Air Quality Modelling & Assessment Unit
(AQMAU)

Environment
Agency

AQMAU reference: AQMAU-C1457-RP01

Project title: Diesel generator short term NO_2 impact assessment

Date requested: 13/09/2016 **AQMAU response date:** 01/11/2016

1 Summary of work request

1.1 The Environment Agency's Air Quality Modelling and Assessment Unit (AQMAU) were asked by the Department for Environment, Food & Rural Affairs (Defra) to investigate the potential for diesel generator arrays, for National Grid back up to cause a breach of the short term nitrogen dioxide (NO_2) air quality Standard[1]. The NO_2 short term standard is an hourly mean limit value of 200 µg/m^3, not to be exceeded more than 18 times a year. Diesel generator arrays are a popular choice for applicants and operators in the energy capacity market to provide backup to the National Grid, due to lower cost, no gas connection requirements and quick ramp up times. This assessment considers diesel generator arrays with a combined power input of less than 50 megawatt thermal (MW_{th}) and operating for up to 500 hours per year. The 50 MW_{th} constraint has been selected because under the Industrial Emissions Directive[2] these arrays would be Part A(1) installations and subject to regulation by the Environment Agency. 500 operating hours has been selected because generators operating less than 500 hours per year may be exempt from complying with emission limits under the Medium Combustion Plant Directive[3].

1.2 We have conducted conservative modelling of three generic diesel array sizes under a range of different scenarios:

- Case 1 – Diesel generator array with a total rated thermal input of just below 50 MW_{th}.
- Case 2 – Diesel generator array with a total thermal rated input of 20 MW_{th}.
- Case 3 – Small diesel generator array with total rated thermal input of 5 MW_{th}.

1.3 AQMAU were asked to investigate potential stack design measures, operating pattern restrictions and emission at the Medium Combustion Plant Directive (MCPD) Emission Limit Value (ELV) of 190 mg/Nm^3 at standard temperature and pressure (STP), dry and 15% oxygen.

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[1] Statutory Instruments 2010 No. 1001, Environmental Protection, The Air Quality Standards Regulations 2010

[2] Directive 2010/75/EU of the European Parliament and of the council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast)

[3] Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitations of emissions of certain pollutants into the from medium combustion plants

2 Conclusions

2.1 AQMAU undertook precautionary modelling making conservative assumptions on emissions and the maximum downwind predictions from the source, along with more realistic assumptions for NO_X to NO_2 conversion.

2.2 Our precautionary modelling indicates that diesel generators without stack design measures, such as multiflue tall stack designs, operating pattern restrictions or abatement to achieve stringent ELVs are likely to cause breaches of the short term standard if there are sensitive receptors nearby. With design and control measures implemented the likelihood of exceedances can be significantly reduced. However, potential exceedances could still occur for some plant even with control measures if there are sensitive receptors nearby, see section 2.3 below.

2.3 From our modelling assessment we make the following general observations:

- Stack engineering design to ensure good emissions dispersion through release height, buoyancy and momentum can substantially reduce these worst case impacts.
    - Where individual engine stacks are implemented they should use good engineering design practices so that the downwash effects from engine containers and other structures are minimised and downwind dispersion is improved.
    - Where individual engine stacks are implemented fewer larger engines are likely to have slightly less of an impact than a greater number of smaller engines.
    - Combining multiple engine flows into multiflue tall stacks or implementing very large engines with tall stacks, greater than 20 m is the most effective design method for reducing the impacts and lowering the risk of short term exceedances.
- Operational hours restricted to 50 hours per year still has the potential to exceed the standard within 160 m under the worst modelled case, just less than 50 MW_{th} with 2.5 m individual engine stacks.
- At the MCPD ELV there is still potential for an exceedance within 110 m under the worst modelled case, just less than 50 MW_{th} with 2.5 m individual engine stacks.
- An unabated diesel generator array with individual engine stacks (2.5 m) and a total rated thermal input of 5 MW_{th} still has potential to exceed the standard within 120 m.

2.4 Based on these observations we recommend that site specific assessment is conducted unless large multiflue stack configurations are proposed, or any of the following:

- Operational hours are restricted to 50 hours per year and there are no sensitive receptors within 150 m.
- Emissions are at the MCPD ELV and there are no sensitive receptors within 150 m.
- The total rated thermal input is less than 5 MW_{th} and there are no sensitive receptors within 150 m.

3 Evidence for conclusions

Modelling assumptions and sensitivity analysis

3.1 The project brief was to conduct predictive modelling and assess the impact of new unabated diesel generator arrays and assess the effectiveness of various control measures such as: stack height and mutiflue designs; operational pattern restrictions; and abatement to achieve emissions at the MCPD ELV of 190 mg/Nm^3, STP, dry and 15% oxygen. Conservative assumptions have been used to conduct precautionary screening modelling and assess the risk of exceeding the short term NO_2 standard for various scenarios.

3.2 Diesel generators have very high NO_X emissions compared to other forms of generators such as similarly sized gas generators. Diesel generator emissions can vary greatly from engine to engine depending on the age and engine tuning.

3.3 Information provided to Defra by the generator manufacturing industry indicate that unregulated diesel engines are likely to have NO_X emission concentrations of between 1500 and 2200 mg/Nm^3 or 12 to 17 kg/MWh$_e$. Information from DECC[4] reported unabated diesel engine NO_X emissions between 2890 and 3012 mg/Nm^3, 19.81 to 20.65 kg/MWh$_e$.

3.4 Diesel engines are lean-burn ie the fuel is burnt with excess air. There is therefore likely to be high levels of excess oxygen in the exhaust gases. AQMAU were asked to model emissions at a concertation of 2000 mg/Nm^3 STP, dry and 15% oxygen. However, to properly derive emission rates at this concentration the actual oxygen and moisture content in the exhaust gas is required, this data was not provided. We have used two emission factors to derive emission rates 12 kg/MWh$_e$ and 19 kg/MWh$_e$. The large combustion plant BREF[5] states that the best available technique electrical efficiency ranges from 40 to 45% for diesel engines. An engine efficiency of 40% has therefore been assumed to derive the electrical output from the rated thermal input.

3.5 In addition we have conducted stoichiometric checks assuming typical diesel chemical compositions to estimate actual oxygen and moisture content from molar air to fuel ratios. Our checks indicate that for an emission concentration of 2000 mg/Nm^3, actual oxygen of approximately 11.6%, moisture content of 6% and actual temperature of 450°C is equivalent to an emission factor of 12 kg/MWh$_e$. For the same emission concentration actual oxygen of approximately 5.5%, moisture content of 10% and actual temperature of 450°C is equivalent to an emission factor of approximately 19 kg/MWh$_e$. Diesel generators are unlikely to have such a low level of excess oxygen in the exhaust gas. Using the 11.6% actual oxygen, 6% moisture and 450°C, 19 kg/MWh$_e$ is equivalent to an emission concentration of approximately 3150 mg/Nm^3. The actual exhaust conditions are therefore a key parameter in deriving representative emission rates. An emission factor of 19 kg/MWh$_e$ is likely to be on the high end of the

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[4] Department of Energy & Climate Change, Developing Best Available Techniques for combustion plants operating in the balancing market, March 2015 (Amec Foster Wheeler Environment & Infrastructure UK Limited)
[5] Integrated Pollution Prevention and Control Reference Document on Best Available Techniques for Large Combustion Plants, July 2006 (European Commission)

possible emission rate ranges and should represent a precautionary worst case emission.

3.6 Table 1 details the modelled emission parameters for the engines used in the assessment.

Table 1

	Engine scenario 1	**Engine scenario 2**	**Engine scenario 3**	**Engine scenario 4**	
Thermal input	2.5	5.4	16.2	1.25	**MW_{th}**
Efficiency	40%	40%	40%	40%	**%**
Electrical output	1	2.16	6.48	0.5	**MW_e**
Temperature	450	450	450	450	**°C**
Diameter	0.35	0.5	0.7 0.9	0.247	**m**
Velocity	31	33	51 31	31	**m/s**
Actual Flow	2.98	6.48	19.63 19.72	1.49	**Am^3/s**
Emission factor	12	12	12	12	**kg/MWh_e**
Emission rate	3.33	7.20	21.60	1.67	**g/s**
High emission factor	19	19	19	19	**kg/MWh_e**
High emission rate	5.28	11.40	34.20	2.64	**g/s**

3.7 The Environment Agency does not prescribe the use of any particular model. However, the chosen model should be fit for purpose and based on established scientific principles. It also needs to have been validated and independently reviewed.

3.8 Modelling was carried out using ADMS 5.1 and BREEZE AERMOD 7.10 (US EPA version 15181). Both are new generation Gaussian dispersion models that are regularly used for Environmental Permitting application and compliance. Model validation studies[6, 7] generally suggest that these dispersion models are able to predict maximum short term high percentiles concentrations within a factor of two.

3.9 The maximum prediction at various distances from the centre of the diesel array has been used as a basis for determining the impact. Polar grids centred on the source array have been used for this purpose, giving the maximum prediction at a distance in any direction. This ensures a precautionary generic assessment. However it does not represent site specific assessment at specified locations that will always be below these predictions.

3.10 Predictions have been made at the following distances from the source array centre: 50, 100, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1250, 1500, 1750 and 2000 m.

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[6] ADMS 5.0 Flat Terrain Validation: Kincaid, Indianapolis and Prairie Grass, June 2013 (Cambridge Environmental Research Consultants)

[7] AERMOD: Latest Features and Evaluation Results, EPA-454/R-03-003, June 2003 (United States Environmental Protection Agency)

3.11 ADMS and ARMOD use hourly sequential meteorological data. Meteorological parameters can have a significant impact on predictions. We therefore conducted sensitivity analysis to 2007 data from 9 different meteorological stations to compare maximum and high percentile predictions for different areas around England. The meteorological stations considered were: Coleshill Warwickshire, Conningsby Lincolnshire, Herstmonceux East Sussex, Leeming North Yorkshire, Watnall Nottinghamshire, Wattisham Suffolk and Wittering Cambridgeshire. Interannual variation can also have an impact on predictions; we therefore conducted sensitivity analysis to 3 years of meteorological data observed at Wattisham 2005 and 2007.

3.12 Surface roughness is a parameter used in dispersion modelling to express the land surface characteristics that influences the mechanical turbulence derived by the software in their modelled atmosphere. Sensitivity analysis was conducted to surface roughness[8] of 0.1 m, 0.5 m and 1.0 m.

3.13 The engine containers are also likely to influence the dispersion for short stacks through building downwash effects. We have therefore conducted sensitivity analysis to building effects using both ADMS and AERMOD. An engine container height of 2.5 m has been assumed.

3.14 Additionally we conducted sensitivity analysis to different individual engine stack heights. Stack heights of 2.5, 5.0, 7.5 and 10 m were modelled. US EPA Guideline for Determination of Good Engineering Practise (GEP) Stack Height[9] suggests the stack should be the height of nearby structures plus 1.5 times L, where L is the lesser dimension of the nearby structures height or projected width. In this case the US EPA GEP stack height would be 6.25 m. Following the ADMS User Guide[10], in this case a source height greater than 3 times the building height, ie greater than 7.5m would ignore the effect of buildings.

3.15 Based on the above, stack heights of 7.5 m should theoretically have no building downwash effects from a 2.5 m building. However, our sensitivity analysis indicated that this was not the case. Both ADMS and AERMOD gave higher predictions 50 m from the centre of the array than when the buildings modules were not used for the same runs. ADMS and AERMOD building downwash modules give rise to higher uncertainties within 10 times the building height. Due to the large source array area predictions made 50 m from the centre of the array are likely to fall within this high uncertainty area. Therefore, predictions at 100 m and greater have been used as a basis for conclusions for the individual engine stack scenarios.

3.16 We have considered rural and urban background NO_2 concentrations in the assessment. To calculate the predicted environmental concentration (PEC) annual average background concentrations have been doubled. Annual rural concentration of 15 µg/m^3 has been assumed and an annual urban concentration of 35 µg/m^3 has been assumed. For urban assessment we also conducted sensitivity analysis in ADMS to hourly 2014 background data from

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[8] 0.1 m is indicative of root crops; 0.5 m is indicative of parkland and open suburbia; and 1.0m is indicative cities or woodland in ADMS.

[9] US EPA Guideline for Determination of Good Engineering Practise Stack Height (Technical Support Document For the Stack Height Regulations EPA-450/4-80-023R, June 1985

[10] CERC, ADMS 5 Atmospheric Dispersion Modelling System, User Guide, Version 5.1, May 2015

London Harlington urban industrial monitoring site, which has an annual average of 36.2 µg/m^3.

3.17 NO$_X$ to NO$_2$ conversion depends on a complex set of photo-chemical reactions and is dependent on the primary NO$_2$/NO$_X$ ratio emitted from the source, locations of receptors in relation to the source and the background concentrations of NO, NO$_2$ and ozone (O$_3$), and to a lesser extent background hydrocarbons. A detailed analysis of the NO$_X$ to NO$_2$ conversion is beyond on the scope of this study. We have therefore conducted some sensitivity analysis to form a reasonable simplified approach.

3.18 The Environment Agency recommends a phased approach[11] consisting of three phases:

- Screening scenario – 50% and 100% conversion for short term and long term respectively.
- Worst case scenario – 35% and 70% conversion for short term and long term respectively.
- Case specific scenario – Justification of any percentages lower than 35% for short term and 70% for long term.

3.19 Due to the very high NO$_X$ emissions of the diesel generator engines and the very high resulting process contributions (PCs) the amount of conversion is likely to be limited by the amount of available O$_3$ in the background. We have therefore conducted sensitivity analysis using the ADMS chemistry module to determine a typical conversion ratio that can be used indicatively for all modelled scenarios. The chemistry module was ran for Cases 1 to 3, with individual stack heights assumed to be 2.5 m and hourly 2014 background NO$_X$, NO$_2$ and O$_3$ data from the rural site Harwell and the urban industrial site London Harington. A primary NO$_2$/NO$_X$ ratio of 10% was assumed based on data from the US EPA In-Stack Ratio (ISR) Database[12].

3.20 Our checks indicate that a short term conversion ratio of 15% is likely to be reasonably representative within the first few hundred meters from the source. At greater distances the conversion ratio is likely to increase as the PCs become lower and therefore larger proportions are converted. A 15% conversion is more likely to underestimate the impacts greater than 500 m from the source; however it is within 500 m that potential exceedances are more likely to occur.

3.21 The following assumptions have been made for the cases and scenarios modelled and results presented in this report. These assumptions were made to give worst case predictions for the majority of modelled scenarios. Due to the conservative nature of these assumptions the modelling uncertainties have not been explicitly considered as the predictions are expected to be at the upper end of the uncertainty range.

3.22 Modelling assumptions for results reporting and conclusions:

- ADMS 5, version 5.1
- 19 kg/MWh$_e$ emission factor

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[11] Conversion Ratios for NOX and NO2, Air Quality Modelling and Assessment Unit, Environment Agency

[12] https://www3.epa.gov/scram001/no2_isr_database.htm

- 2007 Wattisham hourly sequential metrological data
- 0.5 m dispersion site surface roughness
- Building downwash effects included
- Flat terrain
- 15% NO_X to NO_2 short term conversion
- PEC calculated using 2 times annual mean rural (15 µg/m^3) and urban (35 µg/m^3) background.

Statistical analysis

3.23 The diesel generator arrays considered in this assessment can be operational for up to 500 hours per year. For short term infrequent operation statistical analysis can be used to determine the probability of an exceedance of the hourly standard. For this assessment the hypergeometric distribution has been used to assess the likelihood of exceedance hours coinciding with the operational hours. The hypergeometric distribution can be used to compute the probability of exactly x successes in a randomly selected sample size n from a population N without replacement, where in the population there are k successes and N-k failures.

3.24 For this to be appropriate the assumption that operational hours are random at any time of the year must be made. This is not likely to be strictly correct because times of higher energy demand when these plants operate are likely to coincide with specific times of the year and times of the day. However, a standard environmental permit would not normally restrict when the 500 operational hours happen and theoretically they can be any 500 hours within a year. The hypergeometric distribution allows discrete hours to be trialled independently and has therefore been selected as a reasonable representation of these unplanned operations.

3.25 19 or more hours over the 200 µg/m^3 would indicate an exceedance of the standard. Therefore the cumulative hypergeometric distribution must be used to compute the probability of an exceedance.

3.26 We have determined the number of exceedance hours per year by modelling various hourly percentiles. Where the percentile is predicted to exceed 200 µg/m^3 indicates the approximate number of exceedance hours in the year. For example if the 90th percentile hourly predictions is 100% of the short term standard then 10%, 876 hours exceed the standard.

3.27 The 100, 99.79, 99, 98, 97.5, 97, 96.2, 96, 95, 90, 85, 80, 75, 70, 60 and 50 percentiles have been modelled. Table 2 shows the theoretical probability for each hourly percentile if the prediction was 100% of the standard and assuming 499 operational hours.

Table 2

Percentile	Number of exceedance hours per year	Operational hours	Probability of 19 or more exceedance hours
50%	4380	499	1

60%	3504	499	1
70%	2628	499	1
75%	2190	499	1
80%	1752	499	1
85%	1314	499	1
90%	876	499	1
95%	438	499	0.92
96%	350	499	0.62
96.2%	333	499	0.53
97%	263	499	0.17
97.5%	219	499	0.044
98%	175	499	0.005
99%	88	499	3.64E-07
99.79%	18	499	0
100%	0	499	0

3.28 As can be seen from Table 2 with 499 operational hours if more than 5% of yearly hours exceed the standard, ie the 95th percentile, then the probability of exceedance is highly likely, greater than 90% chance. The 95th percentile has therefore been used as an indicator of ‘likely exceedances’ for 499 operational hours. The 96.2nd percentile represents 333 exceedance hours per year and at this level probability of an exceedance is around 50:50. At the 97.5th percentile, 219 exceedance hours the probability of randomly selecting 19 or more exceedance hours from 499 trials is 0.044, less than 0.05 or 1/20th. 1/20th indicatively means 1 in 20 years could exceed the short term standard. If the operational lifetime of these plants is approximately 20 years then values less than 1/20th can be considered an acceptable probability threshold. The 97.5th percentile has therefore been used as an indicator of ‘unlikely exceedances’ for 499 operational hours.

3.29 By reducing the operational hours the probability of an exceedance is reduced. Table 3 shows the probability of an exceedance for the same percentiles if operational hours were restricted to 50 hours per year.

Table 3

Percentile	**Number of exceedance hours per year**	**Operational hours**	**Probability of 19 or more exceedance hours**
50%	4380	50	0.97
60%	3504	50	0.66
70%	2628	50	0.14
75%	2190	50	0.028
80%	1752	50	0.002
85%	1314	50	5.63E-05
90%	876	50	1.24E-07
95%	438	50	9.39E-13
96%	350	50	1.63E-14
96.2%	333	50	6.54E-15

97%	263	50	8.16E-17
97.5%	219	50	2.55E-18
98%	175	50	3.40E-20
99%	88	50	3.29E-26
99.79%	18	50	0
100%	0	50	0

3.30 Table 3 indicates that with 50 operational hours the probability of an exceedance is high if more than 50% of yearly hours exceed the standard. If around 25% of hours exceed the standard, the 75th percentile then the probability of exceeding the standard is less than 1/20th and can be considered unlikely.

3.31 The model outputs from each scenario were then analysed and the hypergeometric distributions for the 499 and 50 operational hours applied to understand the likelihood of an exceedance.

Case 1 modelled scenarios and results discussion

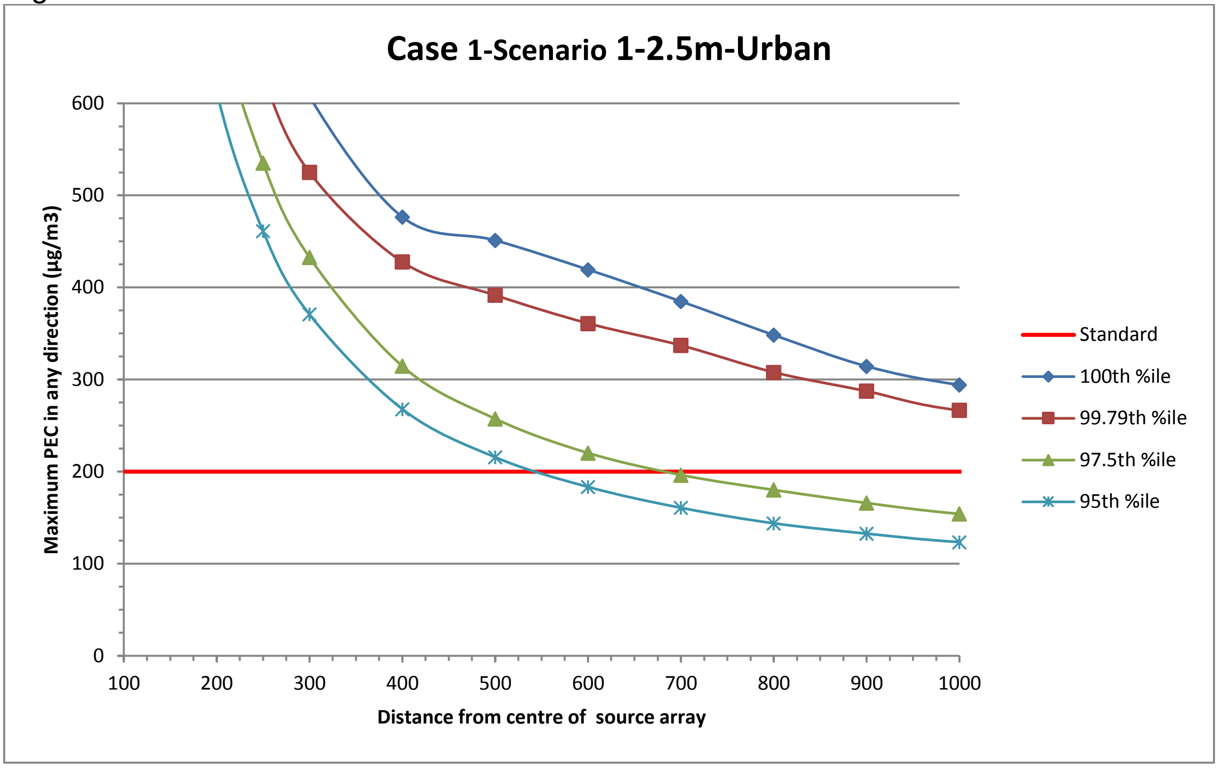
3.32 Three engine scenarios have been modelled for Case 1, less than 50 MW_{th} rated thermal input:

- Scenario 1 – 19 times 2.5 MW_{th} engines. Scenario 1 represents a large number of small engines and is likely to be the 'worst case' for Case 1. Individual point sources were placed in a rectangular array of 4 rows and 5 columns with a 10 and 20 m horizontal and vertical spacing. Stack heights of 2.5 m and 7.5 m have been reported.
- Scenario 2 – 9 times 5.4 MW_{th} engines. Scenario 2 is representative of fewer larger engines. Individual point sources were placed in a rectangular array of 3 rows and 3 columns with a 10 and 20 m horizontal and vertical spacing. Stack heights of 2.5 m and 7.5 m have been reported.
- Scenario 3 – 3 times 16.2 MW_{th} engines. Scenario 3 is representative of either three very large diesel engines or three times 3 smaller 5.4 MW_{th} engines being combined and emitted through a single or multiflued stack. Point sources were placed in a single column with 20 m vertical spacing. Stack heights of 20 and 30 m are reported.

3.33 For engine scenario 1 (19 times 2.5 MW_{th}), assuming the high 19 kg/MWh_e emission factor and 2.5 m individual engine stacks the PECs are likely to be very high in nearfield under worst case met conditions. The highest PEC at 100 m is around 1850 $\mu g/m^3$. A large portion of hours per year exceed the standard. The 70th percentile exceeds the standard at 100 m, suggesting more than 30% of hours per year will exceed the standard. Our statistical analysis indicates that there is potential for an exceedance within 700 m assuming urban background and within 550 m for rural background.

3.34 Figure 3.1 shows the 100th, 99.79th, 97.5th and 95th hourly percentile PECs from 700 to 2000 m from the centre of the source array for urban background.

Figure 3.1

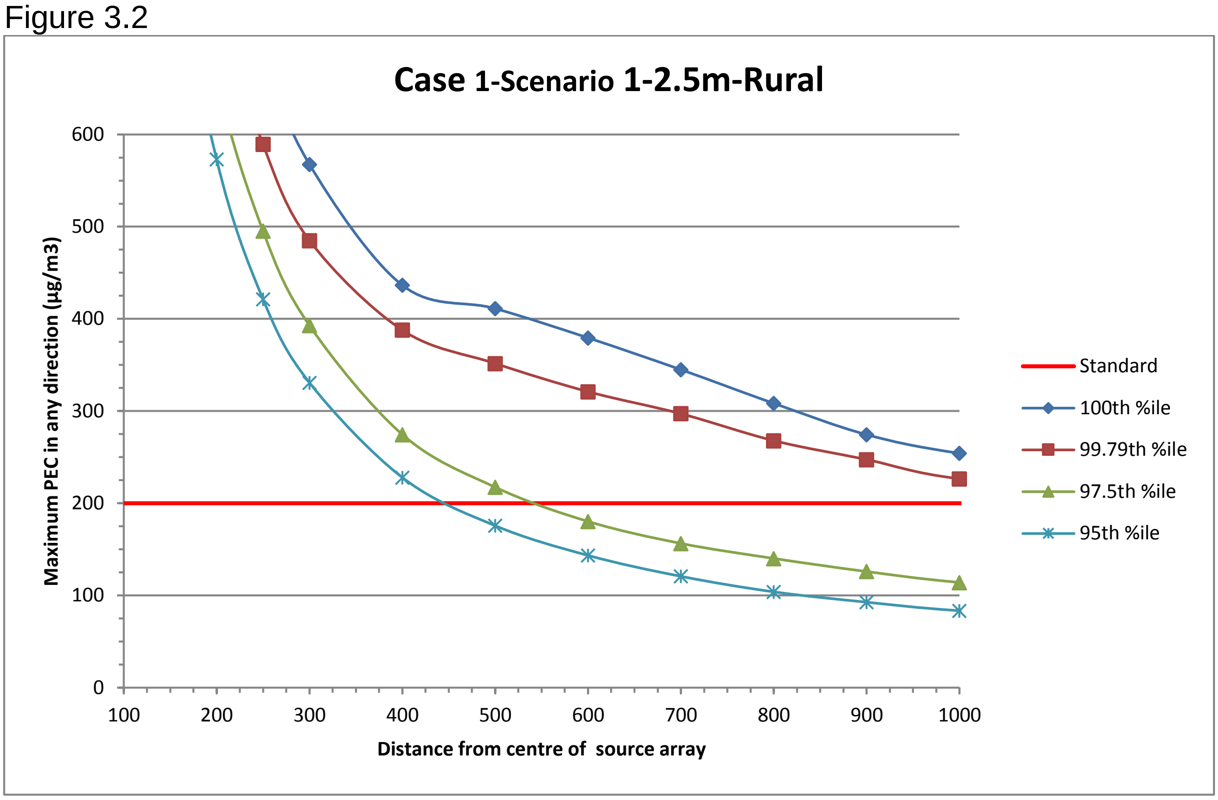


3.35 The 100th percentile represents the worst hour in any direction; the 99.79th percentile represents the 18th highest hour. The 100th and 99.79th percentile urban PEC exceeds the standard up to 1500 m.

3.36 The 95th percentile PEC line intersects the standard at approximately 550 m, indicating exceedances are likely within this distance assuming 499 operational hours. The 97.5th percentile PEC line intersects the standard at approximately 700 m indicating exceedances are unlikely beyond this distance assuming 499 operational hours. There is therefore potential for an exceedance within 700 m under this scenario.

3.37 Figure 3.2 shows the same data for the rural background. Indicating exceedances are likely within 450 m and are unlikely beyond 550 m assuming 499 operational hours. Therefore there is potential for an exceedance within 550 m under this scenario.

Figure 3.2



3.38 Increasing the individual stack heights to 7.5 m does reduce these distances. For example, there is potential for an exceedance within 600 m assuming urban background and 500 m for rural background see Figures 3.3 and 3.4 respectively.

Figure 3.3

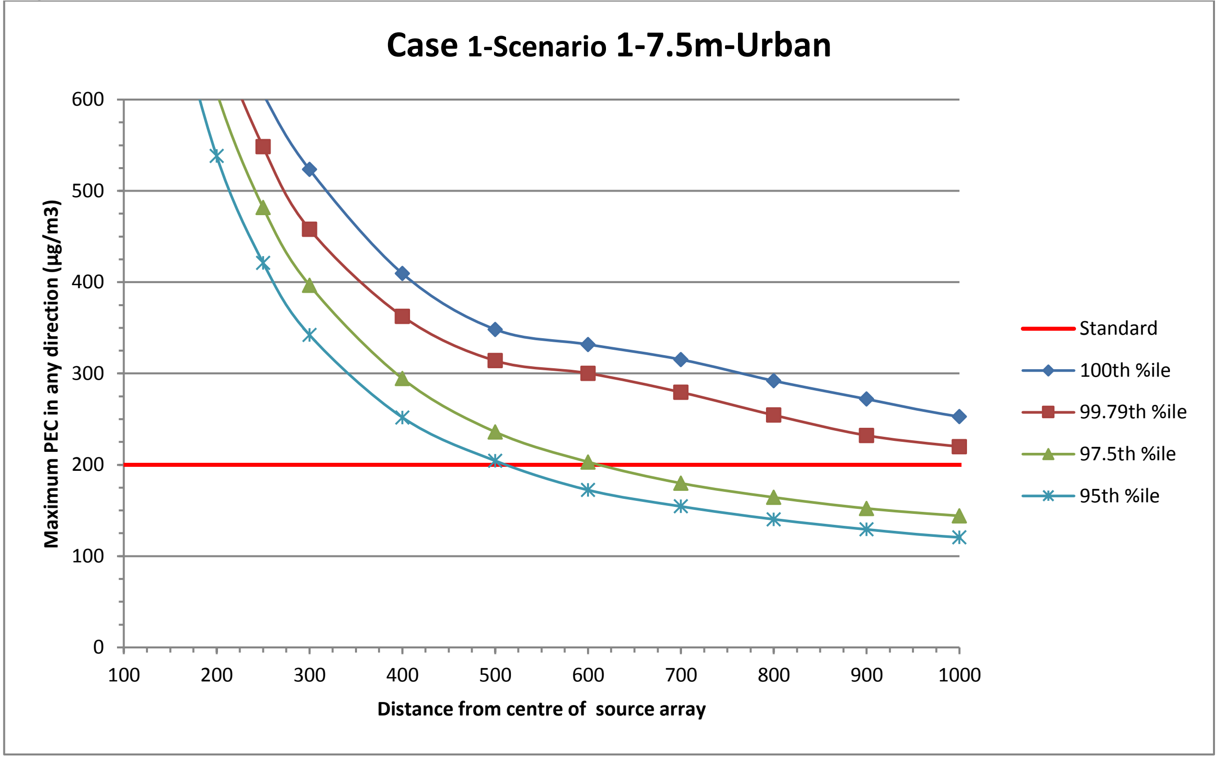
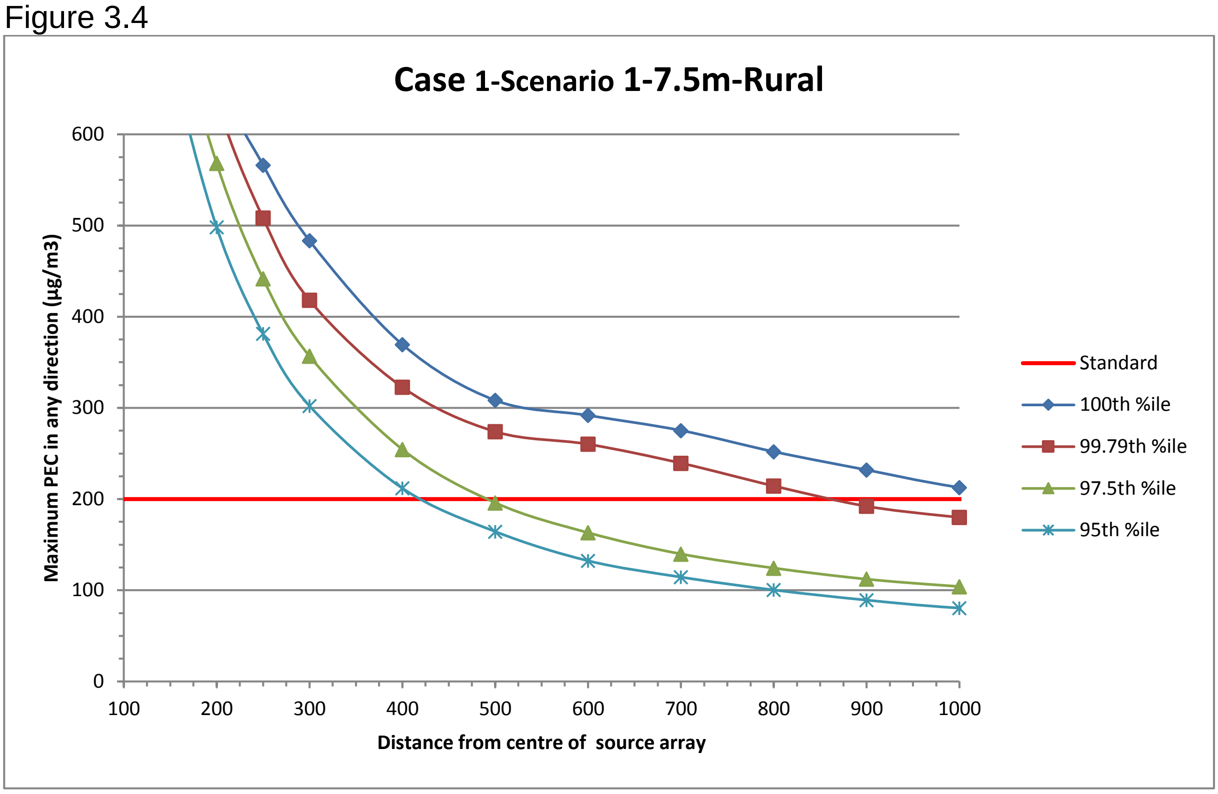


Figure 3.4



3.39 Although with an increased individual engine stack heights of 7.5 m there is still potential for exceedances some distance from the plant it does improve dispersion, particularly in the near field. The highest PEC at 100 m is just below 1250 µg/m^3. A reduction of about a third compared to 2.5 m stack heights. It is therefore recommended that in cases where individual engine stacks are employed these should follow good engineering practises to both reduce building downwash effects and help downwind dispersion.

3.40 Using our statistical analysis method, the 75th percentile exceeds the standard up to 150 m. With a 50 hour per year operational hour restriction, there is potential for an exceedance within 150 m under this scenario. However, the 50th percentile is well below the standard at all modelled distances. Therefore, although there is potential for an exceedance within 150 m, it is not highly likely.

3.41 For engine scenario 2 (9 times 5.4 MW_{th} engines) assuming the high 19 kg/MWh_e emission factor and 7.5 m individual engine stacks the PECs are still very high in nearfield under worst case met conditions. The highest PEC is approximately 1150 µg/m^3. For 499 hours our statistical analysis indicates that there is potential for an exceedance within 500 m assuming urban background and within 425 m for rural background; see Figures 3.5 and 3.6 respectively.

Figure 3.5

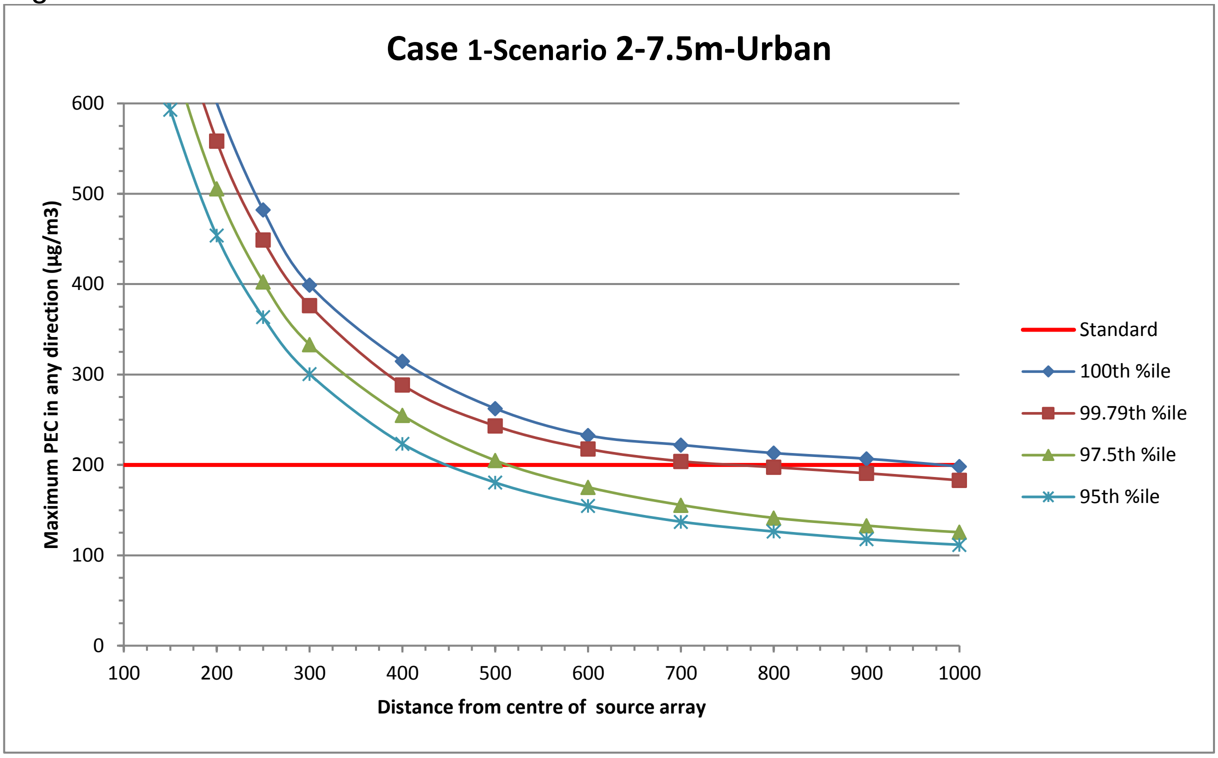
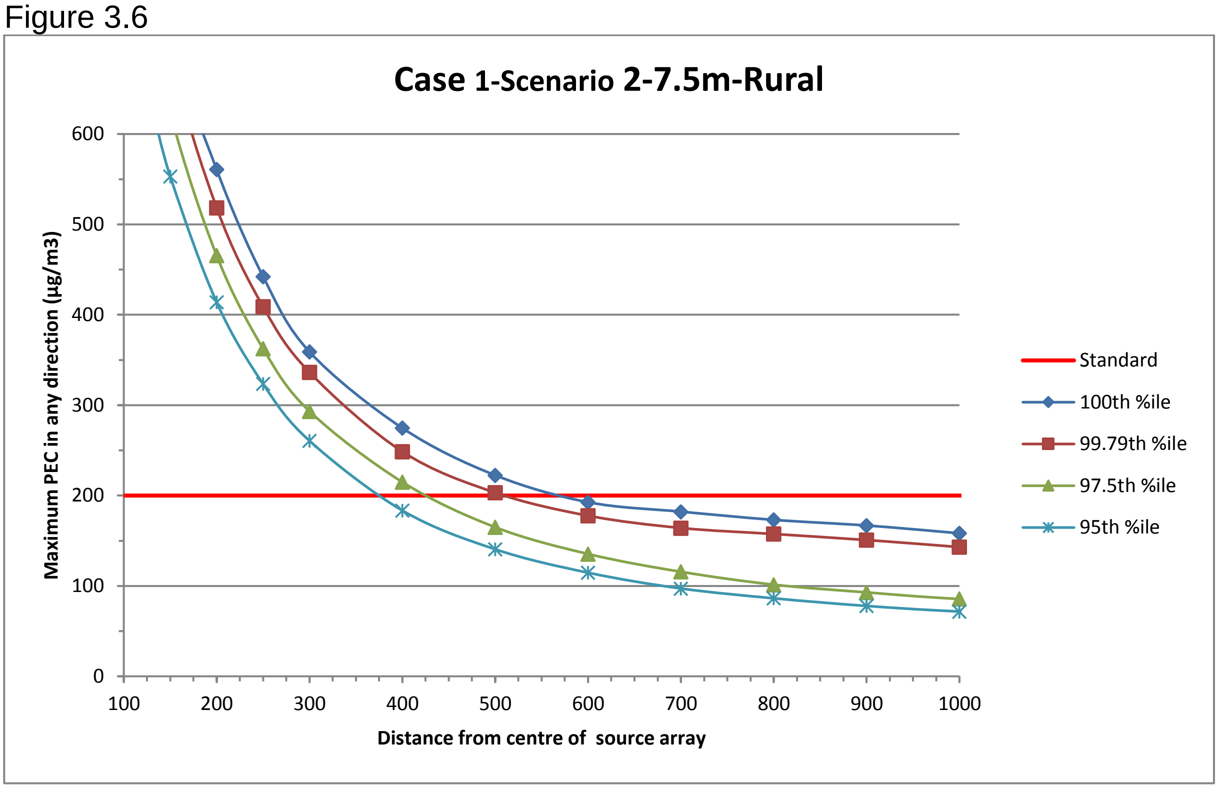


Figure 3.6



3.42 This demonstrates that fewer larger engines are likely to reduce the distance where there are potential exceedances, compared to a larger number of smaller engines. This is due to larger flow rates from larger engines, which increases the buoyancy flux[13] and resultant plume rise.

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[13] Buoyancy flux is a measure of the amount of buoyancy added to the atmosphere per unit of time from a plume emission

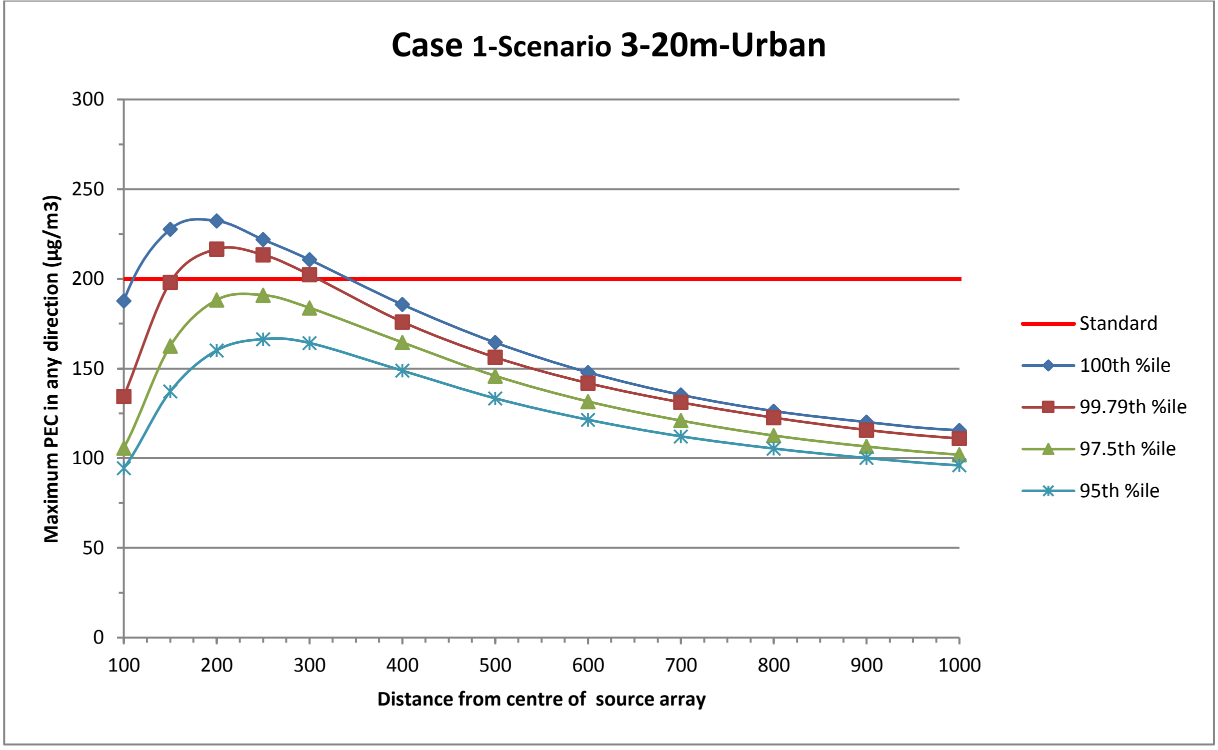
3.43 While there is still potential for exceedances some distance from the plant, arrays using larger engines are likely to have less of an impact than a similar sized array using larger number of smaller engines. It is therefore recommended that where possible larger engines should be used in multiengine arrays.

3.44 Using our statistical analysis method, the 75th percentile no longer exceeds the standard for these scenarios. Therefore, with a 50 hour per year operational hour restriction, there is unlikely to be an exceedance under these larger engine and 7.5 m individual stack scenarios.

3.45 For engine scenario 3 (3 times 16.2 MW_{th} engines) assuming the high 19 kg/MWh_e emission factor and stack heights of 20 m then the impact is greatly improved compared to the other two engine scenarios. The highest PEC is approximately 230 µg/m^3 at a distance of 200 m. The combination of taller stack and larger flow rates results in much better dispersion and an improved impact in the near field.

3.46 Figure 3.7 illustrates the PECs for the urban case.

Figure 3.7



3.47 Although the 100th percentile and 99.79th percentile PECs still exceed the standard, the 97.5th percentile PEC does not. Indicating that for 499 operational hours there is unlikely to be an exceedance.

3.48 Based on the engine scenario 3 modelling using large engines and tall stacks or combining multiple smaller engines into multiflue tall stacks is a highly effective method for reducing the impacts. Under these scenarios there is unlikely to be exceedances of the short term standard for 499 operational hours.

Case 2 modelled scenarios and results discussion

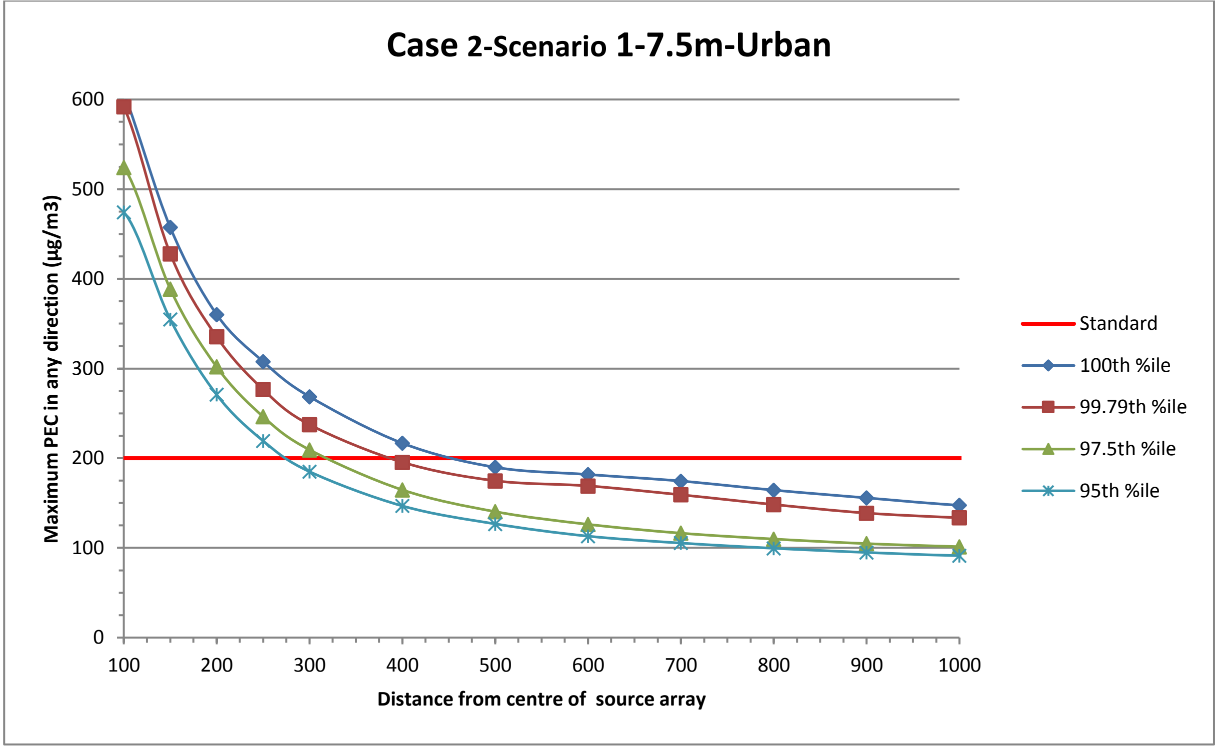
3.49 One engine scenario has been modelled for Case 2, 20 MW_{th} rated thermal input, scenario 1 (8 times 2.5 MW_{th}).

3.50 For this scenario assuming the high 19 kg/MWh_e emission factor, 2.5 m and 7.5 m individual engine stacks the PECs are still likely to be very high in the nearfield under worst case met conditions and a large portion of hours per year still exceed the standard. The highest PEC is approximately 880 $\mu g/m^3$ for 2.5 m stacks, and approximately 610 $\mu g/m^3$ for 7.5 m, at a distance of 100 m.

3.51 As stated in paragraph 3.39, it is recommended that individual engine stack heights should follow good engineering practises to both reduce building downwash effects and help downwind dispersion. Therefore only the 7.5 m results are presented here.

3.52 Figure 3.8 illustrates 20 MW_{th}, engine scenario 1, high 19 kg/MWh_e emission factor, 7.5 m individual stack heights and urban background case.

Figure 3.8



3.53 Assuming 499 operational hours, the 97.5th percentile urban PEC exceeds the standard within 300 m, indicating the potential for an exceedance of the standard within this distance. The 95th percentile exceeds the standard within 275 m, indicating exceedances are highly likely within this distance.

3.54 For the rural background case there is potential for an exceedance within 250 m and exceedances are highly likely within 225 m.

3.55 With operational hours limited to 50 hours per year there is unlikely to be an exceedance of the short term standard because the 75th percentile PECs are below the standard under these scenarios.

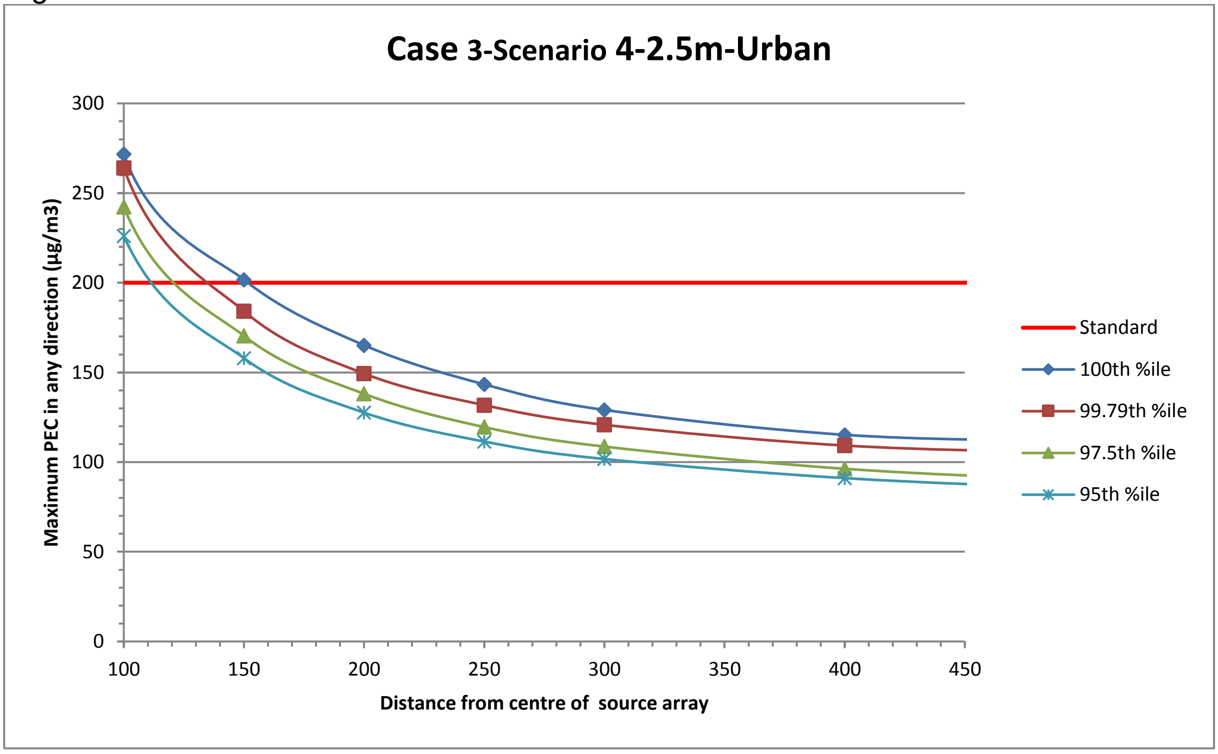
3.56 Based on our precautionary modelling and statistical analysis site specific assessment is still likely to be required for plant with a combined 20 MW_{th} input if no operational hour restrictions are implemented.

Case 3 modelled scenarios and results discussion

3.57 AQMAU were asked whether there was a total rated thermal input threshold that indicated no likely exceedance of the short term standard. Case 3 represents a small diesel generator array with a total rated thermal input of 5 MW_{th}. Four 1.25 MW_{th} engines have been assumed to make up the array. Individual stack heights of 2.5 m and 7.5 m have been modelled and the high 19 kg/MWh_e emission factor has been assumed for these results.

3.58 Our precautionary modelling indicates that for 499 operational hours, 2.5 m individual stack heights and assuming an urban background there is still likely to be potential for an exceedance within 120 m and exceedances are highly likely within 110 m. See Figure 3.9 for an illustration.

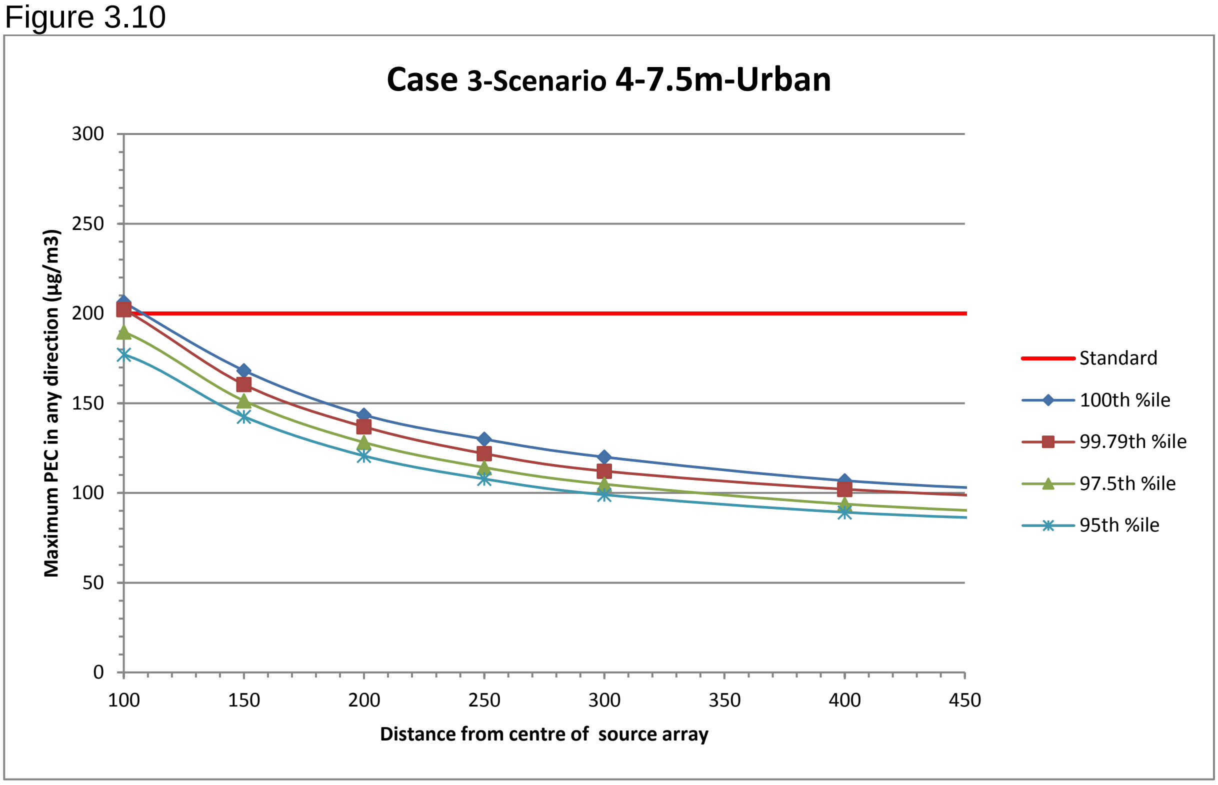
Figure 3.9



3.59 Assuming a rural background for the same case, there is potential for an exceedance within 100 m, however due to the high uncertainties within this distance it is not possible to confidently comment on the likelihood of those exceedances.

3.60 A 2.5 m individual stack height assumes the release height is at the same level as container height and is therefore a worst case. Following good engineering stack design practises the impacts will be slightly less. For example for the 7.5 m individual stack heights and assuming an urban background both the 97.5th and 95th percentile PECs are below the standard 100 m from the centre of the source array, see Figure 3.10. This indicates that exceedances beyond 100 m are unlikely; however due to the higher uncertainties within this distance it is not possible to confidently say exceedances are unlikely.

Figure 3.10



3.61 For all the above 5 MW_{th} modelled scenarios our checks indicate that with operational hours limited to 50 hours there is unlikely to be an exceedance of the short term standard.

3.62 Based on these results for a generic unabated 5 MW_{th} array and applying the precautionary principle we would recommend that 5 MW_{th} should only be used as thermal input threshold if there are no receptors within 100 m in a rural background area and 150 m in an urban background area.

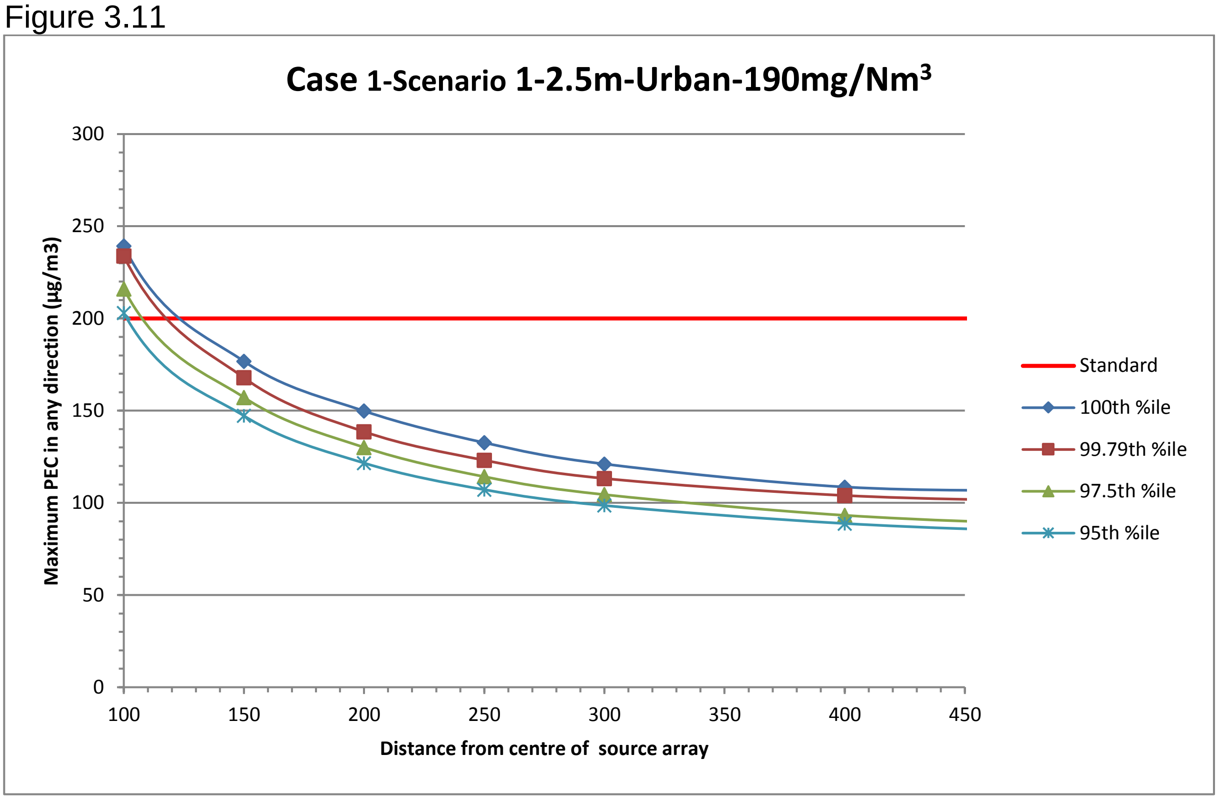
Impacts at the MCPD ELV

3.63 AQMAU were asked to investigate the potential impacts if the emissions from the diesel generators were abated to achieve emissions at the MCPD ELV of 190 mg/Nm^3 at STP, dry and 15% oxygen.

3.64 Making the assumption that any mitigation or abatement techniques do not significantly alter the emissions parameters such as temperature, efflux velocity and actual oxygen and moisture content, we have scaled down our model outputs. We have scaled the outputs by a factor of 190/2000, ie the MCPD ELV over the theoretical emission concentration of 2000 mg/Nm^3. The results are therefore indicative only.

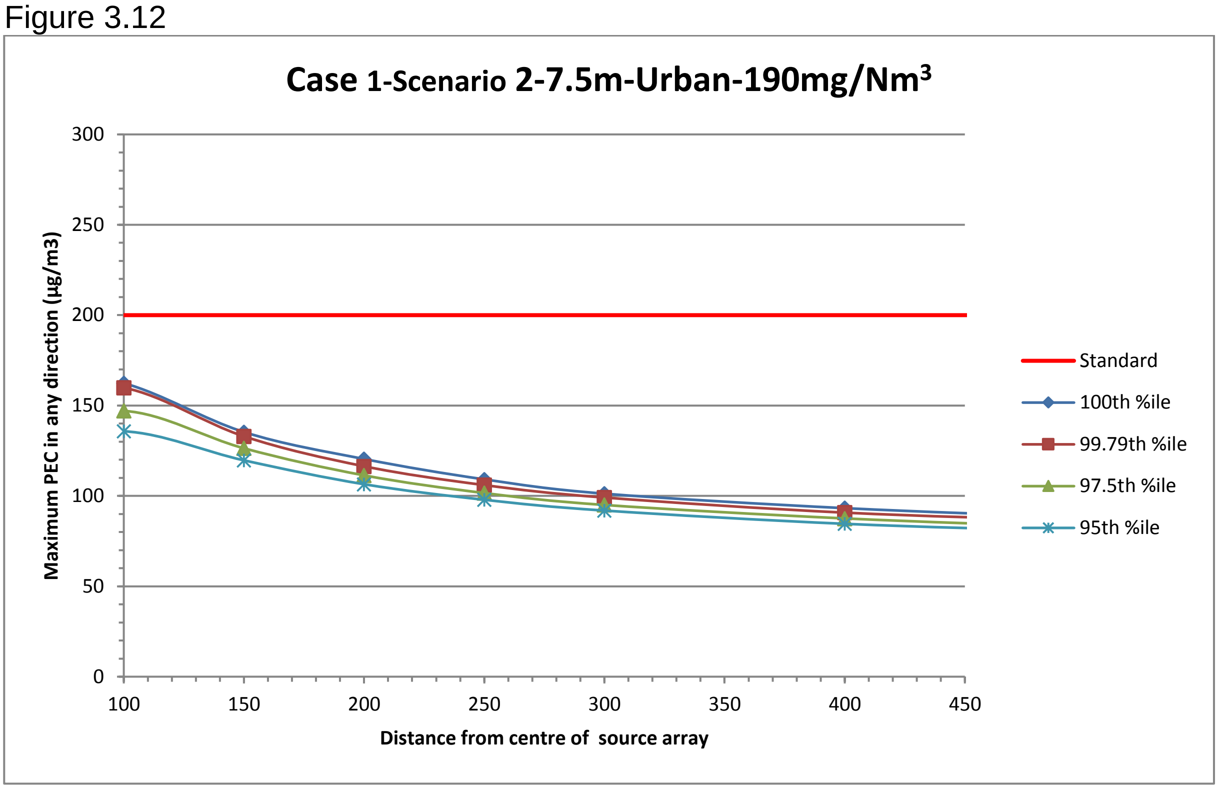
3.65 The worst case modelled scenario is Case 1, less than 50 MW_{th}, 19 times 2.5 MW_{th} engines, individual stack heights of 2.5 m and assuming an urban background. Our indicative checks suggest that even at the MCPD ELV there is potential for short term exceedances in the near field. There are potential exceedances within 110 m and likely exceedances within 100 m, see Figure 3.11.

Figure 3.11



3.66 Under the best case modelled individual engine stack scenario, Case 1, 9 times 5.4 MW_{th} engines, individual stack heights of 7.5 m and assuming a rural or urban. Our indicative checks suggest that at the MCPD the risk of an exceedance is unlikely as even the 100th percentile PEC is below the standard, see Figure 3.12.

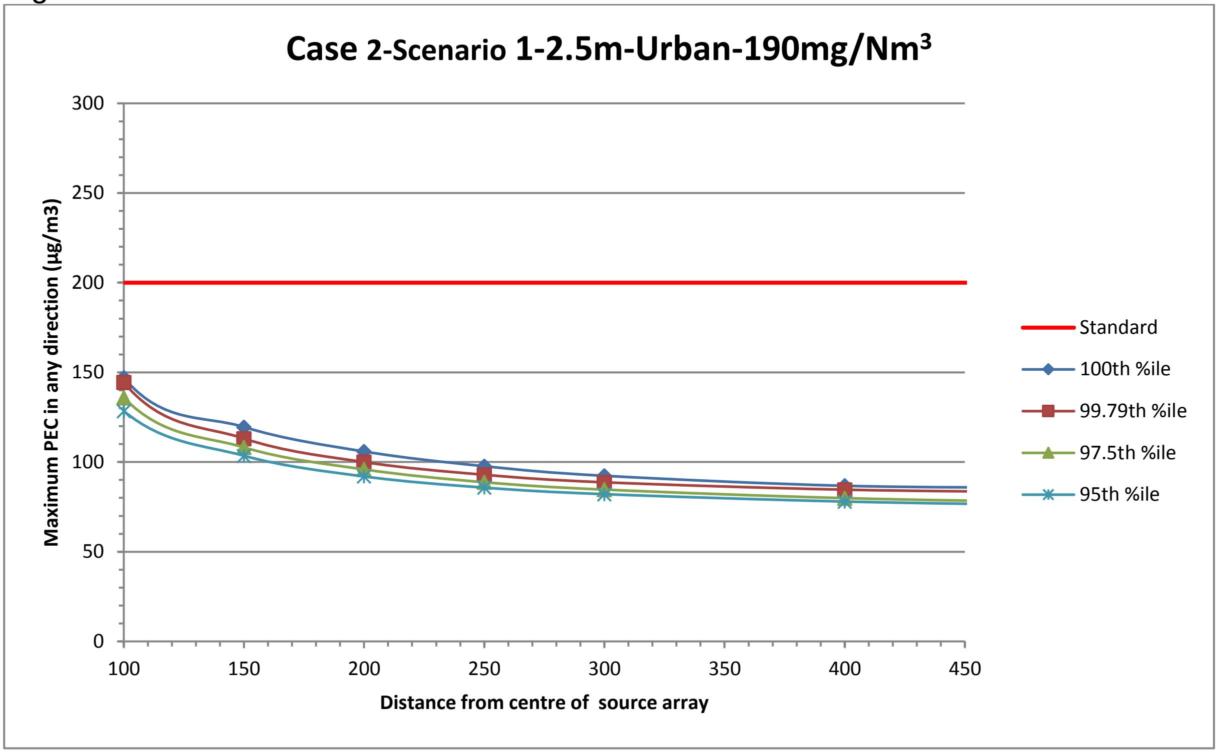
Figure 3.12



3.67 Based on our indicative checks at the MCPD ELV for plant just less than 50 MW_{th} we cannot rule out potential short term exceedances in the near field where multiple engines with poorly designed individual stacks are proposed. Applying the precautionary principle site specific assessment is likely required if there are sensitive receptors within 150 m.

3.68 For information we have also conducted checks on Case 2, 20 MW_{th} array, 8 times 2.5 MW_{th} engines with individual stack heights at the MCPD ELV. Our checks indicate that under the 2.5 m individual stack heights and urban background case there is only potential for an exceedances within 100 m where the uncertainties are higher due to building downwash, see Figure 3.13.

Figure 3.13



Results summary

3.69 Table 3 give a brief summary of the results and conclusions for each modelling scenario. It gives the distances where the modelling indicates potential exceedances of the standard as well as a summary of operational hour restrictions, eg 50 hours per year and emissions at the MCPD ELV for a number of the modelled scenarios.

Table 3

Case	**Engine scenario**	**Stack height**	**Summary**
Case 1 - Just less than 50 MWth	Scenario 1 - 19 times 2.5 MWth engines	2.5m - No stack above engine containers	High emission (19 kgMWhe): potential exceedance within 550m (rural) and 700m (urban). With operational hours limited to 50 hours per year then there is potential for an exceedance within 160m. At 190 mg/Nm3 there is potential for an exceedance within 110m.
Case 1 - Just less than 50 MWth	Scenario 1 - 19 times 2.5 MWth engines	7.5m - 3 times container height	High emission (19 kgMWhe): potential exceedance within 500m (rural) and 600m (urban). With operational hours limited to 50 hours per year then potential for exceedance would be within 120m. Increasing stack makes little difference to overall area of impact, but does provide benefit in near field. At 190 mg/Nm3 there is unlikely to be an exceedance.
Case 1 - Just less than 50 MWth	Scenario 2 - 9 times 5.4 MWth engines	2.5m - No stack above engine containers	High emission (19 kgMWhe): potential exceedance within 450m (rural) and 550m (urban). With operational hours limited to 50 hours per year then potential for exceedance would be within 110m. Engine size makes little difference to overall area of impact, but does provide benefit in near field. At 190 mg/Nm3 there is unlikely to be an exceedance.
Case 1 - Just less than 50 MWth	Scenario 2 - 9 times 5.4 MWth engines	7.5m - 3 times container height	High emission (19 kgMWhe): potential exceedance within 425m (rural) and 500m (urban). With operational hours limited to 50 hours per year then there is unlikely to be an exceedance. At 190 mg/Nm3 there is unlikely to be an exceedance.
Case 1 - Just less than 50 MWth	Scenario 3 - 3 times 16.2 MWth	20m - Large engine and large stack or multiflue stack design	High emission (19 kgMWhe): unlikely to be an exceedance under 499 operational hours. Larger stacks with larger combined exhaust flow rates have the most significant effect on improving the impact.
Case 2 - 20 MWth	Scenario 1 - 8 times 2.5 MWth engines	2.5m - No stack above engine containers	High emission (19 kgMWhe): potential exceedance within 290m (rural) and 340m (urban). With operational hours limited to 50 hours per year then potential for exceedance would be within 100m. At 190 mg/Nm3 there is unlikely to be an exceedance.
Case 2 - 20 MWth	Scenario 1 - 8 times 2.5 MWth engines	7.5m - 3 times container height	High emission (19 kgMWhe): potential exceedance within 250m (rural) and 300m (urban). With operational hours limited to 50 hours per year then there is unlikely to be an exceedance. At 190 mg/Nm3 there is unlikely to be an exceedance.
Case 3 - 5 MWth	Scenario 4 - 4 times 1.25 MWth engines	2.5m - No stack above engine containers	High emission (19 kgMWhe): potential exceedance within 100m (rural) and 120m (urban). With operational hours limited to 50 hours per year then there is unlikely to be an exceedance.
Case 3 - 5 MWth	Scenario 4 - 4 times 1.25 MWth engines	7.5m - 3 times container height	High emission (19 kgMWhe): unlikely to be exceedances beyond 100m (higher uncertainties within 100m, therefore exceedances canot be confidently ruled out). With operational hours limited to 50 hours per year then there is unlikely to be an exceedance.