation in return temperature	°C	+0/-5
Max. rate of return temperature fluctuation	°C/min	10

The final pressure drop will be given after final order clarification and must be taken from the P&ID order documentation.

connection variant H2-i

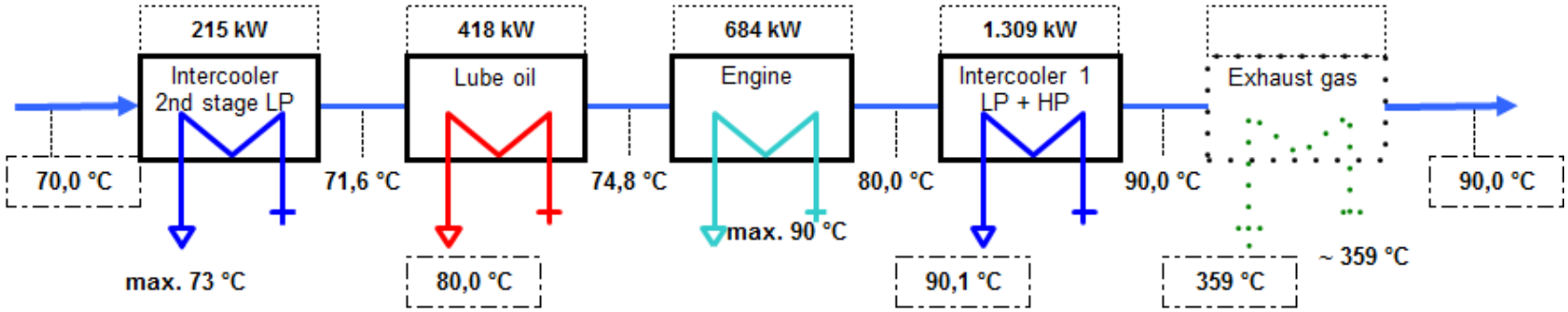
Navigat J 624 GS-H112

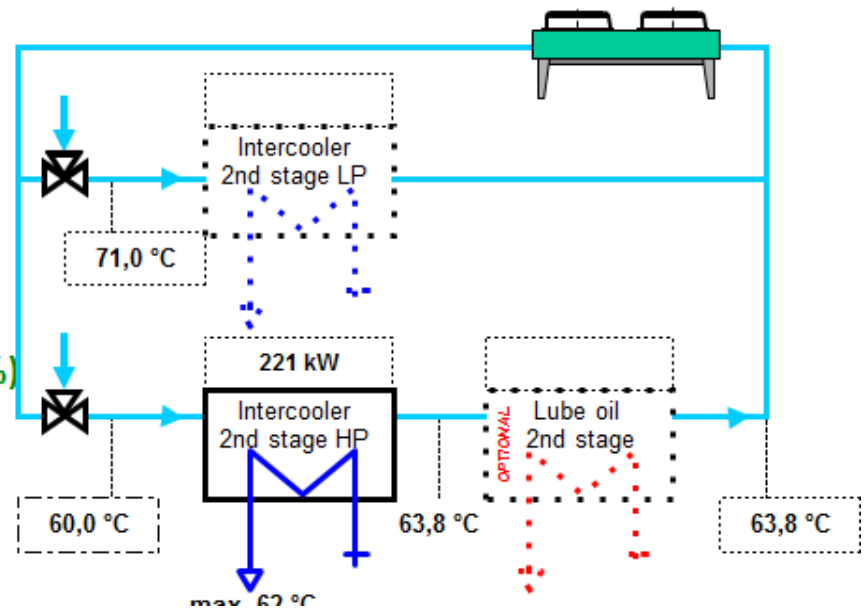
Hot water circuit (calculated with Glykol 3%)

Recoverable thermal output = 2.626 kW

(±8 % tolerance +5 % reserve for cooling requirements)

Hot water flow rate = 113,8 m³/h





Low temperature circuit (calculated with Glykol 3%)

Heat to be dissipated = 221 kW

(±8 % tolerance +5 % reserve for cooling requirements)

Cooling water flow rate = 50,0 m³/h

0.10 Technical parameters

All data in the technical specification are based on engine full load (unless stated otherwise) at specified temperatures and the methane number and subject to technical development and modifications.

All pressure indications are to be measured and read with pressure gauges (psi.g.).

(1) At nominal speed and standard reference conditions ICFN according to DIN-ISO 3046 and DIN 6271, respectively
(2) According to DIN-ISO 3046 and DIN 6271, respectively, with a tolerance of +5 %.
Efficiency performance is based on a new unit (immediately upon commissioning).Effects of degradation during normal operation can be mitigated through regular service and maintenance work.
(3) Average value between oil change intervals according to maintenance schedule, without oil change amount
(4) At p. f. = 1.0 according to VDE 0530 REM / IEC 34.1 with relative tolerances, all direct driven pumps are included
(5) Total output with a tolerance of ±8 %
(6) According to above parameters (1) through (5)
(7) Only valid for engine and generator; module and peripheral equipment not considered (at p. f. = 0,8), (guiding value)
(8) Exhaust temperature with a tolerance of ±8 %
(9) Intercooler heat on:
*** standard conditions (Vxx)** - If the turbocharger design is done for air intake temperature > 30°C w/o de-rating, the intercooler heat of the 1st stage need to be increased by 2%/°C starting from 25°C. Deviations between 25 – 30°C will be covered with the standard tolerance.
*** Hot Country application (Vxxx)** - If the turbocharger design is done for air intake temperature > 40°C w/o de-rating, the intercooler heat of the 1st stage need to be increased by 2%/°C starting from 35°C. Deviations between 35 – 40°C will be covered with the standard tolerance.

Radio interference level
The ignition system of the gas engines complies the radio interference levels of CISPR 12 and EN 55011 class B, (30-75 MHz, 75-400 MHz, 400-1000 MHz) and (30-230 MHz, 230-1000 MHz), respectively.

Definition of output
- ISO-ICFN continuous rated power:
  Net break power that the engine manufacturer declares an engine is capable of delivering continuously, at stated speed, between the normal maintenance intervals and overhauls as required by the manufacturer. Power determined under the operating conditions of the manufacturer's test bench and adjusted to the standard reference conditions.
  - Standard reference conditions:

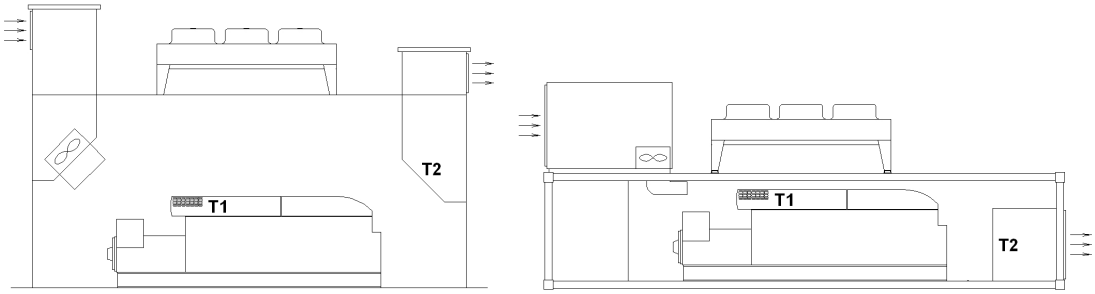
Barometric pressure:	1000 mbar (14.5 psi) or 100 m (328 ft) above sea level
Air temperature:	25°C (77°F) or 298 K
Relative humidity:	30 %

- Volume values at standard conditions (fuel gas, combustion air, exhaust gas)

Pressure:	1013 mbar (14.7 psi)
Temperature:	0°C (32°F) or 273 K

Output adjustment for turbo charged engines

Standard rating of the engines is for an installation at an altitude ≤ **0 m** and combustion air temperature ≤ **40 °C** (T1)
Engine room outlet temperature: **50°C** (T2) -> engine stop



If the actual methane number is lower than the specified, the knock control responds. First the ignition timing is changed at full rated power. Secondly the rated power is reduced. These functions are carried out by the engine management system.
Exceedance of the voltage and frequency limits for generators according to IEC 60034-1 Zone A will lead to a derate in output.

Parameters for the operation of GE Jenbacher gas engines
The genset fulfils the limits for mechanical vibrations according to ISO 8528-9.
The following "Technical Instruction of GE JENBACHER" forms an integral part of a contract and must be strictly observed: **TA 1000-0004, TA 1100 0110, TA 1100-0111**, and **TA 1100-0112.**
Transport by rail should be avoided. See **TA 1000-0046** for further details

Failure to adhere to the requirements of the above mentioned TA documents can lead to engine damage and may result in loss of warranty coverage.

Parameters for the operation of control unit and the electrical equipment
Relative humidity 50% by maximum temperature of 40°C.
Altitude up to 2000m above the sea level.

APPENDIX B. EMISSION CALCULATIONS

Table 1. Emission Summary (Scenario 1 WPP)

Pollutant	Gas engines 1 (kg/hr)	Hot Oil Heater 1 (kg/hr)	Hot Oil Heater 2 (kg/hr)	Medium Pressure Boiler (kg/hr)	Low Pressure Boiler (kg/hr)	Cooling Towers (kg/hr)	Total Emissions [2] (kg/hr)	(metric tonne/yr)
SO_2	0.19	2.75	3.19	0.08	1.32	--	**7.54**	**59.71**
NO_X	15.91	1.55	1.80	1.64	25.96	--	**46.85**	**371.07**
PM_{10}	0.37	0.26	0.30	1.26	19.97	0.36	**22.51**	**178.24**
$PM_{2.5}$	0.37	0.26	0.30	1.09	17.32	0.04	**19.37**	**153.41**

[1] There will be four gas engines that could be operated at the same time during normal operation when gas engines are installed. There will be a fifth gas engine serving as backup. The steam generated by the gas engines will serve the process units that would have operated with steam from the High Pressure Boiler.

[2] Annual emissions are based on 330 days/yr operation.

Table 2. Emission Summary (Scenario 2 WOPP)

Pollutant	Hot Oil Heater 1 (kg/hr)	Hot Oil Heater 2 (kg/hr)	High Pressure Boiler (kg/hr)	Medium Pressure Boiler (kg/hr)	Low Pressure Boiler (kg/hr)	Cooling Towers (kg/hr)	Total Emissions [1] (kg/hr)	(metric tonne/yr)
SO_2	2.75	3.19	0.62	0.08	1.32	--	**7.97**	**63.13**
NO_X	1.55	1.80	0.35	1.64	25.96	--	**31.29**	**247.81**
PM_{10}	0.26	0.30	0.06	1.26	19.97	0.36	**22.20**	**175.80**
$PM_{2.5}$	0.26	0.30	0.06	1.09	17.32	0.04	**19.06**	**150.97**

[1] Annual emissions are based on 330 days/yr operation.

Table 3. Emissions for Gas engines

Pollutant	Emission Factor [1] (lb/MMBtu)	Emission Rate for Each engine 2,3 (kg/hr)	(metric tonne/yr)
SO_2	0.0034	0.05	0.37
PM_{10}/ $PM_{2.5}$	0.0066	0.09	0.72
	(mg/Nm3)	(kg/hr)	(metric tonne/yr)
NO_X	250	3.98	31.51

[1] Emission factors are from AP-42 Tables 3.1-1 and 3.1-2 for uncontrolled natural gas-fired engines.

[2] The engines are used for cogeneration of electricity and thermal energy with the following parameters from GE's Technical Description for J624 GS-N.L natural gas-fired engines, 250 mg/nm3 NOX.

		Load -->	100%	75%	50%
Energy input	kW	[2]	9805	7507	5209
Gas volume	Nm³/h	*)	1032	790	548
Mechanical output	kW	[1]	4491	3368	2246
Electrical output	kW el.	[4]	4405	3299	219

Electrical output needed: 4000 kW

Approximate Load: 91%

Electrical Efficiency: 44.53%

Based on these parameters, the heat input required for each gas engine is:

8960 kW 30.57 MMBtu/hr

Corresponding Flow 4.42 Nm3/s (dry)

4.88 Nm3/s (wet)

[3] Annual emissions are based on 330 days/yr operation.

Table 4. Diesel-Fired Boiler/Heater Emissions

Pollutant	Emission Factor [1] (lb/1000 gal)	Hot Oil Heater 1 Emissions [2,3] (kg/hr)	(metric tonne/yr)	Hot Oil Heater 2 Emissions [2,3] (kg/hr)	(metric tonne/yr)	High Pressure Boiler Emissions [2,3] (kg/hr)	(metric tonne/yr)
SO_2	35.5	2.75	21.76	3.19	25.30	0.62	4.92
NO_X	20	1.55	12.26	1.80	14.25	0.35	2.77
PM_{10}/ $PM_{2.5}$	3.3	0.26	2.02	0.30	2.35	0.06	0.46

[1] Emission factors are from AP-42 Tables 1.3-1 and 1.3-2 for uncontrolled distillate oil-fired boilers less than 100 MMBtu/hr. SO_2 emissions conservatively assume the sulfur content of 2500 ppm, which is the sulfur limit for diesel fuel with cetane number 48 according to SK 978/2013 rule (versus 500 ppm for diesel with cetain number of 51 or above); this assumption also assumes that the diesel fired in the heaters would be sources from the same supplies as vehicle diesel. The particulate matter emission factor is the sum of filterable PM factor for distillate oil-fired boilers and condensable PM factor for No.2 oil-fired boilers. It is assumed that all PM have sizes smaller than 2.5 μm.

[2] The heat inputs for each unit:

Hot Oil Heater 1 (Acid 1):	7000	kW input	23.9	MMBtu/hr
Hot Oil Heater 2 (Alcohol 1):	8140	kW input	27.8	MMBtu/hr
High Pressure Boiler:			5.4	MMBtu/hr

The emission rates are calculated based on AP-42's default heating value of 140 MMBtu/1000 gal for distillate fuel oil.

[3] Annual emissions are based on 330 days/yr operation.

Table 5. Medium Pressure/Low Pressure Boilers Emissions

Pollutant	Diesel Emission Factor [1] (lb/1000 gal)	Emissions From Diesel Firing [2] (kg/hr/boiler)	Palm Kernel Shell Emission Factor [3] (lb/MMBtu)	Boiler Palm Kernel Shell Firing Emissions [4] (kg/hr)	Boiler Palm Kernel Shell Firing Emissions [4] (kg/hr)	Medium Pressure Boiler Emissions [5] (kg/hr)	Medium Pressure Boiler Emissions [5] (metric tonne/yr)	Low Pressure Boiler Emissions [5] (kg/hr)	Low Pressure Boiler Emissions [5] (metric tonne/yr)
SO_2	35.5	1.77E-04	0.025	0.08	1.32	0.08	0.66	1.32	10.49
NO_X	20	9.99E-05	0.49	1.64	25.96	1.64	12.96	25.96	205.57
PM_{10}	3.3	1.65E-05	0.377	1.26	19.97	1.26	9.97	19.97	158.17
$PM_{2.5}$	3.3	1.65E-05	0.327	1.09	17.32	1.09	8.65	17.32	137.19

[1] Emission factors are from AP-42 Tables 1.3-1 and 1.3-2 for uncontrolled distillate oil-fired boilers less than 100 MMBtu/hr. SO_2 emissions conservatively assume the sulfur content of 2500 ppm, which is the sulfur limit for diesel fuel with cetane number 48 according to SK 978/2013 rule. The particulate matter emission factor is the sum of filterable PM factor for distillate oil-fired boilers and condensable PM factor for No.2 oil-fired boilers. It is assumed that all PM have sizes smaller than 2.5 μm.

[2] Each boiler will fire 1 liter diesel for boiler startup. It is assumed that 1 liter of diesel fuel per day per boiler will be fired. The hourly emissions listed here represent a daily average hourly emission rate.

[3] Palm kernel shells are assumed to have similar properties as the wood residue since palm kernel shells specific emission factors are not available. Generally, palm kernel shells contain low moisture content (<20%) than other agricultural biomass (M. Kavalek et. al., *Oil Palm Shell Use as Alternative Biofuel* , Agronomy Research 11(1), 183-188, 2013; B. Jagustyn et. al., *Evaluation of Physicochemical Properties of Palm Kernel Shell as Agro Biomass Used in the Energy Industry* , CHEMIK 2013, 67, 6, 552-229). Therefore, the emission factors for uncontrolled dry wood firing from AP-42 Tables 1.6-1 and 1.6-2 are used. Sum of filterable PM_{10}/ $PM_{2.5}$ emission factors and condensable PM emission factors are used here.

[4] Emissions from palm kernel shells firing are based on the boiler heat inputs:

Medium Pressure Boiler: 7.36 MMBtu/hr

Low Pressure Boiler: 34.98 MMBtu/hr

[5] Hourly emissions are the sum of diesel firing and palm kernel shell firing. Annual emissions are based on 330 days/yr operation.

Table 6. Cooling Tower Emissions

Emission Unit	Number of Cells	Total Water Flow Rate [1] (m^3/hr)	Estimated Drift Loss [2] (%)	TDS Content [3] (ppm)	PM Emissions [4] (kg/hr)	PM_{10} Emissions [4,5] (kg/hr)	PM_{10} Emissions [4,5] (metric tonne/yr)	$PM_{2.5}$ Emissions [4,5] (kg/hr)	$PM_{2.5}$ Emissions [4,5] (metric tonne/yr)
Cooling Towers Set 1	3	1400	0.020	20,600	5.77	0.105	0.830	0.011	0.090
Cooling Towers Set 2	3	1400	0.020	20,600	5.77	0.105	0.830	0.011	0.090
Cooling Towers Set 3	3	750	0.020	20,600	3.09	0.056	0.444	0.006	0.048
Cooling Towers Set 4	4	600	0.020	20,600	2.47	0.045	0.356	0.005	0.038
Cooling Towers Set 5	3	500	0.020	20,600	2.06	0.037	0.296	0.004	0.032
Cooling Towers Set 6	4	135	0.020	20,600	0.56	0.010	0.080	0.001	0.009

[1] Total flow rates are provided by PHG.

[2] Estimated drift loss is assumed to be 0.02% based on AP-42 Chapter 13.4.

[3] TDS content is obtained from AP-42 Table 13.4-2, the average TDS content for all induced-draft cooling towers tested.

[4] PM emissions are calculated as: TDS (ppm)/10^6 × drift loss (%)/100 × total flow rate (m^3/hr) × water density (1000 kg/m^3). PM_{10} and $PM_{2.5}$ emissions are calculated based on the particle size distributions below.

[5] Annual emissions are based on 330 days/yr operation.

Table 7. Particle Size Distribution of PM Emissions Based on TDS [1]

TDS (ppmw)	20,600	
EPRI Droplet Diameter [2] (µm)	Solid Particle Diameter [3] (µm)	EPRI % Mass Smaller [2]
10	2.11	0
20	4.22	0.196
30	6.32	0.226
40	8.43	0.514
50	10.54	1.816
60	12.65	5.702
70	14.75	21.348
90	18.97	49.812
110	23.19	70.509
130	27.40	82.023
150	31.62	88.012
180	37.94	91.032
210	44.26	92.468
240	50.59	94.091
270	56.91	94.689
300	63.23	96.288
350	73.77	97.011
400	84.31	98.34
450	94.85	99.071

[1] Particle size distribution calculated based on emission calculations outlined in *Reisman, J. and G. Frisbie "Calculating Realistic PM10 Emissions from Cooling Towers" Greystone Environmental Consultants, Inc., 650 University Avenue, Suite 100, Sacramento, CA 95825.*

[2] The EPRI Droplet Diameter and the EPRI % Mass Smaller are provided in Reisman, J. and G. Frisbie "*Calculating Realistic PM_{10} Emissions from Cooling Towers*", Table 1, Greystone Environmental Consultants, Inc., 650 University Avenue, Suite 100, Sacramento, CA 95825.

[3] Solid particle diameter is calculated from EPRI droplet diameter assuming that each water droplet evaporates shortly after being emitted into a single, solid, spherical particle. Other assumptions include:

$\rho_{droplet}$	1	g/cm^3
ρ_{solid}	2.2	g/cm^3

Table 8. Particle Size Distribution for $PM_{2.5}$ and PM_{10}

TDS (ppmw)	Solid Particle Diameter used for PM_{10} [1] (µm)	% of Particles where diameter < 10 µm	Solid Particle Diameter used for $PM_{2.5}$ [1] (µm)	% of Particles where diameter < 2.5 µm
20,600	10.54	1.816	4.22	0.196

[1] The solid particle diameters are determined based on the particle size distribution presented in Table 5 above, assuming water is evaporated instantly when the droplet is emitted to atmosphere.

Table 9. Unit Conversion

1 kW=	3412.142 Btu/hr
1 lb =	453.5924 gram
1 gallon =	3.785412 liter
1 ft =	0.3048 m

APPENDIX C. MODELLED PARAMETERS

Table 1. Parameters for Boiler/Heaters

EU ID	Unit Description	UTM Easting [1] (m)	UTM Northing [1] (m)	Elevation [5] (m)	Stack Height [2] (m)	Stack Diameter [3] (m)	Exit Velocity [4] (m/s)	Temperature [3] (K)	Flow Rate [3] (acfm)	Emission Rate (g/s) SO_2	NO_X	PM_{10}	$PM_{2.5}$
BO_HP	High Pressure Boiler	548003.7	372884.1	3.00	38.32	0.243	20.00	505.37	1,970.67	0.173	0.097	0.016	0.016
BO_MP	Medium Pressure Boiler	547952.0	372873.0	3.00	18.30	0.306	20.00	519.26	3,107.81	0.023	0.454	0.350	0.303
BO_LP	Low Pressure Boiler	547962.0	372869.0	3.00	42.50	0.666	20.00	519.26	14,771.68	0.368	7.210	5.547	4.812
HOH1	Hot Oil Heater 1	547964.5	373027.3	2.98	38.32	0.512	20.00	505.37	8,715.45	0.763	0.430	0.071	0.071
HOH2	Hot Oil Heater 2	547920.6	373063.6	2.97	30.23	0.552	20.00	505.37	10,134.83	0.887	0.500	0.082	0.082

[1] UTM coordinates are in WGS84 Datum, Zone 47N. Locations are determined based on Google Earth aerial image and information provided by PHG.

[2] Stacks of boilers and heaters are existing, and heights determined based on site data (engineering as-built specifications and/or measurements) .

[3] Flow rates and temperatures are calculated based on the size of combustion device and the fuel type with engineering estimate (Perry's Handbook), assuming 20% of access air for combustion. Stack diameters are back-calculated based on the flow rate and exit velocities.

[4] Exit velocity is assumed to be 20 m/s for all boiler/heaters.

[5] Elevations are determined from Shuttle Radar Topography Mission (SRTM), distributed by USGS, and adjusted as necessary so the emission units have the same elevation as the building that they are residing in.

Table 2. Parameters for engines

EU ID	Unit Description	UTM Easting [1] (m)	UTM Northing [1] (m)	Elevation [5] (m)	Stack Height [2] (m)	Stack Diameter [2] (m)	Exit Velocity [4] (m/s)	Temperature [3] (K)	Flow Rate [4] (m3/s)	Emission Rate (g/s) SO_2	NO_X	PM_{10}	$PM_{2.5}$
Cogen1	Gas engine 1	548073.6	372918.9	3.75	16.34	0.61	22.06	393.15	6.44	0.0131	1.1051	0.0254	0.0254
Cogen2	Gas engine 2	548079.2	371916.5	3.75	16.34	0.61	22.06	393.15	6.44	0.0131	1.1051	0.0254	0.0254
Cogen3	Gas engine 3	548084.8	372914.1	3.75	16.34	0.61	22.06	393.15	6.44	0.0131	1.1051	0.0254	0.0254
Cogen4	Gas engine 4	548090.3	372911.8	3.75	16.34	0.61	22.06	393.15	6.44	0.0131	1.1051	0.0254	0.0254
Cogen5	Gas engine 5	548095.9	372909.3	3.75	16.34	0.61	22.06	393.15	6.44	0.0000	0.0000	0.0000	0.0000

[1] UTM coordinates are in WGS84 Datum, Zone 47N. Locations are determined based on information provided by PHG.

[2] Stack height and diameter are obtained from engineering drawings for J624 GS NL units (Drawing no. NEI-STD-01-624-05-LA-03).

[3] Temperature is obtained from GE Jenbacher type 6 brochure. For natural gas units, exhaust gas temperature is 120 °C.

[4] Exit velocity calculated based on engine specification flow rate (19238 Nm3/hr (wet), converted from Normal conditions based on 25 C normal conditions listed in sheet).

[5] Elevations are determined from Shuttle Radar Topography Mission (SRTM), distributed by USGS, and adjusted as necessary so the emission units have the same elevation as the building that they are residing in.

Table 3. Parameters for Cooling Towers

Cooling Tower ID	# of Cells	UTM Easting [1] (m)	UTM Northing [1] (m)	Elevation [5] (m)	Stack Height [2] (m)	Stack Diameter [3] (m)	Exit Velocity [4] (m/s)	Temperature [4] (K)	Flow Rate [4] (acfm)	Water Flow Rate (m^3/hr)	Emission Rate (g/s) PM_{10}	Emission Rate (g/s) $PM_{2.5}$
Cooling Towers Set 1	3	--	--	--	10.144	3.3	--	-2.78	787,624.08	1400	0.105	0.0113
CT1_1	--	547897.3	373212.8	2.87	10.144	3.3	14.49	-2.78	262,541.36		0.035	0.0038
CT1_2	--	547895.3	373207.4	2.87	10.144	3.3	14.49	-2.78	262,541.36		0.035	0.0038
CT1_3	--	547893.2	373201.6	2.87	10.144	3.3	14.49	-2.78	262,541.36		0.035	0.0038
Cooling Towers Set 2	3	--	--	--	10.144	3.3	--	-2.78	787,624.08	1400	0.105	0.0113
CT2_1	--	547887.7	373189.8	2.66	10.144	3.3	14.49	-2.78	262,541.36		0.035	0.0038
CT2_2	--	547885.4	373183.8	2.66	10.144	3.3	14.49	-2.78	262,541.36		0.035	0.0038
CT2_3	--	547883.1	373179.0	2.66	10.144	3.3	14.49	-2.78	262,541.36		0.035	0.0038
Cooling Towers Set 3	3	--	--	--	10.144	2.5	--	-2.78	421,941.47	750	0.056	0.0061
CT3_1	--	547923.7	373215.9	2.94	10.144	2.5	13.52	-2.78	140,647.16		0.019	0.0020
CT3_2	--	547928.4	373214.2	2.94	10.144	2.5	13.52	-2.78	140,647.16		0.019	0.0020
CT3_3	--	547933.0	373211.7	2.94	10.144	2.5	13.52	-2.78	140,647.16		0.019	0.0020
Cooling Towers Set 4	4	--	--	--	10.144	3.5	--	-2.78	337,553.18	600	0.045	0.0048
CT4_1	--	547952.7	373060.2	3.00	10.144	3.5	4.14	-2.78	84,388.29		0.011	0.0012
CT4_2	--	547963.9	373055.7	3.00	10.144	3.5	4.14	-2.78	84,388.29		0.011	0.0012
CT4_3	--	547948.7	373049.0	3.00	10.144	3.5	4.14	-2.78	84,388.29		0.011	0.0012
CT4_4	--	547960.2	373044.0	3.00	10.144	3.5	4.14	-2.78	84,388.29		0.011	0.0012
Cooling Towers Set 5	3	--	--	--	10.144	2.2	--	-2.78	281,294.32	500	0.037	0.0040
CT5_1	--	547925.9	372997.1	3.23	10.144	2.2	11.64	-2.78	93,764.77		0.012	0.0013
CT5_2	--	547924.2	372992.3	3.23	10.144	2.2	11.64	-2.78	93,764.77		0.012	0.0013
CT5_3	--	547921.9	372987.9	3.23	10.144	2.2	11.64	-2.78	93,764.77		0.012	0.0013
Cooling Towers Set 6	4	--	--	--	10.144	1.5	--	-2.78	75,949.47	135	0.010	0.0011
CT6_1	--	547992.2	372880.0	3.00	10.144	1.5	5.07	-2.78	18,987.37		0.0025	0.00027
CT6_2	--	547994.9	372878.9	3.00	10.144	1.5	5.07	-2.78	18,987.37		0.0025	0.00027
CT6_3	--	547997.6	372877.8	3.00	10.144	1.5	5.07	-2.78	18,987.37		0.0025	0.00027
CT6-4	--	548000.3	372876.9	3.00	10.144	1.5	5.07	-2.78	18,987.37		0.0025	0.00027

[1] UTM coordinates are in WGS84 Datum, Zone 47N. Locations are determined based on Google Earth aerial image and information provided by PHG.

[2] The cooling towers are assumed to be 30 ft high (9.14 m). The release point is assumed to be 1 m higher than the cooling tower structure.

[3] Stack diameters are estimated based on Google Earth aerial imagery.

[4] Flow rates are determined based on the water flow rates. The flow rates are calculated assuming the temperature of water is reduced from 98 °F to 88 °F, while the air temperature is heated from 80 °F to 85 °F. Exhaust temperature is assumed to be 5 °F above than ambient (annual average ambient temperature is 300.8 Kelvin). Exit velocities are calculated based on estimated flow rate and stack diameter.

[5] Elevations are determined from Shuttle Radar Topography Mission (SRTM), distributed by USGS, and adjusted as necessary so the emission units have the same elevation as the building that they are residing in.