

# DRAFT

# AIR EMISSION CONTROL FOR BACK-UP POWER SUPPLIES FOR DATA CENTRES AND OTHER LAND USES

Department of Planning, Industry and Environment

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# **DRAFT** Air Emissions Control for Back-Up Power Supplies for Data Centres and Other Land Uses

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#### 1 **INTRODUCTION**

This report has been prepared by Todoroski Air Sciences (TAS) on behalf of the Department of Planning, Industry and Environment (DPIE). The Air Emissions Control for Back-Up Power Supplies for Data Centres and Other Land Uses (the Project) is part of Initiative 4.5 – Supercharging complying development and supporting emerging new industries of the Planning Reform Action Plan.

### **1.1 Project Objectives**

The purpose of DPIE Initiative 4.5 is to provide a streamlined assessment pathway for job-creating development where the environmental impacts are well understood and manageable through development standards. These reforms are intended to support greater innovation by better tailoring assessment processes based on risk and complexity.

Initiative 4.5 will expand complying development provisions in employment zones as well as support emerging industries, such as data centres, so that more activities can be undertaken without the need for a development application. To facilitate this, any new planning and building standards will need to be such that they are able to be signed off by an accredited certifier.

The Project aims to develop appropriate complying performance requirements and specifications for back-up power supplies that support data centres and other land uses (such as warehousing and distribution centres). This will assist the expansion of land use types and the intensity of development permitted through the complying development pathway, while providing appropriate environmental and amenity controls for those developments.

Whilst it is the aim for any new approach is to streamline the assessment and approval process and thus help to bolster employment and development opportunities, it is also important to ensure that any new approach can be economically delivered by engine and pollution abatement providers and that it does not potentially lead to adverse environmental or health outcomes in a given situation.

Generally, it is recognised that the NSW market would be too small for plant providers to economically develop and supply bespoke plant to achieve bespoke NSW performance standards, hence it would be reasonable to adopt performance specifications from another large jurisdiction (e.g. USA or Europe) that are the most appropriate for use in NSW. The project thus aims to review plant performance requirements in other jurisdictions to identify the potentially appropriate level of emissions performance, and an accompanying framework for performance testing and compliance that could be adopted in NSW.

As adverse environmental and health impacts must be avoided, it is recognised it may not be possible to provide a simplified and streamlined approach in every situation, for example a very large development with significant scope for emissions near sensitive receptors. Thus, a secondary objective of the project is to check on the scale of any such impacts for a typical small, medium and large scale development, and where possible to define suitable categories of environmental or health risk for such developments, so that an appropriate overall approach can be developed.

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#### 2 BACKGROUND

A back-up power supply (also commonly referred to as a standby or emergency generator) is typically defined as a generator or engine that is operated for the sole purpose of providing power in emergency situations, that is, an interruption to the supply of mains grid electricity or failure of onsite electrical transmission equipment beyond the control of the operator of the facility. In some international jurisdictions, this definition may exclude scheduled or planned outages.

#### 2.1 Back-up Power Supply Uses

Back-up power supplies are important for providing electricity when there are electricity grid or supply failures. They can be utilised to provide energy security for various uses including emergency service providers (i.e. hospitals, fire departments, police departments), public service providers (i.e. water agencies), education and research facilities, and multistorey buildings. Data centres and some businesses also use back-up power supplies in order to minimise data loss and economic disruption from power outages. Data centres developments tend to have some of the largest scale back-up power supply plant.

#### 2.2 Types of Generators

In general, one or more reciprocating engines coupled to one or more electricity generators are used as a back-up power supply Whilst turbines could potentially be used, we found this to be rare, (e.g. only one large emergency start-up turbine was identified for a coal fired power station).

The size and number of emergency engines is highly variable depending on site specific needs and the scale of a facility. In general, an industrial facility or multistorey building would typically utilise one, or possibly two engine/generator sets, whereas a data centre may have many more; for example up to 200 for a very large data facility. Due to their scale/ number of engines, data centres tend to have the most scope to generate impact, and are a focus of this study.

By far, the most used fuel for emergency generators is diesel. Generally, developed nations use low sulfur diesel originating from petroleum base materials, however diesel can encompass a range of distillate fuel oils, which can be sourced from petroleum, biological or other base materials. Alternative fuel types may include natural gas, propane, gasoline, liquefied petroleum gas, and residual fuel oils.

This project is focused on low sulfur diesel fuelled reciprocating engines as used at most of the existing and known, anticipated new data centres in NSW. As diesel plant generally has higher emissions than gas fuelled plant it represents the case for which there is the greatest need to strike a balance between having a streamlined assessment and approval process and achieving environmental obligations.

#### 2.3 Generator operational hours

The review of regulations (**Section 3**) indicates that there is significant variation between different jurisdictions on the anticipated maximum operating time of an emergency generator. This may arise as it is very difficult to predict the likelihood of power failures/emergency events and the grid stability and plant reliability can vary greatly from place to place.

The US EPA adopts a default value of 500 hours per year for the number of hours that an emergency generator could be expected to operate under worst-case conditions for modelling purposes (**US EPA**,

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**1995**), whereas in NSW, a maximum of 200 hours is assumed (**NSW Government, 2019**). Other jurisdictions use values between 200 to 500 hours to limit annual use.

The literature review indicates that typically a one-hour period or less is required for a generator for testing and maintenance purposes, and this is generally required every one to two months.

### **3 REVIEW OF REGULATIONS**

This section outlines the existing regulations and guidance from state, national and international jurisdictions for air emissions from back-up power supplies.

In NSW and Europe, emergency generators are exempt from compliance with emissions standards provided they operate for less than a set number of hours per year, or maintenance/testing activities occur for less than a set number of hours per year. The US provides emission standards for all generators including emergency generators (the US standards are also adopted by Canada) however they may exempt emergency generators from permitting requirements.

The allowable emergency operational hours and hours for maintenance/testing activities is variable across jurisdictions.

### 3.1 Australia

There is limited information pertaining to the use of emergency backup diesel generators in Australia. This section presents available data for New South Wales (NSW) and Victoria including legislation, planning approvals and development applications for the use of emergency backup diesel generators.

Australian product emission standards are aligned with current European Union emissions standards for non-road engines (**AWE**, **2021**). Australia has adopted a phased approach to emissions standards to allow for more stringent standards to be introduced over time. These changes are set out under section 52 of the Product Emissions Standards Rules 2017 (**Australian Government**, **2019**). European Stage V emissions standards cover Directive 2016/1628 and any future Directive amendments (**European Union**, **2016**).

#### 3.1.1 New South Wales

#### 3.1.1.1 POEO

Schedule 1, Clause 17(1A) of the Protection of the Environment Operations Act 1997 (**NSW Government, 2020**) indicates that back-up power supplies are not considered to be scheduled activities, stating:

"However, this clause does not apply to the generation of electricity by means of electricity plant that is emergency stand-by plant operating for less than 200 hours per year."

However, the Protection of the Environment Operations (Clean Air) Regulation (**NSW Government**, **2019**) Clause 57A, "Exemption relating to emergency electricity generation" states:

"Emergency standby plant comprising a stationary reciprocating internal combustion engine for generating electricity is exempt from the air impurities standard for nitrogen dioxide and nitric oxide specified in Schedule 4 in relation to that plant if the plant is used for a total of not more than 200 hours per year."

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As the standards in Schedule 4 apply to scheduled activities, it is not completely clear whether emissions from emergency standby generation of electricity are exempt in full or part. Regardless, for the purposes of this study we simply compare the likely maximum impacts from such plant with current criteria to assess the potential acceptability of any impacts.

As written, the 200-hour limit appears to include both emergency operational hours and testing/maintenance hours. This interpretation is consistent with the consent conditions outlined in **Section 3.1.1.2.2** which state that the operation of the back-up generators (including testing) cannot not exceed 200 hours per year. However, there may be some inconsistency in this regard for some projects. For example, the expert opinion letter for the Smeaton Grange data centre (**ARUP, 2017**) notes the NSW EPA advised that the hours that generators are run for the purposes of commissioning and annual essential maintenance activities is not counted towards the 200 hour per year threshold.

It is also noted in the AirTrunk Air Quality Assessment (**Air Noise Environment, 2020**) that the NSW EPA indicated that multiple generators being operated concurrently for an hour would count as one hour, rather than the sum of the testing time of each generator.

### 3.1.1.2 Planning Approvals

We conducted a review of 16 recent NSW Development Applications (DA's) for facilities with backup power supplies. Notably, five did not contain any information about the back-up power supply. The 11 that containing information that could be reviewed are outlined in more detail in Section 3.1.1.3.

#### 3.1.1.2.1 SEAR's Requirements

For state significant developments, recent SEAR's requirements have requested assessments for projects with back-up power supplies as follows:

- scenarios which assess construction works, realistic operations, back-up generator testing and a justified worst-case scenario
- + justification for the proposed back-up power source and any alternatives considered
- an assessment of emissions from the back-up generators against the standards of concentration outlined in the Protection of the Environment Operations (Clean Air) Regulation 2010 (including, but not limited to, polycyclic aromatic hydrocarbons (PAHs) and oxides of nitrogen (NOx) impacts)
- an assessment of criteria pollutants in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA, 2016)
- details of any mitigation, management and monitoring measures (including for back-up generators) required to ensure compliance with section 128 of the Protection of the Environment Operations Act 1997.

#### 3.1.1.2.2 Consent Conditions

Consent conditions specific to back-up power supplies were found in Development Consent SSD-10330 (**Minister for Planning and Public Spaces, 2020**) for a data centre at Eastern Creek.

#### Back-up Generator System

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A6. The Applicant must install, maintain and operate an uninterruptable power supply (UPS) system, including back-up batteries, which is capable of powering critical components of the development for a period of not less than seven minutes.

A7. The Applicant must ensure that the back-up generators installed and operated under this consent do not exceed a total installed generating capacity of more than 170 megawatts.

A8. The Applicant must ensure:

(a) operation of the back-up generators (including testing) does not exceed 200 hours per year; and

(b) the diesel fuel storage capacity of the site does not exceed 2,000 tonnes at any one time.

A9. The Applicant must ensure that the back-up generators are only operated under the following circumstances:

(a) for testing of the back-up generators:

(i) testing may only be carried out between 9:00 AM and 4:00 PM, Monday to Friday; and

(ii) no more than five (5) back-up generators are to be tested at any one time;

(b) during a power outage event, but only following the significant depletion of the back-up batteries contained within the development's UPS system (see Condition A6).

A10. This development consent does not permit the use of the back-up generators:

(a) for the purposes of generating electricity to be exported off-site; or

(b) to support load curtailment at the site.

B10. The Applicant must ensure that the design, installation and operation of the back-up generators and/or generator enclosures does not preclude the ability for air pollution emission controls to be retrofitted.

### **Emission Limits**

B11. The development must comply with section 128 of the POEO Act, which sets out the concentration standards and emission rates which must not be exceeded, except as expressly provided for in an EPL.

#### Annual Emission Testing

B12. Within twelve (12) months of the commencement of operation, and every twelve (12) months thereafter, unless the Planning Secretary directs otherwise, the Applicant must conduct an annual emissions test on at least one (1) back-up generator for the pollutants and parameters identified in Table 4. The sampling methods are those contained in the Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (EPA, 2007).

Table 4 Annual emissions testing requirements

Pollutant/Parameter	Units of measure	Frequency	Sampling Method

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Nitrogen dioxide or nitric oxide (as NO <sub>2</sub> equivalent)	Milligrams per cubic	Annual	TM-11
	metre		
Temperature	Degrees Celsius (°C)	Annual	TM-2
Velocity	Metres per second	Annual	TM-2
Oxygen (O <sub>2</sub> )	Percent (%)	Annual	TM-25
Volumetric flow rate	Cubic metres per second	Annual	TM-2

#### **Back-up Generator Annual Report**

C5. Within three months after the first year of commencement of operation, and in the same month each subsequent year (or such other timing as agreed to in writing by the Planning Secretary), the Applicant must prepare a Back-up Generator Annual Report to the satisfaction of the Planning Secretary. The report must be submitted to the Planning Secretary and the EPA, and include:

(a) an operations log for the back-up generators, detailing the date, time and duration of each use (including both testing and use during a power outage event); and

(b) details regarding the:

(i) total number of hours the back-up generators were operated for (see Condition A8(a));

- (ii) total quantity of diesel fuel used by the back-up generators;
- (iii) results of the annual emissions testing (see Condition B12); and
- (iv) development's compliance with section 128 of the POEO Act (see Condition B11).

### **Back-up Generator Incident Reporting**

C9. Within 30 days of the back-up generator system being used to power the development, the Applicant must prepare a Back-up Generator Incident Report to the satisfaction of the Planning Secretary. The report must be submitted to the Planning Secretary and the EPA, and include:

- (a) details regarding the:
- (i) date and time of the power outage event;
- (ii) total number of back-up generators used to power the development;
- (iii) total number of hours the back-up generators were operated for;
- (iv) total quantity of diesel fuel used by the back-up generators; and
- (v) total amount of electricity produced by the back-up generators;

(b) an assessment of any air quality impacts resulting from the operation of the back-up generators; and

(c) an assessment and consideration of any additional measures which could be implemented to reduce future air quality impacts.

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Note: Additional measures could include, but are not limited to, measures to reduce the likelihood of the back-up generators being operated and retrofitting of emission controls to the back-up generators.

### 3.1.1.3 Recently Approved or proposed projects

A review was made of 16 recently approved or proposed data centre projects. These projects do not appear to have specific air emissions limits in the approval conditions regarding any back-up power generators. The conditions regarding air quality in the approvals are typically limited to requiring compliance with the POEO. As outlined above, it is not clear whether POEO regulations would apply at all or only partially.

In some cases, the approvals include general conditions for an Environmental Management Plan covering all aspects of the development that have the potential to cause air pollution.

Based on our review and assessment (overall) for all of these projects, it is not clear that there would not be any impact above the NSW EPA impact assessment criteria which apply to ambient, ground level concentration in the air that people may breathe, nor is it clear that there has been adequate consideration made to minimise potential impacts during routine maintenance and testing.

Recent applications are considered in more detail in the following sub sections.

#### 3.1.1.3.1 Sirius Road, Lane Cove West SSD-9741

An application was submitted for the Approved DA for the development of a data centre incorporating 51 emergency standby diesel generators at Sirius Road, Lane Cove West. The generators each have a prime rating of 3,350kW.

The air quality assessment (**ARUP, 2018**) compares the emissions from the generator specification with US EPA and POEO standards. While exceedance of the limits for  $NO_x$  emissions are predicted, it is noted that the POEO standards are not directly applicable to standby generators which operate for less than 200 hours per year.

It is anticipated that the generators would only be required for 50 hours per year (approximately 0.6% of the time). The generators would be tested on a monthly basis for approximately one hour of operation per month to ensure the generators can continue to provide an uninterrupted power supply when required. Each generator would be tested independent of each other (not operating concurrently) and completed during daytime conditions when conditions are favourable for dispersion.

The assessment concludes that as the standby generators will operate within relevant emissions limits, are a considerable distance from sensitive receptors (400m from nearest sensitive receptor) and are only expected to be used for short, intermittent periods, the air quality impact from them is anticipated to be minor and transient and therefore no further assessment (i.e. dispersion modelling) is needed.

There are no conditions in the consent specific to emergency backup generators.

#### 3.1.1.3.2 August Street, Blacktown SSD-10469

An application was submitted for the Approved DA for the development of a data centre at Augusta Street, Blacktown.

The air quality assessment (**Air Noise Environment, 2020**) indicates that there would be 84 emergency standby diesel generators associated with Stage 1 of the project and an additional 66 emergency

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standby diesel generators each with Stages 2 and 3. The diesel generators are expected to run on standard diesel fuel and each generator will be DCC rated 1800-1840 kW/2250 kVA 400V.

Dispersion modelling was conducted which predicted exceedances for NO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub> and CO for short term averaging periods (i.e. 1-hour, 8-hour and 24-hour) at the nearest sensitive receptors during the worst-case emergency scenario.

At the time of writing, this project was at the response to submission stage of the assessment process.

### 3.1.1.3.3 Khartoum Road and Talavera Road, Macquarie Park SSD-10467

An application was submitted for the Approved DA for the development of a five-storey data centre including 18 emergency generators at Khartoum Road and Talavera Road, Macquarie Park.

The SEAR's outlines specific requirements for the assessment of backup generators (refer to Section 0).

Dispersion modelling is presented for maintenance and testing operations for two different types of generators (CAT and Cummins) in the air quality impact assessment (**AECOM, 2020**). The results indicating that the project can comply with the regulatory limits.

At the time of writing, this project was at the response to submission stage of the assessment process.

#### 3.1.1.3.4 Bluett Drive, Smeaton Grange DA-2017/1310

An application was submitted for the Approved DA for the development of a data centre including standby generators at Bluett Drive, Smeaton Grange. The generator capacity is not provided however it is understood that up to 20,000 litres of diesel fuel will be provided on site, with 1,000 litres of fuel provided within belly tanks of each individual standby generator on site.

The expert opinion letter (**ARUP**, **2017**) indicates that as diesel generators will be operated for less than 200 hours per year and therefore as a non-scheduled premise there is no requirement to assess air quality with regard to nitrous oxides or other pollutants.

The draft consent conditions state that:

"Discharge of pollutants is strictly forbidden. Measures to prevent the pollution of waters, air and land shall be incorporated into the development to comply with the requirements of the Protection of the Environment Operations Act 1997. Where there is potential for pollutant discharge, a report by a suitably qualified expert shall be provided to the PCA detailing the pollution mitigation measures incorporated into the building design so that any discharges comply with the requirements of the Protection of the Environment Operations Act 1997."

#### 3.1.1.3.5 Gardners Road, Alexandria D/2017/1797

An application for a data centre facility at Gardeners Road, Alexandria was approved by the City of Sydney Council (**City of Sydney, 2018**).

It is indicated that diesel generators will be used to provide power back up should the electrical power supply fail. Specific details on the number of emergency backup generators or their size is not provided, however it is noted that the site has several days of diesel fuel storage to enable operation during prolonged power outage.

An air quality assessment is not presented.

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The conditions of consent (**City of Sydney, 2018**) include a general requirement for compliance with the POEO Act.

#### 3.1.1.3.6 Sargents Road, Minchinbury SPP-18-01554

An application for a two-storey data centre at Sargents Road, Minchinbury was approved by Blacktown City Council (**Blacktown City Council, 2019**).

On-site diesel fuel storage for the emergency power generators is to be installed. Each of the generators will be provided with a base fuel tank to provide 24 hours operation at full load before requiring refilling.

Specific details on the number of emergency backup generators, their capacity or the maximum quantity of diesel fuel storage are not provided.

An air quality assessment is not presented.

The conditions of consent include a general requirement for compliance with the POEO.

### 3.1.1.3.7 Eastern Creek Drive, Eastern Creek SPP-19-00013

An application for a two-storey data centre at Eastern Creek Drive, Eastern Creek was approved by Blacktown City Council (**Blacktown City Council, 2020b**).

Specific details on the number of emergency backup generators or their capacity is not provided however it is noted that there would be 325,000 litres of diesel fuel storage for the back-up.

An air quality assessment is not presented.

The conditions of consent include a general requirement for compliance with the POEO.

### 3.1.1.3.8 Healy Circuit, Huntingwood SPP-19-00014

An application for a four storey data centre and associated facility at Healy Circuit, Huntingwood was approved by Blacktown City Council (**Blacktown City Council, 2020a**). The application includes the use of backup power generators when required in an emergency situation such as a power failure.

Specific details on the number of emergency backup generators or their capacity is not provided however it is noted that there would be 777,600 litres of diesel fuel storage for the back-up.

An air quality assessment is not presented.

The conditions of consent include a general requirement for compliance with the POEO.

#### 3.1.1.3.9 Roberts Road, Eastern Creek SSD-10330

An application for was submitted to expand the Approved DA for the operation of an existing data centre at Roberts Road, Eastern Creek. The application includes the installation of 48 standby generators in addition to the existing 15 on site standby generators, giving a total of 63 with a combined electrical generation capacity of 169MW (individual electrical generation capacity of 2,680kW).

The air quality assessment (**SLR, 2019**) includes dispersion modelling for emergency generator operation. The modelling indicated potential exceedances of the 1-hour  $NO_2$  criterion at sensitive receptors and provides further analysis of the likelihood of this occurring. Note that the nearest sensitive receptor is approximately 900m from the site.

The development consent includes specific conditions for the backup generator system as outlined in **Section 3.1.1.2.2**.

#### 3.1.1.3.10 Grand Avenue, Rosehill DA-751/2019

An application for a three storey high data centre and associated works including 19 emergency standby diesel generators at Grand Avenue, Rosehill was approved by the City of Parramatta Council (**City of Paramatta, 2020**).

An air quality assessment is not presented and there does not appear to be any further detail on the emergency standby diesel generators such as engine capacity.

The council assessment report notes that project is not considered likely to result in unacceptable air quality impacts and includes general approval conditions as outlined in **Section 3.1.1.3**.

#### 3.1.1.3.11 McIntosh Drive, Mayfield West DA2020/00411

Development consent was granted for a data centre at McIntosh Drive, Mayfield West by the City of Newcastle Council (**City of Newcastle, 2020**). The consent includes a general condition that the premises is not to give rise to the emission of any 'air impurity' as defined under the Protection of the Environment Operations Act 1997 (NSW), that interferes unreasonably with the amenity of neighbouring premises and/or other sensitive receivers and if it is considered that unreasonable levels of air impurities have been emitted from the premises, the owner/occupier will be required to engage a suitably qualified consultant to recommend measures to control emissions of air impurities to an acceptable level and such measures being implemented within a nominated time period.

The Statement of Environmental Effects (**Barr Property & Planning, 2020b**) states that there are two generators for each data centre, which only operate should there be a power failure. The site plans appear to show four data centre buildings and thus it is assumed that there would be eight backup generators in total. There is no further detail on the proposed backup generators or any assessment of air quality impacts and it is stated that the proposed data centres do not emit air pollutants. The Environmental Management Plan (**Barr Property & Planning, 2020a**) states that "the generators will only run if there is a power outage. The day to day operations do not create any air pollution contributing to reduced air quality" and that the development is not expected to have an adverse impact on ambient air quality.

### 3.1.1.4 Other studies

Holmes Air Sciences conducted an assessment (**Holmes Air Sciences, 2008**) of the air quality impacts of using existing standby emergency diesel generators in the Sydney Central Business District (CBD) to provide relief for the local electricity network during times of network constraints. The study concludes that emissions from diesel generators have the potential to cause exceedances of the 1-hour average NO<sub>2</sub> criterion at ground level and elevated receptors and exceedances of the 24-hour PM<sub>10</sub> criterion at some locations, however due to the infrequent operation of all proposed diesel generators simultaneously, the probability of maximum impacts occurring with maximum background levels would be low.

Notably, in almost every case these were for single engines used for CBD building emergency back-up generators, often with roof mounted exhausts. The Holmes study considered a potentially less impacting case than in this study where there may be a large number of co-located engines.

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#### 3.1.2 Victoria

#### 3.1.2.1 Morwell Power Station, Latrobe Valley

The 2017-2018 summer in Victoria required the temporary use of 105 standby emergency diesel generators to meet Victoria's power needs at the former Morwell Power Station in the Latrobe Valley, Victoria (**Aggreko**, **2017**).

Modelling by the Australian Energy Market Operator (AEMO) forecasted electricity shortages of approximately 220MW during the 2017-18 summer and under extreme conditions including heatwaves, this was expected to increase to 760MW. A supplier/ installer (Aggreko) was contracted to provide 110MW of power supply to meet part of this need. The duration of the campaign was for three months (early January to early April 2018).

The generators were likely to be only necessary for a few hours at a time, up to a cumulative maximum of 20 hours over the summer period. Further approval from the EPA must be sought to operate more than the indicated time over the whole three-month period.

Operations were limited to 7:00am to 10:00pm, however, if the generators were required to operate, they would most likely do so between approximately 1:00 pm and 5:00 pm on hot afternoon/s. They were unlikely to run on weekends, as peak power demand occurs on weekdays.

The Victorian EPA issued a Section 30a approval that required Aggreko to implement a monitoring program including monitoring noise levels at sensitive receptors and monitoring of nitrogen dioxide (NO<sub>2</sub>) when the generators are in operation. Aggreko installed noise and air quality monitors in the vicinity of the project site. These monitors remained in place until early April 2018, and monitoring occurred during the operation of the generators.

### 3.2 USA

Regulation of back-up power supply in the USA varies widely between national level, state level and within air quality management districts.

US federal regulations outline the national regulations for emergency generators. The relevant national standards in the code of federal regulations for combustion ignition (CI) (i.e. diesel) emergency generators are outlined in **Section 3.2.1**. The regulations specify engine emissions performance in various tiers (Tier, 1, 2 3 etc), with lower emissions for the higher tiers. These regulations are of primary interest as they provide a proven regulatory framework that could be adapted to the situation considered in this study.

The corresponding requirements for spark ignition (SI) internal combustion engines (ICE) are set out in **Section 3.2.1** and **Appendix A** and those for reciprocating internal combustion engines (RICE) in Hazardous Air Pollutant (HAP) attainment areas are set out in **Section 3.2.1** and **Appendix B**. The SI and RICE in HAP area regulations are not the key focus of this review, as for example, no existing SI emergency generators were identified or are known to be proposed in NSW, and in general, there are no large residential areas with problematic hazardous pollutants in NSW. These US regulations are included however to illustrate how these sources are regulated in the US. Potentially aspects of these regulations could be adapted as part of any potential alternative approval pathway to prevent impacts in certain situations, for example in more-at-risk localities, or for large developments near receptors.

In summary, there is no time limit on engine use during an emergency.

However, an emergency engine may operate for a maximum of 100 hours per calendar year for any combination of the purposes below;

- + for maintenance checks and readiness testing.
- + for emergency demand response for authorised periods.
- for periods where there is a deviation of voltage or frequency of 5 percent or greater below standard voltage or frequency.

An Emergency stationary ICE may also be operated for up to 50 hours per calendar year in nonemergency situations. The 50 hours of operation in non-emergency situations are counted as part of the 100 hours per calendar year for maintenance and testing and emergency demand response. The 50 hours per calendar year for non-emergency situations cannot be used for peak shaving or nonemergency demand response, or to generate income for a facility to an electric grid or otherwise supply power as part of a financial arrangement with another entity.

The 50 hours per year for non-emergency situations can be used to supply power as part of a financial arrangement with another entity if all the following conditions are met:

 The engine is dispatched by the local balancing authority or local transmission and distribution system operator;

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- The dispatch is intended to mitigate local transmission and/or distribution limitations so as to avert potential voltage collapse or line overloads that could lead to the interruption of power supply in a local area or region.
- The dispatch follows reliability, emergency operation or similar protocols that follow specific NERC, regional, state, public utility commission or local standards or guidelines.

Emission standards are provided for  $NO_x$ , HC, NMHC + NOx, CO and PM but vary between engine type, maximum rated power and model year.

Diesel fuel can have a maximum sulfur content of 15ppm.

### 3.2.1 40 CFR Part 60 Subpart IIII Standards of Performance for Stationary Compression Ignition Internal Combustion Engines

The relevant parts of 40 CFR Part 60 Subpart IIII have been summarised in the sections below.

# 3.2.1.1 40 CFR 60.4202 - What emission standards must I meet for emergency engines if I am a stationary CI internal combustion engine manufacturer?

#### 3.2.1.1.1 Maximum engine power less than or equal to 2,237 KW (3,000 HP)

Emergency stationary CI internal combustion engines with a maximum engine power less than or equal to 2,237 KW (3,000 HP) and a displacement of less than 10 litres per cylinder that are not fire pump engines must be certified to the following emission standards.

#### For maximum engine power less than 37kW (50HP):

#### Model year 2007 engines

## Table 3-1: 40 CFR 89.112 - Oxides of nitrogen, carbon monoxide, hydrocarbon, and particulate matter exhaust emission standards

Rated	Tion	Model	Emission standards (g/k W-hr)					Upper limit for family emission limits* (g/k W-hr)		
(kw)	Her	year	NOx	нс	NMHC + NOx	СО	PM	NOx FEL	NMHC + NOx FEL	PM FEL
-0	1	2000			10.5	8	1		16	1.2
<8	2	2005			7.5	8	0.8		10.5	1
$9 \pm 0 < 10$	1	2000			9.5	6.6	0.8		16	1.2
810 < 19	2	2005			7.5	6.6	0.8		9.5	0.8
10 to 27	1	1999			9.5	5.5	0.8		16	1.2
1910<37	2	2004			7.5	5.5	0.6		9.5	0.8
	1	1998	9.2					14.6		
37 to <75	2	2004			7.5	5	0.4		11.5	1.2
	3	2008			4.7	5	0.4		7.5	1.2
75 to	1	1997	9.2	1.3				14.6		
/5 10	2	2003			6.6	5	0.3		11.5	1.2
<130	3	2007			4	5	0.3		6.6	1.2
120 to 4	1	1996	9.2	1.3		11.4	0.54	14.6		
130 10 <	2	2003			6.6	3.5	0.2		10.5	0.54
225	3	2006			4	3.5	0.2		6.6	0.54
225 to	1	1996	9.2	1.3		11.4	0.54	14.6		
225 10	2	2001			6.4	3.5	0.2		10.5	0.54
<b>&lt;4</b> 50	3	2006			4	3.5	0.2		6.4	0.54
450 to	1	1996	9.2	1.3		11.4	0.54	14.6		
450 to	2	2002			6.4	3.5	0.2		10.5	0.54
< <u>500</u>	3	2006			4	3.5	0.2		6.4	0.54

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<b>NE60</b>	1	2000	9.2	1.3		11.4	0.54	14.6		
>500	2	2006			6.4	3.5	0.2		10.5	0.54

\*Family emission limit (FEL) means an emission level that is declared by the manufacturer to serve in lieu of an emission standard for certification purposes and for the averaging, banking, and trading program. A FEL must be expressed to the same number of decimal places as the applicable emission standard.

Engines may be designated "Blue Sky Series" engines by meeting the voluntary standards listed in Table 3, which apply to all certification and in-use testing, as follows:

Maximum rated power (kw)	NMHC + NOx	PM
<8	4.6	0.48
8 to <19	4.5	0.48
19 to <37	4.5	0.36
37 to <75	4.7	0.24
75 to <130	4	0.18
130 to < 560	4	0.12
>560	3.8	0.12

#### Table 3-2: 40 CFR 89.112 - Voluntary emission standards (g/kwh)

#### Table 3-3: 40 CFR 89.113 - Smoke emission standard

Mode	Maximum exhaust opacity
Acceleration mode	20
Lugging mode	15
Peaks in either acceleration or lugging mode	50

Exclusions: single cylinder engines, propulsion marine diesel engines and constant speed engines

#### Model year 2008 and later engines

#### Table 3-4: 40 CFR 1039.105 - Smoke emission standard

Mode	Maximum exhaust opacity
Acceleration mode	20
Lugging mode	15
Peaks in either acceleration or lugging mode	50

Exclusions: single cylinder engines, constant speed engines and engines certified to a PM emission standard or FEL of 0.07 g/kWhr or lower

40 CFR 1039.107 specifies that there are no evaporative emission standards for diesel-fuelled engines, or engines using other non-volatile or nonliquid fuels (for example, natural gas). If your engine uses a volatile liquid fuel, such as methanol, you must meet the evaporative emission requirements of 40 CFR 1048.40 CFR 1048.105 indicates that evaporative hydrocarbon emissions may not exceed 0.2 grams per gallon of fuel tank capacity.

40 CFR 1039.115 – other requirements

- Adjustable parameters. Engines that have adjustable parameters must meet all the requirements of this part for any adjustment in the physically adjustable range. An operating parameter is not considered adjustable if you permanently seal it or if it is not normally accessible using ordinary tools. We may require that you set adjustable parameters to any specification within the adjustable range during any testing, including certification testing, selective enforcement auditing, or in-use testing.
- Prohibited controls: You may not design your engines with emission-control devices, systems, or elements of design that cause or contribute to an unreasonable risk to public health, welfare,

or safety while operating. For example, this would apply if the engine emits a noxious or toxic substance it would otherwise not emit that contributes to such an unreasonable risk.

 Defeat devices: You may not equip your engines with a defeat device. A defeat device is an auxiliary emission-control device that reduces the effectiveness of emission controls under conditions that the engine may reasonably be expected to encounter during normal operation and use. This does not apply to auxiliary-emission control devices operated only in emergency situations.

#### For maximum engine power greater than or equal to 37 KW (50 HP):

Engines with a maximum engine power greater than or equal to 37 KW (50 HP) must meet the emissions standards outlined above for 40 CFR 89.112 and 40 CFR 89.113.

#### 3.2.1.1.2 Maximum engine power greater than 2,237 KW (3,000 HP)

Emergency stationary CI internal combustion engines with a maximum engine power greater than 2,237 KW (3,000 HP) and a displacement of less than 10 litres per cylinder that are not fire pump engines must be certified to the following emission standards.

#### For 2007 through 2010 model years

# Table 3-5: Table 1 to subpart III of part 60 Emission Standards for Stationary Pre-2007 Model Year Engines With a Displacement of <10 Litres per Cylinder and 2007-2010 Model Year Engines >2,237 KW (3,000 HP) and With a Displacement of <10 Litres per Cylinder

Maximum rated power (kw)	NMHC + NOX	нс	NOX	со	РМ
<8	10.5 (7.8)			8.0 (6.0)	1.0 (0.75)
8 to <19	9.5 (7.1)			6.6 (4.9)	0.80 (0.60)
19 to <37	9.5 (7.1)			5.5 (4.1)	0.80 (0.60)
37 to <56			9.2 (6.9)		
56 to <75			9.2 (6.9)		
75 to <130			9.2 (6.9)		
130 to <225		1.3 (1.0)	9.2 (6.9)	11.4 (8.5)	0.54 (0.40)
225 to <450		1.3 (1.0)	9.2 (6.9)	11.4 (8.5)	0.54 (0.40)
450 to <560		1.3 (1.0)	9.2 (6.9)	11.4 (8.5)	0.54 (0.40)
>560		1.3 (1.0)	9.2 (6.9)	11.4 (8.5)	0.54 (0.40)

#### For 2011 model year and later

2011 model year and later must meet the emissions standards outlined above for 40 CFR 89.112 and 40 CFR 89.113.

<u>Other</u>

Stationary CI internal combustion engine manufacturers must certify the following emergency stationary CI ICE that are not fire pump engines to the certification emission standards for new marine CI engines in 40 CFR 94.8:

 Their 2007 model year through 2012 emergency stationary CI ICE with a displacement of greater than or equal to 10 litres per cylinder and less than 30 litres per cylinder;

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- Their 2013 model year and later emergency stationary CI ICE with a maximum engine power greater than or equal to 3,700 KW (4,958 HP) and a displacement of greater than or equal to 10 litres per cylinder and less than 15 litres per cylinder;
- Their 2013 model year emergency stationary CI ICE with a displacement of greater than or equal to 15 litres per cylinder and less than 30 litres per cylinder; and
- Their 2014 model year and later emergency stationary CI ICE with a maximum engine power greater than or equal to 2,000 KW (2,682 HP) and a displacement of greater than or equal to 15 litres per cylinder and less than 30 litres per cylinder.

#### 40 CFR 94.8 Exhaust emission standards

#### Tier 1 standards:

 $NO_X$  emissions from model year 2004 and later engines with displacement of 2.5 or more litres per cylinder may not exceed the following values:

- + 17.0 g/kW-hr when maximum test speed is less than 130 rpm.
- + 45.0 × N−0.20 when maximum test speed is at least 130 but less than 2000 rpm, where N is the maximum test speed of the engine in revolutions per minute.
- + 9.8 g/kW-hr when maximum test speed is 2000 rpm or more.

#### Tier 2 standards:

Engine Size litres/cylinder, rated power	Category	Model year	THC + NOX g/kW-hr	CO g/kW-hr	PM g/kW-hr
disp. <0.9 and	Category 1, Commercial	2005	7.5	5.0	0.40
power ≥37 kW	Category 1, Recreational	2007	7.5	5.0	0.40
0.9 ≤disp. <1.2 all	Category 1, Commercial	2004	7.2	5.0	0.30
power levels	Category 1, Recreational	2006	7.2	5.0	0.30
1.2 ≤disp. <2.5 all	Category 1, Commercial	2004	7.2	5.0	0.20
power levels	Category 1, Recreational	2006	7.2	5.0	0.20
2.5 ≤disp. <5.0 all	Category 1, Commercial	2007	7.2	5.0	0.20
power levels	Category 1, 2009 Recreational	7.2	5.0	0.20	
5.0 ≤disp. <15.0 all power levels	Category 2	2007	7.8	5.0	0.27
15.0 ≤disp. <20.0 power <3300 kW	Category 2	2007	8.7	5.0	0.50
15.0 ≤disp. <20.0 power ≥3300 kW	Category 2	2007	9.8	5.0	0.50
20.0 ≤disp. <25.0 all power levels	Category 2	2007	9.8	5.0	0.50

#### Table 3-6: Primary Tier 2 Exhaust Emission Standards (g/kW-hr)

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25.0 ≤disp. <30.0 all power levels	Category 2	2007	11.0	5.0	0.50
disp. ≥30.0 all power levels	Category 3	Not finalised			

Category 1 and Category 2 engines may be designated "Blue Sky Series" engines by meeting the voluntary standards listed below.

Rated brake power (kW)	THC + NOX	РМ
Power ≥37 kW, and displ. <0.9	4.0	0.24
0.9 ≤displ. <1.2	4.0	0.18
1.2 ≤displ. <2.5	4.0	0.12
2.5 ≤displ. <5	5.0	0.12
5 ≤displ. <15	5.0	0.16
15 ≤disp. <20, and power <3300 kW	5.2	0.30
15 ≤disp. <20, and power ≥3300 kW	5.9	0.30
20 ≤disp. <25	5.9	0.30
25 ≤disp. <30	6.6	0.30

 Table 3-7: Voluntary emission standards [g/kW-hr]

Stationary CI internal combustion engine manufacturers must certify the following emergency stationary CI ICE to the certification emission standards and other requirements applicable to Tier 3 new marine CI engines in 40 CFR 1042.101, 40 CFR 1042.107, 40 CFR 1042.115, 40 CFR 1042.120, and 40 CFR 1042.145, for all pollutants, for the same displacement and maximum engine power:

- Their 2013 model year and later emergency stationary CI ICE with a maximum engine power less than 3,700 KW (4,958 HP) and a displacement of greater than or equal to 10 litres per cylinder and less than 15 litres per cylinder; and
- Their 2014 model year and later emergency stationary CI ICE with a maximum engine power less than 2,000 KW (2,682 HP) and a displacement of greater than or equal to 15 litres per cylinder and less than 30 litres per cylinder.

40 CFR 1042.101 - Exhaust emission standards for Category 1 and Category 2 engines

Power density and application	Displacement (L/cvl)	Maximum engine power	Model year	PM (g/kW-hr)	NOX+HC (g/kW-hr)
All	disp. < 0.9	kW < 19	2009+	0.40	7.5
	·	19 ≤ kW < 75	2009-2013	0.30	7.5
			2014+	0.30	4.7
Commercial engines with kW/L ≤ 35	disp. < 0.9	kW ≥ 75	2012+	0.14	5.4
	0.9 ≤ disp. < 1.2	all	2013+	0.12	5.4
	1.2 ≤ disp. < 2.5	kW < 600	2014-2017	0.11	5.6
			2018+	0.10	5.6
		kW ≥ 600	2014+	0.11	5.6
	2.5 ≤ disp. < 3.5	kW < 600	2013-2017	0.11	5.6
			2018+	0.10	5.6
		kW ≥ 600	2013+	0.11	5.6
	3.5 ≤ disp. < 7.0	kW < 600	2012-2017	0.11	5.8
			2018+	0.10	5.8
		kW ≥ 600	2012+	0.11	5.8

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Commercial engines with kW/L > 35, and all recreational engines ≥ 75 kW	disp. < 0.9	kW ≥ 75	2012+	0.15	5.8
	0.9 ≤ disp. < 1.2	all	2013+	0.14	5.8
	1.2 ≤ disp. < 2.5		2014+	0.12	5.8
	2.5 ≤ disp. < 3.5		2013+	0.12	5.8
	3.5 ≤ disp. < 7.0		2012+	0.11	5.8

#### Table 3-9: Tier 3 Standards for Category 2 Engines Below 3700 kW

Displacement (L/cyl)	Maximum engine power	Model year	PM (g/kW-hr)	NOX+HC (g/kW-hr)
7.0 ≤ disp. < 15.0	kW < 2000	2013+	0.14	6.2
	2000 ≤ kW ≤ 3700	2013+	0.14	7.8
15.0 ≤ disp. < 20.0	kW < 2000	2014+	0.34	7.0
20.0 ≤ disp. < 25.0	kW < 2000	2014+	0.27	9.8
25.0 ≤ disp. < 30.0	kW < 2000	2014+	0.27	11.0

#### Table 3-10: Tier 4 Standards for Category 2 and Commercial Category 1 Engines at or Above 600 kW

Maximum engine power	Displacement (L/cyl)	Model year	PM (g/kW-hr)	NOX (g/kW-hr)	HC (g/kW-hr)
600 ≤ kW < 1400	all	2017+	0.04	1.8	0.19
1400 ≤ kW < 2000	all	2016+	0.04	1.8	0.19
2000 ≤ kW ≤ 3700	all	2014+	0.04	1.8	0.19
kW > 3700	disp. < 15.0	2014-2015	0.12	1.8	0.19
	15.0 ≤ disp. < 30.0	2014-2015	0.25	1.8	0.19
	all	2016+	0.06	1.8	0.19

#### Table 3-11: Optional Tier 3 and Tier 4 Standards for Category 2 Engines at or Above 1400 kW

Tier	Maximum engine power	Model year	PM (g/kW-hr)	NOX (g/kW-hr)	HC (g/kW-hr)
Tier 3	kW ≥ 1400	2012-2014	0.14	7.8 NOX+HC	
Tier 4	1400 ≤ kW ≤ 3700	2015	0.04	1.8	0.19
	kW > 3700	2015	0.06	1.8	0.19

40 CFR 1042.107 specifies that are no evaporative emission standards for diesel-fuelled engines, or engines using other non-volatile or nonliquid fuels (for example, natural gas). If an engine uses a volatile liquid fuel, such as methanol, the engine's fuel system and the vessel in which the engine is installed must meet the evaporative emission requirements of 40 CFR 1045.

40 CFR 1042.115 - other requirements

 Prohibited controls: You may not design your engines with emission-control devices, systems, or elements of design that cause or contribute to an unreasonable risk to public health, welfare, or safety while operating. For example, this would apply if the engine emits a noxious or toxic substance it would otherwise not emit, that contributes to such an unreasonable risk. Defeat devices: You may not equip your engines with a defeat device. A defeat device is an auxiliary emission control device that reduces the effectiveness of emission controls under conditions that the engine may reasonably be expected to encounter during normal operation and use. (Note that this means emission control for operation outside of and between the official test modes is generally expected to be similar to emission control demonstrated at the test modes.)

#### 3212 40 CFR 60.4205 - What emission standards must I meet for emergency engines if I am an owner or operator of a stationary CI internal combustion engine?

Owners and operators of pre-2007 model year emergency stationary CI ICE with a displacement of greater than or equal to 10 litres per cylinder and less than 30 litres per cylinder that are not fire pump engines must comply with the emission standards in 40 CFR 94.8.

Owners and operators of 2007 model year and later emergency stationary CI ICE with a displacement of less than 30 litres per cylinder that are not fire pump engines must comply with the emission standards for new nonroad CI engines in 40 CFR 60.4202.

Owners and operators of emergency stationary CI engines with a displacement of greater than or equal to 30 litres per cylinder must meet the following requirements:

- + For engines installed prior to January 1, 2012, limit the emissions of NO<sub>X</sub> in the stationary CI internal combustion engine exhaust to the following:
  - 17.0 g/kW-hr (12.7 g/HP-hr) when maximum engine speed is less than 130 rpm;
  - $\circ$  45 · n<sup>-0.2</sup> g/kW-hr (34 · n<sup>-0.2</sup> g/HP-hr) when maximum engine speed is 130 or more but less than 2,000 rpm, where n is maximum engine speed; and
  - 9.8 g/kW-hr (7.3 g/HP-hr) when maximum engine speed is 2,000 rpm or more. 0
- For engines installed on or after January 1, 2012, limit the emissions of NOX in the stationary CI internal combustion engine exhaust to the following:
  - 0 14.4 g/kW-hr (10.7 g/HP-hr) when maximum engine speed is less than 130 rpm;
  - $\circ$  44  $\cdot$  n<sup>-0.23</sup> g/kW-hr (33  $\cdot$  n<sup>-0.23</sup> g/HP-hr) when maximum engine speed is greater than or equal to 130 but less than 2,000 rpm and where n is maximum engine speed; and
  - 7.7 g/kW-hr (5.7 g/HP-hr) when maximum engine speed is greater than or equal to 2,000 0 rpm.
- Limit the emissions of PM in the stationary CI internal combustion engine exhaust to 0.40 g/kWhr (0.30 g/HP-hr).

#### 3.2.1.3 40 CFR 60.4209 - What are the monitoring requirements if I am an owner or operator of a stationary CI internal combustion engine?

If you are an owner or operator of an emergency stationary CI internal combustion engine you must install a non-resettable hour meter prior to start-up of the engine.

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# 3.2.1.4 40 CFR 60.4210 - What are my compliance requirements if I am a stationary CI internal combustion engine manufacturer?

Engine manufacturers must add a permanent label stating that the engine is for stationary emergency use only to each new emergency stationary CI internal combustion engine greater than or equal to 19 kW (25 HP) that meets all the emission standards for emergency engines but does not meet all the emission standards for non-emergency engines. Engine manufacturers must specify in the owner's manual that operation of emergency engines is limited to emergency operations and required maintenance and testing.

# 3.2.1.5 40 CFR 60.4211 - What are my compliance requirements if I am an owner or operator of a stationary CI internal combustion engine?

There is no time limit on the use of emergency stationary ICE in emergency situations.

For the engine to be considered an emergency stationary ICE under this subpart, any operation other than emergency operation, maintenance and testing, emergency demand response, and operation in non-emergency situations for 50 hours per year is prohibited.

You may operate your emergency stationary ICE for any combination of the purposes below for a maximum of 100 hours per calendar year.

- Emergency stationary ICE may be operated for maintenance checks and readiness testing, provided that the tests are recommended by federal, state or local government, the manufacturer, the vendor, the regional transmission organization or equivalent balancing authority and transmission operator, or the insurance company associated with the engine.
- Emergency stationary ICE may be operated for emergency demand response for authorised periods.
- Emergency stationary ICE may be operated for periods where there is a deviation of voltage or frequency of 5 percent or greater below standard voltage or frequency.

Emergency stationary ICE may be operated for up to 50 hours per calendar year in non-emergency situations. The 50 hours of operation in non-emergency situations are counted as part of the 100 hours per calendar year for maintenance and testing and emergency demand response. The 50 hours per calendar year for non-emergency situations cannot be used for peak shaving or non-emergency demand response, or to generate income for a facility to an electric grid or otherwise supply power as part of a financial arrangement with another entity.

The 50 hours per year for non-emergency situations can be used to supply power as part of a financial arrangement with another entity if all the following conditions are met:

- The engine is dispatched by the local balancing authority or local transmission and distribution system operator;
- The dispatch is intended to mitigate local transmission and/or distribution limitations so as to avert potential voltage collapse or line overloads that could lead to the interruption of power supply in a local area or region.

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 The dispatch follows reliability, emergency operation or similar protocols that follow specific NERC, regional, state, public utility commission or local standards or guidelines.

# 3.2.1.6 CFR 60 60.4214 - What are my notification, reporting, and recordkeeping requirements if I am an owner or operator of a stationary CI internal combustion engine?

The owner or operator of an emergency stationary internal combustion engine must keep records of the operation of the engine in emergency and non-emergency service that are recorded through the non-resettable hour meter. The owner must record the time of operation of the engine and the reason the engine was in operation during that time.

## 3.2.1.7 Table 2 to Subpart IIII of Part 60

Table 3-12: Standards for 2008 Model Year and Later Emergency Stationary CI ICE <37 KW (50 HP) With a Displacement				
Emission standards for 2008 model year and later emergency stationary CI ICE <37 KW (50 Engine power HP) with a displacement of <10 litres per cylinder in g/kW-hr (g/HP-hr)				ary CI ICE <37 KW (50 nr (g/HP-hr)
	Model year(s)	NOX + NMHC	CO	PM
KW<8 (HP<11)	2008 +	7.5 (5.6)	8.0 (6.0)	0.40 (0.30)
8≤KW<19	2008 +	7.5 (5.6)	6.6 (4.9)	0.40 (0.30)

7.5 (5.6)

5.5 (4.1)

0.30 (0.22)

## 3.2.2 States

(11≤HP<25)

19≤KW<37 (25≤HP<50)

Generally, permits for stationary backup power supplies are required unless otherwise exempt by the relevant state or air quality management district.

In some cases, there are inconsistencies between state and federal standards.

2008 +

The allowable operating hours during an emergency range from 200hrs per year to unrestricted between states. The allowable maintenance and testing hours for states range from 20 to 200 hours/year, with the most common maintenance thresholds at 50 hours/year and 100 hours/year.

Much of the information for the individual states has been sourced from the emergency generator permitting matrix (**RCC, 2020**) the NESCAUM (**2014**) report and state websites.

### 3.2.2.1 Alaska

Emergency generators may operate under preapproved emissions limits (PAEL) to avoid a permit, which restrict the amount of diesel fuel the engine may burn, however this may not be required for emergency generators based on emission levels.

### 3.2.2.2 California

All air permitting activities for emergency generators are conducted by the county or regional Air Pollution Control Districts (APCD) or Air Quality Management Districts (AQMD). Requirements vary by air district, and they may include permitting requirements, emission limits, and operational restrictions.

The following information is contained within guidance from the California Air Resources Board (**CARB**, **2011**) and in the California Code of Regulation 2423. Exhaust Emission Standards and Test Procedures - Off-Road Compression-Ignition Engines.

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Each owner or operator of an emergency standby diesel-fuelled Cl engine shall keep records and prepare a monthly summary that shall list and document the nature of use for each of emergency use hours of operation and maintenance and testing hours of operation.

Fuel is to be CARB Diesel Fuel or an alternative diesel fuel that is biodiesel, a biodiesel blend, a Fischer-Tropsch fuel, an emulsion of water in diesel fuel, or any alternative diesel fuel that meets the requirements of the Verification Procedure.

#### Location

No owner or operator shall operate a new stationary emergency standby diesel-fuelled Cl engine (>50 bhp) for non-emergency use, including maintenance and testing, during the following periods:

- + whenever there is a school sponsored activity, if the engine is located on school grounds, and
- between 7:30 a.m. and 3:30 p.m. on days when school is in session, if the engine is located within 500 feet of school grounds. This does not apply if the engine emits no more than 0.01 g/bhp-hr of diesel PM.

Exemptions – some agricultural emergency standby generator, emergency engines at nuclear facilities, emergency fire pump engines, emergency engines used by the Department of Defence,

Emission standards for new stationary emergency standby diesel-fuelled engines (>50 bhp):

Maximum Engine Power	Model year(s)	РМ	NMHC+NOx	со
50 ≤ HP < 75	2007	0.15 (0.20)	5.6 (7.5)	27/50)
(37 ≤ kW < 56)	2008+	0.15 (0.20)	3.5 (4.7)	5.7 (5.0)
75 ≤ HP < 100	2007	0.15 (0.20)	5.6 (7.5)	27/50)
(56 ≤ kW < 75)	2008+	0.15 (0.20)	3.5 (4.7)	3.7 (5.0)
100 ≤ HP < 175	2007	0.15 (0.20)	20(40)	27(50)
(75 ≤ KW < 130)	2008+	0.15 (0.20)	5.0 (4.0)	3.7 (5.0)
175 ≤ HP < 300	2007	0.15 (0.20)	2 0 (4 0)	2 G (2 E)
(130 ≤ kW < 225)	2008+	0.15 (0.20)	5.0 (4.0)	5.0 (5.5)
300 ≤ HP < 600	2007	0.15 (0.20)	2 0 (4 0)	3.6 (3.5)
(225 ≤ kW < 450)	2008+	0.15 (0.20)	5.0 (4.0)	
600 ≤ HP < 750	2007	0.15 (0.20)	2 0 (4 0)	3.6 (3.5)
(450 ≤ kW < 560)	2008+	0.15 (0.20)	5.0 (4.0)	
HP > 750	2007	0.15 (0.20)	1 Q (C 1)	3.6 (3.5)
(kW > 560)	2008+	0.15 (0.20)	4.0 (0.4)	

 Table 3-13: Table 1: Emission Standards for New Stationary Emergency Standby

 Diesel-Fuelled CI Engines g/bhp-hr (g/kW-hr)

The District may allow a new stationary emergency standby diesel-fuelled Cl engine (> 50 hp) to operate up to 100 hours per year for maintenance and testing purposes on a site-specific basis, provided the diesel PM emission rate is less than or equal to 0.01 g/bhp-hr.

 Table 3-14: Table 3: Summary of the Emission Standards and Operating Requirements for

 In-Use Stationary Emergency Standby Diesel-Fuelled CI Engines > 50 BHP

Diesel PM			Other Pollutants
Diesel PM	Maximum Allowa	ble Annual Hours of Operation for Engines	HC, NOx, NMHC+NOx,
Standards	Meeting Diesel PM Standards		and CO Standards
(g/bhp-hr)	Emergency use Non-emergency use		(g/bhp-hr)

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	Not limited by	Emission testing to show compliance	Maintenance & testing (hours/year)	Not limited by ATCM2		
>0.40	ATCM2	ATCM2	20	Not limited by ATCM2		
>0.15 and <0.40	Not limited by ATCM2	Not limited by ATCM2	21 to 30	For engines with emission control strategies not verified through the		
>0.01 and <0.15	Not limited by ATCM2	Not limited by ATCM2	31 to 50 (upon approval by the District)	verification procedure: Off- Road Cl Engine Certification Standards for an off- road engine of the model year and		
<0.01	Not limited by ATCM2	Not limited by ATCM2	51 to 100 (upon approval by the District)	maximum rated power of the engine installed to meet the applicable PM standard, or Tier 1 standards. OR Both (i) and (ii) must be met: (i) No increase in HC or NOx above 10% from baseline levels OR No increase in NMHC+NOx emissions above baseline levels (ii) No increase in CO above 10% from baseline levels		

The California Code of Regulation presents the same Tier 1 to Tier 3 standards as 40 CFR 89.112.

New Emergency Standby Engines greater than or equal to 25 bhp but less than 50 hp shall meet the tier 4 interim Off-Road Compression Ignition Engine Standards for PM, NMHC+NOx, and CO.

Engine power (kw)	Model yr	type	РМ	NMHC+NOx	NMHC	NOX	со
<8	2008 +	final	0.4	7.5			8
8 to <19	2008 +	final	0.4	7.5			6.6
19 to <37	2008-2012	interim	0.3	7.5			5.5
	2013 +	final	0.03	4.7			5.5
37 to <56	2008-2012	interim	0.2	4.7			5
	2013 +	final	0.2	4.7			5
		phase-in	0.2			0.4	5
	2012-2014	phase-out	0.2	4.7			5
56 to <75		or/alt NOx	0.2			3.4	5
	2012-2014	or/alt NOx+NMHC	0.2	3.5			5
	2015 +	final	0.2		0.19	0.4	5
	2012-2014	phase-in	0.2		0.19	0.4	5
		phase-out	0.2	4		3.4	5
75 to <130		or/alt NOx	0.2		0.19		5
75 10 150		or/alt NOx+NMHC	0.2	3.5			5
	2015 +	final	0.2		0.19	0.4	5
130 to < 560	2011-2013	phase-in	0.2		0.19	0.4	3.5
		phase-out	0.2	4		2	3.5
		or/alt NOx	0.2		0.19		3.5
		or/alt NOx+NMHC	0.2	2.1			3.5
	2014 +	final	0.2		0.19	0.4	3.5
560 to <900	2011-2014	interim	0.1		0.4	3.5	3.5
generator engines only	2015 +	final	0.03		0.19	0.67	3.5
	2011-2014	interim	1		0.4	0.67	3.5

Table 3-15: Tier 4 exhaust emission standards (g/kwh)

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>900 generator engines only	2015 +	final	0.03	0.19	0.67	3.5
all mobile	2011-2014	interim	1	0.4	3.5	3.5
machinery excluding generator engines >560	2015 +	final	0.04	0.19	3.5	3.5

No owner or operator shall operate any in-use stationary emergency standby diesel-fuelled Cl engine in response to the notification of an impending rotating outage unless all the following criteria are met:

- the engine's permit to operate allows operation of the engine in anticipation of a rotating outage, or the District has established a policy or program that authorizes operation of the engine in anticipation of a rotating outage; and
- the Utility Distribution Company has ordered rotating outages in the control area where the engine is located, or has indicated it expects to issue such an order at a certain time; and
- + the engine is located in a specific location that is subject to the rotating outage; and
- the engine is operated no more than 30 minutes prior to the time when the Utility Distribution Company officially forecasts a rotating outage in the control area; and
- the engine operation is terminated immediately after the Utility Distribution Company advises that a rotating outage is no longer imminent or in effect.

### 3.2.2.2.1 Bay Area Air Quality Management District (BAAQMD)

Backup generators must meet the California Air Resources Board Risk Guidance requirements regarding emissions below health risk thresholds (an increased cancer risk greater than 10 per million for either residential or workplace receptors).

Assessments in this jurisdiction indicate that diesel engines would meet U.S. EPA Tier 2 emission standards.

Best Available Control Technology (BACT) requirements are triggered if maximum potential emissions from a new source are 10 lbs/day or more of PM<sub>10</sub>, NOx, SO<sub>2</sub>, CO or precursor or non-precursor organic compounds. Once BACT is triggered, BAAQMD can only permit a diesel engine if a natural gas-fuelled engine or electric motor is impractical.

The law, as currently written, requires the District to notify parents of schoolchildren, neighbouring businesses and residents of all new or modified equipment that emits any hazardous air contaminant into the air which will be installed within 1,000 feet of a school site.

Uncontrolled NOx emissions, calculated as nitrogen dioxide from the following engines must be reduced with add-on control equipment by not less than the following:

Table 3-16:				
	Weight percent engine category reduction			
Rich-burn engines using fossil derived gaseous fuel or gasoline	96			
Lean-burn engines using fossil derived gaseous fuel	90			

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Engines using exclusively waste derived gaseous fuel or syngas	90
Engines using diesel or kerosene fuel	90
Dual-fuelled engines	90
Rich-burn engines used exclusively in agricultural operations	80
Lean-burn engines used exclusively in agricultural operations	70

#### Table 3-17: Existing Emergency Standby Engines

Engine Type	Concentration of NOx <sup>1</sup>	Concentration of VOC <sup>2</sup>	Concentration of CO <sup>3</sup>
Rich-burn engines using gaseous fuel	25 ppmv	250 ppmv	4,500 ppmv
Lean-burn engines using gaseous fuel	2.0 g/bhp-hr	N/A	4,500 ppmv
Engines using diesel fuel	69g/bhp-hr	N/A	4 500 ppmy

1 Calculated as nitrogen dioxide in parts per million by volume (ppmv) corrected to 15% oxygen on a dry basis, or in grams of NOx per brake horsepower-hour, as indicated.

2Calculated as methane in ppmv corrected to 15% oxygen on a dry basis.

3Calculated as carbon monoxide in ppmv corrected to 15% oxygen on a dry basis.

#### Concentration of VOC<sup>2</sup> Concentration of CO<sup>3</sup> Engine Type Concentration of NOx<sup>1</sup> Rich-burn engines using gaseous 25 ppmv 86 ppmv 540 ppmv fuel Lean-burn engines using 2.0 g/bhp-hr or 160 ppmv 1.0 g/bhp-hr or 86 ppmv 4.0 g/bhp-hr or 540 ppmv gaseous fuel Black start engines using 2.0 g/bhp-hr or 160 ppmv 1.0 g/bhp-hr or 86 ppmv 4.0 g/bhp-hr or 540 ppmv gaseous fuel Certified engines using diesel 3.5 g/bhp-hr N/A 3.7 g/bhp-hr fuel, $50 \le bhp < 100$ Certified engines using diesel 3.0 g/bhp-hr N/A 3.7 g/bhp-hr fuel, 100 ≤ bhp < 175 Certified engines using diesel 3.0 g/bhp-hr N/A 2.6 g/bhp-hr fuel, 175 ≤ bhp < 750 Certified engines using diesel 4.8 g/bhp-hr N/A 2.6 g/bhp-hr fuel, bhp $\geq$ 750

#### Table 3-18: New or Replacement Emergency Standby Engines

1 Calculated as nitrogen dioxide in ppmv corrected to 15% oxygen on a dry basis, or in grams of NOx per brake horsepowerhour, as indicated.

2 Calculated as methane in ppmv corrected to 15% oxygen on a dry basis, or in grams of VOC per brake horsepower-hour, as indicated, and excluding emissions of formaldehyde.

3 Calculated as carbon monoxide in ppmv corrected to 15% oxygen on a dry basis, or in grams of CO per brake horsepower-hour, as indicated.

The emission standards do not apply to any emergency standby engine provided that operation of the engine for non-emergency purposes does not exceed 52 hours per calendar year or any engine which operates less than 200 hours per calendar year.

During the preparation of this study the BAAQMD issued a new rule for BACT on 22 December 2020, as set out in **Appendix C**.

The new rule imposes more stringent requirements and applies retrospectively from 1 January 2020 for new engines > 1,000 bhp.

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#### 3.2.2.2.2 San Diego Air Pollution Control District

A stationary internal combustion engine with a brake horsepower (bhp) rating of 50 or greater located at a stationary source which emits or has a potential to emit 50 tons per year or more of oxides of nitrogen (NOx) requires a permit to operate.

If a piece of equipment or a process emits more than 10 pounds per day of particulate matter (PM10), oxides of nitrogen (NOx), volatile organic compounds (VOC) or oxides of sulfur (SOx), the application must include a best available control technology (BACT) analysis. For emergency engines, this requirement is most frequently triggered by NOx.

### 3.2.2.2.3 South Coast Air Quality Management District

All internal combustion engines (ICEs) including emergency backup generators greater than 50 brake horsepower (bhp) and gas turbines greater than 2,975,000 British thermal units (Btu) per hour are required to obtain a permit to construct from the South Coast AQMD prior to installation of the engines at a site.

A backup generator is considered to be ICE or turbine for non-utility power generation that does not operate more than 200 hours a year and is only operated in the event of an emergency power failure or for routine testing and maintenance.

ICEs for emergency power generation that are fired on natural gas only and are permitted by the South Coast AQMD may be operated during Stage II or Stage III electrical emergencies declared by the Independent System Operator (ISO) and during actual or imminent blackouts. The hours the engines are operated during these periods in any one year are accumulated toward the total 200 hours.

Testing and maintenance hours are limited, in most cases, to 20 - 50 hours annually.

#### 3.2.2.3 Colorado

Emergency generators are exempt from permitting where:

- The stationary internal combustion engine that powers the emergency generator operates no more than 250 hours per year;
- The unit's uncontrolled actual emissions of each criteria pollutant are less than 5 tons per year; or
- The engine has a manufacturer's site-rated capacity of less than 50 hp.

#### 3.2.2.4 Connecticut

An emergency engine that would otherwise require an individual permit is exempt if the engine only operates during periods of testing and scheduled maintenance or during an emergency, and the following conditions are met:

- + The engine does not operate more than 300 hours during any rolling 12-month period;
- + The engine uses diesel fuel with a sulfur content that does not exceed 15 parts per million; and
- Records of fuel purchases and hours of operation on a monthly and rolling 12-month aggregate are maintained.

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An emergency engine that would otherwise require an individual permit can avoid having to obtain a permit by limiting its potential to emit through restrictions on fuel use, provided records are maintained to document fuel use. To comply with the permit-by-rule, owners/operators must comply with the following fuel restrictions:

- Emergency generators using gaseous fuel must limit facility-wide purchases of gaseous fuels to 3,360,000 cubic feet or less in any calendar year;
- Emergency generators using distillate oil, or a blend of distillate oil and biodiesel must limit facility-wide purchases of distillate oil, including blends with biodiesel fuel, to 21,000 gallons or less in any calendar year; or
- + Emergency generators using propane must limit facility-wide purchases of propane to 100,000 gallons or less in any calendar year.

Participation in price response programs (e.g., non-emergency peak shaving) not allowed. Participation in emergency demand response program allowed for 300 hr/yr using natural gas or ULSD.

### 3.2.2.5 Delaware

A permit for the installation, alteration or operation of an emergency generator is not required if the unit has a stand-by power rating of 450 kW or less.

If the equipment has actual aggregate emissions to the atmosphere or, if there is control device, the inlet of the air contaminant control device, that are equal to or greater than 0.2 and less than 10 pounds per day, during each and every day then registration with Delaware Department of Natural Resources and Environmental Control is required.

An emergency generator may operate for an unlimited number of hours during an emergency and operate for an unlimited number of hours during testing or for maintenance purposes. Testing and maintenance of generators is prohibited on days when there is an Air Quality Alert.

Yearly operating hours during which testing, or maintenance occurred shall be calculated and recorded each calendar month by recording the current calendar month's testing or maintenance hours and adding them to those of the previous eleven consecutive months. A brief description of each testing or maintenance performed shall also be recorded.

Regarding fuel:

- Each shipment of diesel fuel or a biodiesel blend, received for use in a generator on or after April 11, 2006, shall have a sulfur content equal to or less than 0.05% by weight
- Gaseous fuels, except for waste, landfill, or digester gases, combusted in a generator on or after April 11, 2006 shall contain no more than ten grains total sulfur per 100 dry standard cubic feet (170 ppmv total sulfur) on a daily average.
- Waste, landfill, or digester gases combusted in a generator on or after April 11, 2006 shall contain no more than ten grains total sulfur per 100 dry standard cubic feet (170 ppmv total sulfur) on a daily average. An alternative total sulfur limit for waste, landfill, or digester gases shall be allowed based upon a case-by-case determination.

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### 3.2.2.6 District of Columbia

Emergency generators with potential emissions less than 5 tpy of total VOC, NOx, SO2, PM-10, PM-2.5, or aggregate hazardous air pollutants do not require a permit.

### 3.2.2.7 Florida

Stationary reciprocating internal combustion engines, such as those used to power emergency generators, do not require a construction permit, non-Title V operating permit, or a general permit, provided they satisfy the following criteria:

- The engine is not subject to a unit-specific requirement other than 40 CFR 60 IIII, 40 CFR 60 JJJJ, or 40 CFR 63 ZZZZ;
- The engine will not burn used oil or any fuels other than natural gas, propane, gasoline, and diesel fuel;
- If burning only one type of fuel, the total annual amount of fuel burned by all units claiming this exemption at the same facility must not exceed 5,400 gallons of gasoline, 64,000 gallons of diesel fuel, 288,000 gallons or propane, or 8.8 million standard cubic feet of natural gas;
- If burning more than one type of fuel, the equivalent total annual amount of each fuel burned by all units claiming this exemption must not exceed the aforementioned collective maximum annual amount for each fuel multiplied by a fuel percentage. The fuel percentage is the percentage ratio of the total amount of the fuel burned by all engines claiming this exemption at the same facility to the aforementioned total amount of such fuel allowed to be burned by all engines claiming this exemption. The sum of the fuel percentages for all fuels burned by the engines claiming this exemption at the same facility must be less than or equal to 100 percent.
- The engine must comply with the applicable requirements of 40 CFR 60 IIII, 40 CFR 60 JJJJ, or 40 CFR 63 ZZZZ.

### 3.2.2.8 Georgia

Emergency generators burning natural gas, LPG, gasoline, dual fuel, or diesel fuel that are used exclusively as emergency generators do not need Georgia state implementation plan construction and operating permits (issued as a single permit), provided they operate:

- Less than 200 hours per year in the following counties: Banks, Barrow, Bartow, Butts, Carroll, Chattooga, Cherokee, Clarke, Clayton, Cobb, Coweta, Dawson, DeKalb, Douglas, Fayette, Floyd, Forsyth, Fulton, Gordon, Gwinnett, Hall, Haralson, Heard, Henry, Jackson, Jasper, Jones, Lamar, Lumpkin, Madison, Meriwether, Monroe, Morgan, Newton, Oconee, Paulding, Pickens, Pike, Polk, Putnam, Rockdale, Spalding, Troup, Upson, and Walton; or
- + Less than 500 hours/year in all other parts of the state.

### 3.2.2.9 Idaho

Emergency generators powered by stationary internal combustion engines that are operated less than 500 hours per year and powered by natural gas, propane, liquefied petroleum gas, distillate fuel oils, residual fuel oils, and diesel fuel are exempt from the requirement to obtain a permit to construct

provided the maximum capacity to emit any regulated air contaminant does not exceed 100 tons per year.

#### 3.2.2.10 Illinois

Permits are not needed for stationary internal combustion engines with rated power outputs of less than 1,118 kilowatts (kW) (1,500 brake horsepower (bhp)). However, there is an exception to this exemption: a permit is required for any internal combustion engine with a rating equal to or greater than 500 bhp output that is subject to the NOx control requirements of 35 IAC 217.388 (a) or (b).

#### 3.2.2.11 Indiana

Registration and construction permitting requirements do not apply to equipment, including emergency generators, powered by diesel fuel-fired or natural gas-fired internal combustion engines of capacity equal to or less than 500,000 British thermal units per hour (Btu/hr). However, there is an exception to this exemption: if the total capacity of such equipment operated by one stationary source exceeds 2,000,000 Btu/hr, the equipment is not exempt.

Emergency generators may operate under a Source Specific Operating Agreements (SSOA) for internal combustion engines in lieu of a registration or permit, provided the pre-established terms and conditions of the SSOA are acceptable and the total source potential to emit is less than:

- 25 tons per year (tpy) particulate matter, PM-10, SO2, NOx, VOC, hydrogen sulphide, total reduced sulfur, reduced sulfur compounds, and fluorides;
- 100 tpy CO; and
- ✤ 5 tpy lead.

There is a requirement for the use of ultra-low diesel fuels.

#### 3.2.2.12 Iowa

An emergency generator powered by internal combustion engine with a brake horsepower rating of less than 400 measured at the shaft (i.e., the manufacturer's nameplate rated capacity at full load) is exempt from permitting requirements.

An emergency generator does not include:

- + Peaking units at electric utilities; or
- Generators at industrial facilities that typically operate at low rates, but are not confined to emergency purposes; or
- Any standby generators that are used during time periods when power is available from the electric utility.

#### 3.2.2.13 Kansas

The construction/installation or modification of an emergency generator may require either a construction permit.

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#### 3.2.2.14 Kentucky

The construction/installation or modification of an emergency generator may require either a registration or state-origin permit. The requirement to register or obtain a permit is based on the potential emissions of the emergency generator.

#### 3.2.2.15 Louisiana

Louisiana has established a "regulatory permit" for stationary internal combustion engines that functions as a permit-by-rule. This permit-by-rule covers emergency engines like those used to power emergency generators and authorizes associated fuel storage in a tank with a capacity less than 10,000 gallons.

#### 3.2.2.16 Maine

Emergency generators with a capacity equal to or greater than 50 kilowatts (approx. 0.5 MMBtu/hr) must be registered.

Operations are limited to 500 hrs/yr during emergencies and 50 hours of maintenance and testing.

Emergency generators are not allowed to participate in any voluntary demand-reduction program or any other interruptible supply arrangement with a utility, other market participant, or system operator.

All diesel-powered generators must use diesel fuel with sulfur content no greater than 15 parts per million (ppm).

#### 3.2.2.17 Maryland

Permits are not required before installing or modifying emergency generators powered by stationary internal combustion engines with an output of less than 500 brake horsepower and that are not used to generate electricity for sale or load shaving.

A general permit applies to an emergency electric generator set equipped with a stationary internal combustion engine, rated at 500 brake horsepower (373 kilowatts) and up to and including 2,681 brake horsepower (2000 kilowatts) that is ONLY used for emergency operation and maintenance and testing.

There is no time limit on the use of an emergency generator set in emergency situations.

The emergency generator set may operate for 100 hours per year for testing and maintenance purposes. Additionally, the emergency generator set may operate in certain non-emergency situations for 50 hours per year, as described in 40 CFR 60.4211 and 40 CFR 63.6640. Examples of non-emergency situations include storm avoidance, maintenance and testing on electrical systems or primary power systems, and maintenance and testing on elevators and other building components. These 50 hours of non-emergency operation count towards the 100 hours per year of maintenance and testing operation.

The emergency generator set is subject to Code of Maryland Regulations which generally prohibit the discharge of emissions beyond the property line in such a manner that a nuisance or air pollution is created.

The Permittee may not cause or permit the discharge of emissions from any engine, operating at idle, greater than 10 percent opacity or operating at other than idle conditions, greater than 40 percent opacity. This does not apply while maintenance, repair, or testing is being performed.

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The sulfur content of distillate fuel oils is limited to not more than 0.3 percent by weight.

### 3.2.2.18 Massachusetts

Emergency engines with a rated power output equal to or greater than 37 kilowatts (engine output; not electrical output of the generator) that are constructed, installed, modified, or substantially reconstructed after March 23, 2006, are required to certify that they are in compliance with the Massachusetts Department of Environmental Protection applicable requirements.

A permit must be obtained for any internal combustion engine, including those to power emergency generators, with an input capacity equal to or greater than 3 million Btu/hr installed before March 23, 2006, that results in a potential emissions increase of a single air pollutant equal to or greater than 1 ton per year.

The total usage of an emergency engine is limited to 300 hrs/yr.

Participation in price response programs (e.g., non-emergency peak shaving) not allowed.

A diesel engine must use ultra-low sulfur fuel.

#### 3.2.2.19 Michigan

Internal combustion engines, including emergency generators, that have less than 10,000,000 Btu/hour maximum heat input are not required to get a permit to install. Emergency generators are subject to the federal regulations 40 CFR 60 Subpart IIII, 40 CFR 60 Subpart JJJJ and 40 CFR 63 Subpart ZZZZ.

#### 3.2.2.20 Minnesota

Minnesota Pollution Control Agency provides recommended practices for emergency generators (Minnesota PCA, 2013).

Regarding testing:

- Limiting the duration of testing helps minimize the pollution emitted and saves fuel. One hour or less of operation should be sufficient to fulfill most requirements.
- Consider testing between 12 p.m. and 4 p.m. Generally, wind increases in the afternoon, so early afternoons are better for testing generators. Avoid testing in the late afternoon – that coincides with rush hour and higher emissions from vehicles. Another option is testing outside of normal business hours such as weekends.
- + If the engine is located near a building, be aware of when and where people congregate. Avoid operating engines during these peak activity times.
- Operating multiple units at the same time leads to higher impacts due to the combined emissions. Consider staggering the testing on different days as well as at different times on the same day.
- Avoid testing your generator when the Air Quality Index (AQI) is over 90.

**Regarding location:** 

Orient the stack outlet to vent emissions vertically without obstruction.

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Make the stack high enough that the exhaust can disperse easily. A counterbalanced flappertype rain cap is a better choice than a fixed rain cap.

Diesel fuel with a sulfur content limited to 15 ppm is available and required for some engines. For diesel engines, the load should be at least 30% of generator capacity to avoid "wet stacking." This inefficient operation results in higher emissions and unburned fuel in the exhaust.

## 3.2.2.21 Mississippi

Mississippi Department of Environmental Quality does not offer a permit exemption specifically for emergency generators, but an exemption is available for sources with potential emissions below certain thresholds.

## 3.2.2.22 Missouri

Permits are not required for internal combustion engines and electric generator sets used only for emergency services, provided the unit does not exceed a maximum of 500 annual operating hours and the unit is equipped with a non-resettable hour meter.

## 3.2.2.23 Montana

Emergency generators installed in commercial facilities that are used when the usual sources of heat, power, or lighting are temporarily unobtainable or unavailable are exempt from permitting when the loss of heat, power, or lighting causes, or is likely to cause, an adverse effect on public health or facility safety.

Constructing, installing, modifying, or operating an emergency generator with a potential to emit or an increase in potential to emit more than 25 tons per year of a regulated pollutant requires a permit.

#### 3.2.2.24 Nebraska

Operating permits are not required if the only reason for obtaining the permit is due to the presence of a generator exclusively dedicated to providing back-up power when electrical power from the local utility is interrupted. An annual report of operating hours must be submitted to Nebraska Department of Environmental Quality (NDEQ) upon request or by the end of the month following the month in which 500 hours of operation are exceeded.

NDEQ offers a general permit for emergency generators subject to 40 CFR 60, Subpart IIII. This general permit is limited to emergency engines that have a total capacity of up to 10,000 horsepower (hp), use diesel fuel, are model year 2014 or later, have a displacement of less than 30 litres per cylinder, and have less than 500 operating hours per 12 consecutive calendar months.

NDEQ also offers a general permit for other emergency generators that have a total capacity of up to 5,000 hp, use diesel fuel, and have less than 500 operating hours per 12 consecutive calendar months.

## 3.2.2.25 New Hampshire

New Hampshire Department of Environmental Services offers a General Permit for internal combustion engines used as emergency generators that operate no more than 500 hours per any consecutive 12-month period and must emit less than 25 tons per year of NOx if the theoretical potential from all devices at the facility exceed 50 tons per year NOx. Operation for 100 hours per calendar year for any combination of maintenance checks and readiness testing is allowed.

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A temporary permit (i.e., construction permit) must be obtained before constructing, installing or modifying an emergency generator with an internal combustion engine that:

- Combusts liquid fuel oil with an individual design heat input greater than 150,000 Btu/hr and a combined total design heat input for all such engines greater than or equal to 1.5 million Btu/hr;
- Combusts natural gas or liquefied propane gas with an individual design heat input greater than 1,500,000 Btu/hr and a combined total design heat input of all such engines greater than or equal to 10 million Btu/hr; or
- Is subject a National Emissions Standard for Hazardous Air Pollutants under 40 CFR 63, such as 40 CFR 63, Subpart ZZZZ.

Emergency engines shall not operate for demand response or as a load-shaving or peaking power production unit.

Keep records of the hours and purpose of the operation of the engine (i.e. loss of power, maintenance & testing), copy of maintenance plan and maintenance conducted on engine, fuel usage, and sulfur content of fuel.

## 3.2.2.26 New Jersey

Emergency generators considered to be a significant source, and thereby requiring a preconstruction permit, may be exempt from preconstruction permitting requirements if they have a generating capacity less than 500 kilowatts and emissions have been verified to be below established thresholds.

A general permit for emergency generators burning distillate fuels (GP-005A) that applies to a single emergency generator with a maximum rated heat input of less than 100 MMBtu/hr or multiple emergency generators with a combined maximum rated heat input of less than 100 MMBtu/hr.

A general permit for emergency generators burning gaseous fuels (GP-005B) that applies to a single emergency generator with a maximum rated heat input of less than 70 MMBtu/hr or multiple emergency generators with a combined maximum rated heat input of less than 70 MMBtu/hr.

Operators that have a maximum rated heat input of 1 million Btu/hr (approx. 100kW) or greater are considered significant sources and must apply for a permit before installing or modifying the emergency generator.

Operating emergency generators for peak shaving or for any non-emergency use to reduce electrical demand is not allowed by the Department. Emergency generators are only allowed to operate under emergency situations or for testing and maintenance.

The owner or operator of an emergency generator with a maximum rated output of 37 kW, shall maintain on site and record in a logbook or computer data system, the following information:

- + Once per month, the total operating time from the generator's hour meter;
- + For each time the emergency generator is specifically operated for testing or maintenance:
  - The reason for its operation;

- The date(s) of operation and the start-up and shut down time;
- The total operating time for testing or maintenance based on the generator's hour meter; and
- The name of the operator; and
- If a voltage reduction is the reason for the use of the emergency generator, a copy of the voltage reduction notification from PJM or other documentation of the voltage reduction.

Any routine maintenance or testing of the emergency generator may not be performed if poor air quality is predicted. You must check the DEP's air quality web site to ensure good air quality is predicted prior to performing testing or maintenance that will require operation of the emergency generator.

The sulfur content of diesel fuel is limited to 15ppm.

## 3.2.2.27 New Mexico

Standby generators are exempt from permitting provided they are operated only during the unavoidable loss of commercial utility power for a total of less than 500 hours per year, and are either the only source of emissions at the site, or sufficient records are maintained to verify the hours of operation.

Notification must be given for an emergency generator that has the potential to emit more than 10 tpy of any regulated air pollutant. A permit is required an emergency generator with a potential emissions rate greater than 10 pounds per hour or 25 tons per year (tpy) of any criteria pollutant, that emits New Mexico toxic air pollutants in excess of the New Mexico Environment Department hourly rates.

#### 3.2.2.28 New York

Stationary internal combustion engines in emergency generators that operate as mechanical or electric power sources only when the usual supply of power is unavailable and operate for no more than 500 hours per year, are exempt from permitting requirements.

An engine participating in a demand response program is not considered to be an emergency engine per NYS DEC regulations.

Emergency power generating stationary internal combustion engines, and engine test cells at engine manufacturing facilities that are used for either research and development purposes, reliability testing, or quality assurance performance testing are exempt from the requirements.

## 3.2.2.29 North Carolina

Emergency generators are exempt from construction permitting requirements if the generator is the only source at the facility that would require a permit and whose facility-wide actual emissions are less than 100 tons per year (tpy) of any regulated pollutant, 10 tpy of any hazardous air pollutant, or 25 tpy of any combination of hazardous air pollutants. The facility must maintain documentation that this exemption is applicable.

North Carolina Department of Environmental Quality has a general permit for emergency generators used to generate electricity only during the loss of primary power that is beyond the control of the owner or operator of the facility, except for scheduled maintenance.

## 3.2.2.30 North Dakota

A permit to construct/install or operate is not required for any single internal combustion engine with a maximum rating of less than 1,000 brake horsepower (bhp), or multiple engines with a combined rating of less than 1,000 bhp, and which operates a total of 500 hours or less in a rolling twelve-month period.

## 3.2.2.31 Ohio

A permit to install and operate is not required for emergency generators less than or equal to 50 horsepower (hp) that burn gasoline, natural gas, distillate oil, or liquid petroleum gas, provided the units comply with the federal regulations 40 CFR 60 Subpart IIII, 40 CFR 60 Subpart JJJJ and 40 CFR 63 Subpart ZZZZ.

Ohio EPA has a permit-by-rule for emergency generators greater than 50 hp, provided:

- The engine does not operate at any one facility for more than 500 hours per rolling 12-month period;
- + The engine burns gasoline, natural gas, distillate oil, or liquid petroleum gas; and
- The engine complies with the applicable provisions of federal regulations 40 CFR 60 Subpart IIII, 40 CFR 60 Subpart JJJJ and 40 CFR 63 Subpart ZZZZ.

## 3.2.2.32 Oregon

Emergency generators used only during loss of primary equipment or utility service due to circumstances beyond the reasonable control of the owner or operator, or to address a power emergency, are considered categorically insignificant activities provided that the aggregate horsepower rating of all stationary emergency generators and emergency pump engines is not more than 3,000 horsepower. However, emergency generators that are subject to federal regulations 40 CFR 60 Subpart IIII, 40 CFR 60 Subpart JJJJ and 40 CFR 63 Subpart ZZZZ.

The following emergency generators must obtain a permit:

- + Those with an aggregate engine horsepower rating greater than 30,000 horsepower (hp);
- Any individual unit subject to National Emissions Standards for Hazardous Air Pollutants under 40 CFR 63, Subpart ZZZZ, and that is rated at 500 hp or more, excluding two-stroke lean burn engines, engines burning exclusively landfill or digester gas, and four-stroke engines located in remote areas;
- Any individual unit subject to the federal New Source Performance Standard under 40 CFR 60

   Subpart IIII, and the engine has a displacement of 30 litres or more per cylinder, or the engine has a displacement of less than 30 litres per cylinder and is rated at 500 hp or more and the engine and control device are either not certified by the manufacturer to meet the NSPS or not operated and maintained according to the manufacturer's emissions-related instructions; or
- Any individual unit subject to the federal New Source Performance Standard under 40 CFR 60

   Subpart JJJJ, and is rated at 500 hp or more and the engine and control device are either not certified by the manufacturer to meet the NSPS or not operated and maintained according to the manufacturer's emissions-related instructions.

### 3.2.2.33 Pennsylvania

Emergency generators powered by internal combustion engines rated at less than 100 brake horsepower are exempt from plan approval requirements.

### 3.2.2.34 Rhode Island

Rhode Island Department of Environmental Management has a general permit for any emergency generator powered by an internal combustion engine 50 horsepower (hp) or larger, provided it does not operate more than 500 hours per year for maintenance, testing, and emergencies.

The following restrictions apply:

- maximum 1,900 lb/MWh CO2,
- 15 ppm sulfur content liquid fuel or 10 grains of sulfur per 100 dry standard cubic feet gaseous fuel,
- 10% visible emissions

## 3.2.2.35 South Carolina

Emergency generators less than or equal to 150 kilowatts (kW) rated capacity are exempt from permitting requirements. Emergency generators with a rated capacity greater than 150kW are exempt from permitting requirements provided they are operated a total of 500 hours per year or less for testing and maintenance and have a method to record the actual hours of use, such as an hour meter.

## 3.2.2.36 South Dakota

No permit exemptions exist specifically for emergency generators. However, there are permitting exemptions based on emissions levels and heat input that may be able to be used for emergency generators.

#### 3.2.2.37 Texas

The Texas Commission on Environmental Quality offers a permit-by-rule for emergency generator sets driven by internal combustion engines provided the maximum annual operating hours do not exceed 10% of the normal annual operating schedule of the primary equipment.

#### 3.2.2.38 Utah

The Utah Department of Environmental Quality offers permit exemptions based on emissions levels and source category that may apply to emergency generators.

#### 3.2.2.39 Vermont

Emergency use engines, such as those used in emergency generators, typically do not require a permit, provided the emergency use engines are only used for emergency purposes and up to 100 hours per year for routine testing and maintenance, and only if the aggregate capacity of all emergency use engine generators at the entire facility is less than 2,000 brake horsepower.

Emergency generators that emit 5 tons per year of any and all air contaminants must register with the Vermont Agency of Natural Resources Department of Environmental Conservation.

Emergency engines can participate in emergency demand response programs but cannot participate in economic peak shaving programs. Under the Vermont definition of emergency use, emergency events

also include operation as part of the ISO New England or local power company emergency demand response programs. These programs are used to ensure reliability of the electric grid during extreme high demand electric use times and are only implemented after brown-outs have also been implemented. These programs are very limited and do not include most peaking or load shedding programs used to reduce electric usage when power costs are high, but grid reliability is not threatened.

Emergency generators at industrial facilities must install an elapsed hour meter (emergency units), change the oil and filter every 500 hours (emergency units) or 1,000 hours (non-emergency units) of operation but not less than annually, inspect the engine air filter every 1,000 hours of operation but not less than annually, inspect the engine hoses and belts every 500 hours but not less than annually, and maintain records of such.

## 3.2.2.40 Virginia

To qualify as an emergency generator, the unit can only operate when there is an "emergency". In Virginia, "emergency" is defined as a condition that arises from "sudden and reasonably unforeseeable events" where the primary energy or power source is disrupted or disconnected due to conditions beyond the control of an owner or operator of a facility including:

- A failure of the electrical grid,
- On-site disaster or equipment failure,
- Public service emergencies such as flood, fire, natural disaster, or severe weather conditions, or
- An ISO-declared emergency, where an ISO emergency is: +
  - An abnormal system condition requiring manual or automatic action to maintain system frequency, to prevent loss of firm load, equipment damage, or tripping of system elements that could adversely affect the reliability of an electric system or the safety of persons or property,
  - Capacity deficiency or capacity excess conditions,
  - 0 A fuel shortage requiring departure from normal operating procedures in order to minimize the use of such scarce fuel.
  - Abnormal natural events or man-made threats that would require conservative operations to posture the system in a more reliable state, or
  - An abnormal event external to the ISO service territory that may require ISO action.
  - If the emergency generator operates as stated above and participates in the Emergency 0 Load Response Program (ELRP), then it is still considered an "emergency generator".

Note that "Sudden and reasonably unforeseeable events" do not include scheduled or planned power outages associated with electricity service provider activities.

Engines used for emergency purposes, such as those used to power emergency generators, are exempt from permitting requirements, provided each individual engine does not exceed 500 hours of operation in a year including testing and maintenance.

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Gasoline engines must have an aggregate rated brake (output) horsepower of less than 910 horsepower (hp) and gasoline engines powering electrical generators must have an aggregate rated electrical power output of less than 611 kilowatts.

Diesel engines must have an aggregate rated brake (output) horsepower of less than 1,675 hp and diesel engines powering electrical generators must have an aggregate rated electrical power output of less than 1,125 kilowatts.

Emergency generators may also be exempt from permitting requirements based on emissions levels.

## 3.2.2.41 Washington

Stationary emergency internal combustion engines with an aggregate brake horsepower (bhp) that is less than or equal to 500 bhp are exempt from requirements to obtain an order of approval.

Emergency generators may also be exempt from permitting requirements based on emissions levels.

The Washington Department of Ecology has a general order of approval for gas-powered emergency generators with engines less than or equal to 850 bhp, provided the units can satisfy all the terms and conditions of the general order of approval.

The Washington Department of Ecology has a permit-by-rule for diesel-fired, compression ignition emergency engines with a cumulative rating greater 500 bhp but less than or equal to 2000 bhp.

## 3.2.2.42 West Virginia

West Virginia Department of Environmental Protection has two general permits for emergency generators: Class I for a single emergency generator located at a facility that does not have any other point source emissions; and Class II for emissions from emergency generators, including emergency generators installed at Title V facilities and other facilities having additional point sources of emissions.

## 3.2.2.43 Wisconsin

Emergency generators meeting the Wisconsin Department of Natural Resources definition of a restricted use reciprocating internal combustion engine are exempt from permitting provided the engines burn gaseous fuels, gasoline, or a clean fuel; have a combined total electrical output less than 3,000 kilowatts, or the equivalent brake horsepower; and maintain records to document compliance with exemption criteria.

Emergency generators may also be exempt from permitting requirements based on emissions levels.

## 3.2.2.44 Wyoming

The Wyoming Department of Environmental Quality may grant a permitting exemption for an emergency generator if it determines the unit to be insignificant in both terms of emissions rate and ambient air quality impact.

## 3.3 Canada

The Proposed Regulations for Air Pollutants Emission Standards for New Stationary Diesel Engines (**Environment and Climate Change Canada, 2017**) indicates that Canada is adopting the USA emission standards for compression ignition internal combustion engines as set out in 40 CFR 60 subpart IIII.

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## 3.3.1 Ontario

Ontario has a specific policy for emergency generators used in non-emergency situations such as demand response programs, peak shaving and customer-based generation (**Ontario MECP, 2019**). This policy outlines emission limits, fuel standards and air emission standards.

**Table 3-19** presents the applicable emission limits for non-emergency use. Note that these limits apply during normal operating conditions and not during start up.

	Emission limits (kg/MWh)			
Pollutants	2007-2010	2011 onwards		
Nitrogen oxides (NOx)	1.0	0.4		
Particulate matter PM	0.2	0.02		
Total hydrocarbons excluding methane (NMHC)	1.3	0.19		
Carbon monoxide (CO)	3.5	3.5		

For diesel, fuels must be ultra-low sulfur diesel (ULSD) (15ppm) or if a fuel with a higher sulfur content is used then controls are to be implemented to reduce  $SO_2$  emissions so that the performance is equivalent to ULSD.

Compliance with the Ministry of Environment and Climate Change air standards as specified in Ontario Regulation 419 must be demonstrated. **Table 3-20** outlines the air standards for nitrogen oxides.

Schedule	Averaging period	Limit (µg/m³)		
1	Half hour	500		
2	Half hour	500		
2	1 hour	400		
3	24 hours	200		

## 3.4 UK

The UK Environment Agency (xx and 2019b) provides guidance for back-up power generators.

For an on-site emergency, there are no restrictions on the total number of hours. Using a generator for balancing services, and demand side response operations, such as triad avoidance or fast frequency response are not classed as emergencies.

For data centres, times when the transmission system frequency is unstable, as there is potential for damage or disruption to data processing functions, this is considered an onsite emergency, provided the activity is not part of a formal agreement or contract. Such periods of operation are to be kept to a minimum.

There is a limit of up to 50 hours testing per individual generator in a year. This limit is considered to enable adequate testing of back-up generators and act as a disincentive to extend running hours for the purpose of generating revenue from operating at peak times or providing energy balancing services (**Scottish EFD, 2016**).

For each backup generator, the number of testing hours during the year must be recorded. This is to demonstrate compliance with the 50-hour limit.

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Back-up generators are required to meet a NOx emission limit value of 190mg/Nm and no persistent visible emissions if their testing regime exceeds 50 hour per year, with the exemption of nuclear sites (Scottish EFD, 2019 & Welsh DEFRA, 2016).

The UK has the following testing requirements for back-up power supplies:

- stagger the tests if you have multiple backup engines
- keep testing times and frequency to the minimum just enough to demonstrate reliability at the appropriate load
- only test when you expect low ambient nitrogen oxides (NOx) background, such as not during peak traffic periods
- + use the electricity generated from the test on your site

The UK documentation also includes good practice advice for backup generator installation, providing the following guidance:

- + place backup generators away from sensitive receptors
- + exhaust flues terminating vertically without obstructions to increase dispersion
- + do not exhaust below residents' windows or venting onto car parks etc.

## 3.5 EU

The European Union (EU) Directive 2015/2193 (**European Union, 2015**) notes that in some circumstances compliance with emission limit values would lead to disproportionately high costs compared to the environmental benefits and thus medium combustion plants used in cases of emergency should be able to be exempt from compliance with the emission limit values.

Under the Medium Combustion Plant Directive (MCPD), emergency plant which operate for less than 500 hours per year as a five-year rolling average are exempt from complying with the MCPD emission limit values. The MCPD is not prescriptive for member states. European Stage V emissions standards cover Directive 2016/1628 and any future Directive amendments (**European Union, 2016a**). The European Stage V non-road emission standards are currently the most stringent set of emission standards globally (**European Union, 2016b**). The Stage V standards, adopted by the EU parliament in July 2016, have set stricter limits on emission of particulate matter (PM). These standards, along with particulate number (PN) limits require manufacturers to equip non-road engines of between 19kW and 560kW with diesel particulate filters (DPFs). The emission standards include a wider range of engine type and sizes, that is, engines below 19kW or over 560kW.

Engine Category	Equipment Type	Power Range (KW)	Engine Type	CO (G/KWH)	HC (G/KWH)	NOx (G/KWH)	PM (G/KWH)	PN (#/KWH)	A#
NRG-v-1 NRG-c-1	Generating sets	P>560	All	3.50	0.19	0.67	0.035	-	6.0

#### Table 3-21: Stage V emission limits by engine category

#### 3.5.1 Germany

The German Technical Instructions on Air Quality Control (German FMENCNS, 2002) excludes stationary internal combustion engines exclusively designed for emergencies or operated for up to 300 hours per year during periods of peak load from meeting CO and NOx emission standards, however applies a mass concentration limit of 80mg/m<sup>3</sup> for dust and states that the possibilities to further reduce emissions by engine design and other state of the art techniques shall be exhausted.



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## 4 DIESEL ENGINE EMISSION CONTROL TECHNOLOGIES

This section outlines exhaust aftertreatment equipment commercially available to reduce emissions of diesel particulate matter (DPM).

Much of the information pertaining to diesel controls has been sourced from the NSW Coal Mining Non-road Diesel Exhaust Emissions (**NSW EPA, 2014**) report and the DieselNet Technology Guide.

## 4.1 Diesel Oxidation Catalysts (DOCs)

Diesel oxidation catalysts (DOCs) are relatively inexpensive and are the simplest form of diesel exhaust aftertreatment equipment available for the reduction of PM emissions. DOCs are easy to retrofit on existing diesel generators and are essentially maintenance free.

DOCs use a catalyst to promote the oxidation of CO, HC and the soluble organic fraction of PM with the oxygen present in the diesel exhaust to produce carbon dioxide ( $CO_2$ ) and water ( $H_2O$ ).

DOC performance is affected by the sulfur content of the diesel fuel; PM emissions will increase if sulfur levels are above 150 parts per million (ppm), attributable to the increase in SO<sub>2</sub> emissions and conversion to SO<sub>4</sub> (**The World Bank, 2014**). Although DOCs reduce a portion of total PM mass, they do not significantly reduce particle number of black carbon mass emissions as they do not collect or burn the soot portion of the exhaust.

DOC's are most effective at reducing CO and HC. DOC's reduce diesel exhaust odour significantly and typically achieve PM reductions of 15 to 30%. **Table 4-1** presents the control efficiency for DOCs for reducing PM, CO and HC.

## 4.2 Partial Diesel Particulate Filters (pDPF)

Partial Diesel Particulate Filters (pDPFs), (or open filters, flow through filters or particle oxidation catalysts), are halfway between a DOC and a wall flow diesel particulate filter (DPF).

Partial DPFs capture and store soot particles for adequate time to allow catalytic oxidation, while the open flow through passages allow exhaust gasses the pass even if soot storage capacity is saturated. Hence, Partial DPFs will not block and are maintenance free.

Partial DPFs typically achieve PM reductions of 30 to 50%, (lower than a wall flow DPF of 85%). The efficiency of a pDPF declines as more soot accumulates on the filter media under conditions of low regeneration and in some circumstances cause short periods of elevated PM emissions when accumulated soot blows off the filter. Low sulfur diesel fuel (<50 ppm) is required to avoid excessive sulphate particle production and to ensure maximum NO<sub>2</sub> is produced to oxidise trapped soot.

CO and HC emissions are significantly reduced by pDPFs, however an increase in NO<sub>2</sub> emissions usually occurs as with all catalytic exhaust aftertreatment equipment. While the catalyst increases NO<sub>2</sub> emissions, total NOx emissions remain unchanged. **Table 4-1** presents the control efficiency for pDPFs for reducing PM, CO and HC.

## 4.3 Partial Flow Technology (PFT)

Partial Flow Technology is a hybrid of a DOC and a flow-through filter element. The soluble organic fraction of the particulate in the exhaust is oxidised in the DOC and a portion of any remaining soot is captured and combusted in the filter. PFT systems are moderately more effective than a DOC in lowering PM mass, CO and HC.

Typically, a PFT system can provide greater than 50% PM reduction, and greater than 80% CO and HC reduction (**Chatterjee, Walker & Blakeman, 2008**).

Table 4-1 presents the control efficiency for a PFT system for reducing PM, CO and HC.

## 4.4 Diesel Particulate Filters (DPFs)

Diesel particulate filters (DPFs) filter the PM present in diesel exhaust. DPFs are sometimes referred to as wall flow filters or diesel particulate traps.

Diesel particulate filters (DPFs) reduce PM and hydrocarbon emissions more than oxidation catalysts. DPFs generally reduce PM emissions by 80 to 95%, while significantly reducing hydrocarbon and carbon monoxide emissions. **Table 4-1** presents the control efficiency for DPFs for reducing PM, CO and HC. DPF are highly effective at reducing both soluble and insoluble particles.

DPFs trap particulate matter and then burn it off (releasing carbon dioxide and water as a product of combustion), through a process referred to as 'filter regeneration'. Failure of this process may result in the trap becoming clogged and the high back-pressure causes engine performance to deteriorate. There are two main methods for combusting the captured PM:

- Passive regeneration, and;
- + Active regeneration.

## 4.4.1 Passive DPF regeneration

Passive DPF regeneration is the most common method of soot removal from the DPF, whereby the trapped PM is combusted at the high temperatures achieved during the normal operation of the engine. There is no need to manually induce the regeneration process.

Two catalytic methods are used to oxidise the soot, either oxygen or nitrogen dioxide-based oxidation and they may be used either separately or together.

## 4.4.1.1 Catalysed DPF (CDPF) - oxygen-based soot oxidation

Catalysed DPFs (CDPFs) are used to enable oxidation of soot with oxygen, where the filter monolith of the DPF is coated with a noble metal catalyst, most commonly platinum and sometimes in conjunction with small amounts of rhodium for sulphate suppression. Platinum based CDPFs require diesel fuels with less than 50 ppm sulfur to avoid sulfur poisoning and excessive production of sulphate PM emissions.

The catalytic coating lowers the required temperature for the oxidation of the trapped soot using oxygen alone. In order to provide enough regeneration to maintain low soot levels on the filter, manufacturers of CDPFs state that a temperature of greater than 350°C is required for 30% of the time, or 280°C for more than 50% of the time.

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CDPFs generally reduce CO and HC emissions by 80 to 90%. **Table 4-1** presents the control efficiency for CDPFs for reducing PM, CO and HC. CDPFs.

## 4.4.1.2 Oxidation catalyst plus DPF (CRT) - nitrogen dioxide soot oxidation

Nitrogen dioxide (NO<sub>2</sub>) can oxidise soot at a much lower temperature than oxygen, with greater oxidation rates occurring at temperatures around 250°C. To facilitate combustion under normal operating temperatures, NO<sub>2</sub> can be introduced. This oxidation can occur upstream of the filter with the aid of a DOC, and this design is referred to as a continuously regenerating DPF or a continuously regenerating trap (CRT). Although the catalyst increases NO<sub>2</sub> emissions, the total NO<sub>x</sub> emissions are unchanged.

CRTs require the use of diesel fuels with less than 50ppm sulfur and show improved regeneration performance with less than 10ppm sulfur.

Since NO<sub>2</sub> oxidises soot at a much lower temperature than oxygen (around 250°C), CRT type DPFs are more suitable for lower duty operation and reduce the risk of filter clogging through insufficient regeneration.

CRTs generally reduce CO and HC emissions by 80 to 90%. **Table 4-1** presents the control efficiency for CRTs for reducing PM, CO and HC. CDPFs, however, can cause elevated levels of NO<sub>2</sub>. Retrofit exhaust aftertreatment equipment must not increase NO<sub>2</sub> by more than 20% of the baseline total NOx emissions.

## 4.4.1.3 Combination passive DPF

DPFs options that combine both  $NO_2$  and oxygen-based oxidation are available for maximum low temperature regeneration performance. The DPF uses an upstream oxidation catalyst to generate increased levels of  $NO_2$ , in combination with a catalysed filter monolith to promote oxygen-based oxidation and further generation of  $NO_2$  within the filter. Although the catalyst increases  $NO_2$  emissions, the total  $NO_x$  emissions are unchanged.

#### 4.4.2 Active DPFs

Active DPF regeneration is preferred as a safety backup to normal passive DPF regeneration of catalysed DPF to avoid problems with low load (idling) engine operation.

Active DPF regeneration involves sophisticated engine controls to measure back pressure in the filter (which increases as PM accumulates). As the pressure reaches a certain level, excess fuel is injected either into the combustion cylinder or directly into the exhaust. The fuel is oxidised in the oxidation catalyst, causing an exothermic reaction that increases the temperature of the exhaust gas. The resultant heat causes the DPF temperatures to rise, initiating the oxidation of the trapped soot.

#### 4.4.3 DPF Maintenance

DPFs successfully oxidise soot and regenerate the DPF, however, the inorganic ash component of the diesel particulate matter (DPM) is unable to be burnt off and over time accumulates on the filter. Periodically, the DPF must be removed and cleaned (this can be achieved by blowing out with compressed air).

DPF cleaning intervals primarily depend on oil consumption, average engine load and DPF size. High oil consumption decreases cleaning intervals, as does higher average engine loads.

Operation of a passive DPF with higher-sulfur fuels can cause the filter to be overloaded with soot, leading to uncontrolled soot burning and permanent damage to both the filter and the vehicle. Actively regenerated DPFs, meanwhile, can experience increased back pressure under high sulphate levels, requiring more frequent regeneration. This translates into penalties in the form of higher fuel consumption and shorter maintenance intervals.

## 4.5 Selective Catalytic Reduction (SRC)

Selective Catalytic Reduction (SCR) is an active emissions control technology system that injects a liquidreductant agent through a metal-based catalyst into the exhaust stream of a diesel engine. The reductant source is usually automotive-grade urea or ammonia, which initiates a chemical reaction that converts nitrogen oxides into nitrogen, water and small amounts of carbon dioxide (CO<sub>2</sub>).

SCR requires the engine and exhaust system to be at operating temperature in order to work, and this requires special pre-heaters to be useful for reducing NOx for standby generators.

The time delay between when the engine is turned on and when the SCR is warm enough to be activated is a function of the amount of energy coming out of the engine and the thermal mass inertia that absorbs that energy between the engine and SCR system. An approach to shorten this time delay and thereby cut NOx emissions would be to reduce the thermal mass between the engine and SCR. This can be achieved by modifying the SCR placement in the exhaust system (moving it closer to the engine) or by placing the entire aftertreatment system closer to the engine. Insulating the engine exhaust manifold and exhaust pipe could also help, but to a lesser degree. An additional approach is to spray the urea over a hot surface or preheat the urea and inject it under pressure. These heated dosing approaches would make SCR control available much sooner in the test cycle and significantly reduce cold start emissions. California Air Resources Board (CARB) suggest that engine manufacturers are to utilise heated urea dosing in future engine designs (**CARB, 2020**).

More recently, on 22 December 2021, the Bay Area Air Quality Management District (BAAQMD) introduced rule 96.1.5 to retrospectively require Tier 4 equivalent performance from 1 January 2021, and presently this would need pre-heated SCR (See **Appendix C**)

After-market pollution control equipment suppliers, including for example Miratech Corporation, supply SCR systems in purpose-built enclosures that maintain the equipment at operating temperature at all times. Whilst these sorts of systems are relatively expensive, they are required in Silicon Valley, where there can be several moderate or large data centres within an airshed. SCR generally reduces PM by 30 to 50%, CO and HC by 50 to 90 % and NOx emissions up to 90%. **Table 4-1** presents the SCR control efficiency for reducing PM, CO, HC and NOx emissions.

## 4.6 Combined Heat and Power Technology

Another strategy to reduce the short-term peak emissions from emergency standby diesel generators at data centres is to replace them with on-site combined heat and power technology. The diesels are replaced with clean burning, natural gas-fuelled generators, which operate continuously (**CECS, 2002**).

## 4.7 Emission Control Technology Summary

Diesel exhaust aftertreatment controls that are effective in reducing PM, CO and HC emissions, including air toxic compounds are commonly available. Although all catalytic diesel exhaust aftertreatment

equipment for reduction of PM increase the level of NO<sub>2</sub> to some degree, the total NOx emissions are unchanged.

DOCs and pDPFs are effectively maintenance free, while DPFs require periodic cleaning.

Diesel fuel with the lowest possible sulfur content should be used. Diesel that complies with a sulfur content of less than 10 ppm is suitable for all diesel exhaust aftertreatment equipment and will maximise the emission control effectiveness.

**Table 4-1** presents a summary of the control efficiencies for various (previously discussed) diesel engine emission control equipment options for reducing particulate matter (PM), carbon monoxide (CO), hydrocarbon (HC) and oxides of nitrogen (NOx).

Control	PM Control Efficiency (%)	CO Control Efficiency (%)	HC Control Efficiency (%)	NOx Control Efficiency (%)			
<sup>1</sup> Diesel Oxidation Catalysts (DOCs)	15-30	50-90	40-90	-			
<sup>1</sup> Partial Diesel Particulate Filters (pDPFs)	30-50	70-90	60-80	-			
<sup>2</sup> Partial Flow Technology (PFT)	>50	>80	>80	-			
<sup>1</sup> Catalysed Diesel Particulate Filter (CDPF)	>90	80-95	70-95	-			
<sup>1</sup> Oxidation Catalyst plus Diesel Particulate Filter (CRT type DPF)	>90	80-95	70-95	-			
<sup>3</sup> Selective Catalytic Reduction (SRC)	30-50	50-90	50-90	90			

#### Table 4-1: Diesel engine control efficiency for PM, CO, HC and NOx

Source: <sup>1</sup>NSW EPA (2014), <sup>2</sup>Chatterjee S, Walker A.P & Blakeman P.G (2008), <sup>3</sup>Xeres Ventures LLC (2011)



## 5 ASSESSMENT OF STANDBY EMERGENCY DIESEL GENERATORS

Up to two hundred (200) standby emergency diesel generators (at one facility) were modelled at Tier 2 and Tier 4 emission standards to demonstrate the air quality impacts that varying numbers of generators at a facility could have on the surrounding environment. The following sections outline the engine specifications, modelled parameters and emissions.

The air quality impact assessment (AQIA) for the development of a data centre at Augusta Street, Blacktown (**Air Noise Environment, 2020**) was used as a base reference for modelling the 200 standby emergency diesel generators, given that it is for up to approximately 200 such generators, is in a central part of Sydney and is also relatively close to a background air quality monitoring station. It is important to note that this is not an endorsement of that assessment and that only basic information is taken from it for use in this report.

The assessment site is located at Augusta Street, Blacktown. The diesel generators modelled in the assessment were based on an 1800KW Cummins QSK60-G16 engine. The emission rates for the engine were sourced from exhaust emissions data sheet.

The Tier 2 emissions standards we have modelled are based on low emission combustion technology; however, these engines are not fitted with an SRC, oxygen catalysts or diesel particulate matter trap controls. Tier 2 engines are the most common engines currently in use. As can be seen later in the results, it is relatively clear that when cold-start and building wakes effects are considered (as necessary to reliably consider large data centres) the impacts can be large within a relatively close distance. This indicates the need for reduced emissions, hence Tier 4 equivalent controls were also considered.

The "Tier 4" emission standards we have modelled are based on Californian practice, where after-market pollution controls are added to provide approximately Tier 4 <u>equivalency</u> levels of emissions performance (noting that there is no formal Tier 4 Specification for standby emergency plant at present). This level of after-market control is required in some areas of California, and represents best available control technology for such plant. These engines incorporate SRC control technologies to reduce NO<sub>x</sub> emissions and other controls such as an oxidation catalyst and particulate catalyst that will significantly reduce overall pollutant emission rates. These add-on controls are expensive and are not commonly used outside of California at present.

## 5.1 Dispersion Modelling Approach

#### 5.1.1 Introduction

The following sections are included to provide the reader with an understanding of the model and the modelling approach applied for the assessment of the standby emergency diesel generators.

For this assessment, the CALPUFF modelling suite is applied to dispersion modelling. The model was setup in accordance with the NSW EPA documents *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (**NSW EPA, 2017**) and *Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia' (TRC Environmental Corporation, 2011).* 

## 5.1.2 Modelling methodology

## 5.1.2.1 Meteorological modelling

Modelling was undertaken using a combination of the CALPUFF Modelling System and The Air Pollution Model (TAPM). The CALPUFF Modelling System includes three main components: CALMET, CALPUFF and CALPOST and a large set of pre-processing programs designed to interface the model to standard, routinely available meteorological and geophysical datasets. TAPM is a prognostic air model used to simulate the upper air data for input to CALMET, the meteorological component of the CALPUFF modelling suite.

The meteorological modelling methodology applied a 'hybrid' approach which includes a combination of prognostic model data from The Air Pollution Model (TAPM) with surface observations in the CALMET model.

TAPM was applied to generate a 3D upper air data file for use in CALMET. The simulation involved an outer grid of 30km, with three nested grids of 10km, 3km and 1km with 35 vertical grid levels. The 2018 calendar year and the centre of analysis for the TAPM modelling used was based on the Augusta Street AQIA.

## 5.1.2.2 Dispersion modelling

The CALPUFF dispersion model, in conjunction with a CALMET generated meteorological data file, was applied to provide predictions of the ground level concentrations of potential pollutant concentrations associated with the operation of the standby emergency diesel generators.

As discussed, up to 200 standby emergency diesel generators were included in the dispersion modelling.

Up to 200 generators were modelled individually with a stack height of 22 meters (m) and a diameter of 0.4m. The stacks were modelled along one edge of the building, starting from the middle of the long side, with the final few generators modelled being positioned furthest from the middle. The modelled configuration is generally consistent with the plant design in the assessments containing such details.

The modelled generator stack exhaust velocity and temperature varies, depending on the time after start up (from cold) until the time the generator reaches ideal operating conditions. Three operating exhaust velocities and temperatures were applied in the model representing the period for the initial start up, after 10 minutes, and after 20 minutes. This is necessary to present a realistic estimate for emergency use, given that the generators are likely to start from cold. Note that this was only done for the Tier 2 plant that would start from cold and takes over 20 minutes to reach operating temperatures. For the Tier 4 specification, the plant pollutant controls would be pre-heated, and will operate at normal design levels almost immediately.

The modelled stack parameters for the diesel generators are outlined in Table 5-1.

		Parameter						
Source	Stack height (m)	Stack diameter (m)	Time from cold start (minutes)	Temperature (°C)	Exit velocity (m/s)			
Diocol			0 to 10	200	37.0			
generator	22	0.4	10 to 20	250	44.9			
				>20	350	48.7		

Table 5-1: Modelled stack parameters

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The model included consideration of potential building wake effects on air dispersion that arise due to the effect of winds passing over the buildings at the site.

It is noted that the above exhaust velocities may result in high levels of stack-tip noise, however the use of particle filters and other controls may provide some added noise abatement.

## 5.1.2.3 Emission estimation

Pollutants for the standby emergency diesel generators were modelled based on an hourly emissions profile as outlined above.

Whilst a range of pollutants are present in the exhaust, the key pollutants with potential to exceed the EPA ambient ground level impact assessment criteria are nitrogen dioxide (NO<sub>2</sub>) and fine particulates.

In general, particle filters/ particle catalysts/ particle traps would be used on the engines, and these can operate effectively from cold to minimise particulate levels effectively. This means that particulate is unlikely to be the limiting pollutant for compliance, and thus NO<sub>2</sub>, would be the key pollutant to consider for emissions from emergency standby power plant. This is because the controls for NO<sub>2</sub> can only operate effectively at high temperatures, that are not achieved at start up. (note the Tier 4 equivalent specification engines have pre-heated control systems for this reason).

The specifications for the Tier 2 engine are based on the emissions data for a Caterpillar 3516B Engine, at the rated speed (1,800 RPM) and 100% load (2,000kW), i.e., 15,988 g/hr, or 4.44g/s.

For the Tier 4 equivalent plant, the emission rate is based on Best Available Control Technology (BACT) per the Bay Area Air Quality Management District (BAAQMD) Rule 96.1.5, (i.e. 0.5g/bhp-hr, converted to 0.38 g/s for a 2,000Kw Engine). These emission rates are achieved by three facilities, including the Microsoft data centre in Quincy, Washington (see **Appendix C**). The modelled emission rates for each pollutant are summarised in **Table 5-2**. Emission rates for the first and next ten minute periods from cold start were modelled at 200% and 150% respectively.

Table 5-2: Emission rates (g/s)						
Pollutant Tier 2 Tier 4						
NOx (oxides of nitrogen as NO <sub>2</sub> )	4.44	0.38				

The Ozone Limiting Method (OML) outlined in Section 8.1.2 Page 39 of the NSW EPA Approved Methods is used to predict ground level concentrations of NO<sub>2</sub>. This method assumes that all of the available ozone in the atmosphere will react with NO<sub>2</sub> in the plume until either all the O<sub>3</sub> or all the NO<sub>2</sub> is exhausted. Ozone concentrations have been sourced from the Prospect monitoring station.

## **5.2 Dispersion Modelling Results**

The results produced by progressively modelling from 1 to 200 engines, at distances of 100 to 2,000m are presented in this section and in Appendix D. The impact was determined relative to the 1-hour EPA impact assessment criterion for NO<sub>2</sub> of  $246\mu g/m^3$ . As per the criteria, the existing background levels are included, and NO to NO<sub>2</sub> conversion per the OLM methods has been conducted. The results are for a nominal 2,000kW engine component of the generator. The criteria are applied at any "sensitive receptor". It is not controversial to determine that a location is a sensitive receptor when it is a dwelling,

school, hospital, nursing home etc. But is not always clear-cut whether a place of work or public place is a sensitive receptor. Guidance on making this determination simply and clearly is warranted in this case as the emissions would not be constant but may be high for a brief period of time.

It is also noted that the modelling and analysis in this report was prepared before the 15 April Environment Ministers' agreement to amend the NEPM criteria, reducing NO<sub>2</sub> levels from 246 to 185µg/m<sup>3</sup>, however it is pointed out that the NEPM standards are not equivalent in terms of where and to whom and how they apply relative to impact assessment criteria, even when the same numerical value is used.





Figure 5-1: Number of generators that can achieve compliance with EPA criteria for 1-hr average NO<sub>2</sub> as a function of distance, for Tier 2 (top) and Tier 4 (bottom) engine emissions performance (within 2,000m of engines).

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Figure 5-2: Number of generators that can achieve compliance with EPA criteria for 1-hr average NO<sub>2</sub> as a function of distance, for Tier 2 (top) and Tier 4 (bottom) engine emissions performance. (within 500m of engines)

**Figure 5-1** and **Figure 5-2** present the number of predicted generators complying with the NSW EPA  $NO_2$  criterion concentration of  $246\mu g/m^3$  at varying distances , for Tier 2 and Tier 4 engine emissions performance.

It is noted that we did not find Tier 3 engine emissions performance standards for standby emergency back-up diesel generators. It would appear that Tier 3 performance may have been "leap-frogged" by rapid technological developments in the US.

Detailed tables of the Tier 2 and Tier 4  $NO_2$  concentrations and the number of generators at varying distances is provided in **Appendix C**.

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#### 6 DISCUSSION

The results show that relatively few generators with Tier 2 performance would cause short-term 1-hr average impacts above the EPA criteria, and within relatively close distances to the engines. These results thus indicate that the POEO Regulation exemptions may have been intended to only apply to one engine, (and not many, as it appears may be interpreted at present).

The results however show that a large number of generators can operate without impact provided that Tier4 equivalent engine performance is achieved and there is a reasonable separation distance.

Generally, the Tier 4 results follow a curved line of fit, largely due to building wake effects in the near field of the building fetch. This appears to be a distance of approximately 300m for the relatively large data centre buildings presently being approved/ proposed in NSW. The results indicate that a high degree of caution should be approved where there are receptors within 300m of the proposed generator engines.

It is important to note that the probability of exceedances arising has not been considered due to time constraints in this study (and the complexity of modelling up to 200 separate sources and combing them variously). It is noted that the EPA criteria are to be assessed at the 100<sup>th</sup> percentile, meaning that they must be met in every hour of the year. Thus the predicted maximum impact could arise if the facility was operating in the hour that lead to the maximum impact. An impact is also likely to occur in other hours of the year, however just how many hours has not been determined at present. It is acknowledged that for a facility that only operates for a very few hours in any year, the risk of any impact may be relatively low. On the other hand, the greater likelihood that there is a power failure during hot conditions with high background pollutant levels, is also not considered. It is not suggested that these two potentially competing factors cancel each other out or should be ignored, rather that there may need to be more detailed consideration given to these issues should further refinement be done.

Nevertheless, the main issue appears to be the sheer number of co-located engines at a large data centre, and presently the general lack of valid or sufficiently detailed air quality impact assessments being made for these facilities. The results of this study show that there is a significant risk of large short-term impacts within 2km of the facilities being approved. Whilst there are benefits to having stable data and power, there would also be short-term health impacts when the back-up generators operate at a location (or en-masse when there are many such facilities in an air-shed) and these impacts do not appear to be accounted for in the planning assessment process at present.

It needs to be noted that the modelling results are specific to a relatively central part of the Sydney basin, are for vertical stack (whereas many applications specify poorly dispersing horizontal stacks) and may not be applicable in high rise CBD areas, in areas with steep, complex terrain, or if there are other significant sources of NO<sub>2</sub> nearby, such as a motorway etc. In rural areas, where background NO<sub>2</sub> and Ozone levels will be lower, the separations distances may be smaller than the results show.

Nevertheless, the indications are that the results could be further refined and adapted to develop a look-up chart, or that a relatively simple modelling tool could be developed to facilitate speedier assessment of applications. At present, noting the limitations of the modelling, Figure 5-1 and Figure 5-2 can still be used to guide approval agencies on when to seek additional information and detailed air quality impact assessments. For example, if Tier 2 performance engines are being proposed, projects with 10 engines may require separation distances of more than 500m, whereas applications for approximately 100 Tier 4 equivalent engines may be acceptable with the same 500m separation distance.

It is also crucial to note that because there will be high NO<sub>2</sub> emissions when starting from cold, the Tier4 equivalent performance for an emergency standby or back-up generator engine is different to that for a non-emergency (non-standby/ non-back-up) engine that may achieve Tier 4 performance under normal operating conditions. The Tier 4 equivalent performance for an emergency standby back-up generator presently requires third-party pollution controls to be fitted (to a Tier 2 engine), including a pre-heated selective catalytic reduction (SCR) for NO<sub>2</sub> abatement. The pre-heated SCR makes the Tier 4 equivalent specification different to the normal Tier 4 specification for non-emergency engines where the SCR is not pre-heated and may generate high emissions in the initial approx. 20 minute warm up period.

There are various companies in Australia and overseas that can fit Tier 4 equivalent controls to an emergency standby backup generator engine. Apart from a pre-hated SCR system, the add-on pollution controls generally also include a catalysed diesel particulate filter, (normally using a metal and not ceramic substrate), installed close to the turbo so as to reach operating temperature within tens of seconds.

## 7 DRAFT RECCOMENDATIONS

This section provides draft recommendations for back-up power supply operations. It is anticipated that these may need to be adjusted upon receiving feedback from operators and regulators, or further refinement of the study.

Table 7-1: Draft recommendations						
Parameter	Recommendation					
Fuel quality	Require the use of low sulfur diesel for all backup diesel engines.					
Size and number of engines	Engines capacity to be sized for the appropriate load and to ensure no impacts on					
Size and number of engines	existing and likely future receptors.					
	Either make this part of the up to 200 hours per annum of operation time permitted or					
	specify less hours for maintenance and testing (e.g., 50 hours per annum) and					
Emergency operating time	unlimited hours of operation during emergencies.					
	(Note that there appears to be potentially conflicting EPA advice on this for recent					
	projects).					
	Restrict testing and maintenance activities during peak hour times and on poor (or					
Maintenance and testing	worse) Air Quality Index ( AQI) days.					
Wantenance and testing	Potentially limit maintenance and testing to 50 hours per year per generator to					
	prevent perverse outcomes.					
Examplianc	Backup power supplies at nuclear sites and military/defence facilities.					
Exemptions	Research and development of engines or components.					
	Do not allow use for peak shaving and demand response programs					
	Engines that are part of any of the Reliability and Emergency Reserve Trader (RERT) are					
	not considered emergency engines.					
Other non-emergency use	Consider exemptions to the above if there is extremely low risk of impacts, e.g.					
	maximum worst-case cumulative impacts are well below half the criteria, and other					
	policy considerations e.g. GHG etc are met. This may be limited to be a temporary					
	measure during grid changes. Transition periods in a locality.					
	Require backup generators to be installed with consideration of receptors e.g. position					
Leasting	exhausts as far from receptors as feasible.					
Location	Consider developing a simple tool/guideline for appropriate siting to minimise ground					
	level impacts at receptors (or off-site for likely future receptors).					
	Specify high velocity vertically discharging stacks away from structures to minimise					
	huilding downwash and wake effects that can cause emissions to stay near ground					
Design	level. The indication is that this can occur within approximately 300m of data centre					
	buildings/ stacks.					
	Specify minimum anging amissions performance as a concentration (similar to POEO)					
	specify minimum engine emissions performance as a concentration (similar to POEO) and (or adapt emissions standards as $\sigma/kW$ by as par USA					
	The US approach is proforable (over other jurisdictions) as the framework is well					
	established transparent and generally more compatible with many aspects of the NSW					
	framework such as for monitoring					
	Minimum standard would be US Tier II (or EU performance equivalent) for					
	any engine in any location (Reason minimise emissions per POEO/ FPA					
	guidelines, and develop a minimum common level of performance to provide					
	sufficient scale for a viable parts/maintenance/service/supply industry)					
Emission standards	<ul> <li>Tier IV (equivalent) for large installations in Urban locations or within a</li> </ul>					
	specific distance to a recentor. (This is per BAAOMD rule 96.1.5 pollution					
	add-on controls) and appears to be necessary for any significantly large data					
	centre in an urban environment.					
	Potentially see if practical to refine above by linking performance/emission standards					
	with:					
	<ul> <li>Location (e.g. GMR/ distance to receptor/ Urban zoning, etc);</li> </ul>					
	<ul> <li>Outcome of simple modelling tool/guideline for siting; and,</li> </ul>					
	• Size and number.					
Controls	Don't specify type of control required, condition should be to meet emissions					
Controis	standards with ability to retro fit controls if needed.					

	Consider providing <u>examples</u> of currently suitable controls needed to meet specific standards. E.g. BAAQMD Application 27020 San Jose/ Santa Clara; BAAQMD application 25115 Sutro Tower, Microsoft MWH Data Centre, Quincy, Washington (Reason: if a specific type of control is specified, this can become outdated quickly, and can hamper better, cheaper controls being used to achieve the same outcome.
	However, this also requires a higher level of skill by the assessing agency.).
	Require engines to have a non-resettable hour meter.
Record keeping	Require documentation of how many hours are spent for emergency operation,
Record Recping	including the type/cause of the emergency and how many hours are spent for non-
	emergency operation.
	Recommended to require post commissioning testing on a representative number of
Monitoring	generators (per US methods/ framework). These are consistent with the NSW EPA
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**Appendix A** 

40 CFR Part 60 Subpart JJJJ Standards of Performance for Stationary Spark Ignition Internal Combustion Engines

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The relevant parts of 40 CFR Part 60 Subpart JJJJ have been summarised in the sections below.

## 40 CFR 60.4231 - What emission standards must I meet if I am a manufacturer of stationary SI internal combustion engines or equipment containing such engines?

Manufacturers must certify their emergency stationary ICE with a maximum engine power greater than or equal to 130 HP, to the certification emission standards and other requirements for new nonroad SI engines in 40 CFR part 1048. Stationary SI internal combustion engine manufacturers must certify their emergency stationary SI ICE with a maximum engine power greater than 25 HP and less than 130 HP that use gasoline or that are rich burn engines that use LPG and that are manufactured on or after the applicable date to the Phase 1 emission standards in 40 CFR 90.103, applicable to class II engines, and other requirements for new nonroad SI engines in 40 CFR part 90.

Stationary SI internal combustion engine manufacturers who choose to certify their emergency stationary SI ICE greater than 25 HP and less than 130 HP (except gasoline and rich burn engines that use LPG), must certify those engines to the Phase 1 emission standards in 40 CFR 90.103, applicable to class II engines, for new nonroad SI engines in 40 CFR part 90.

Table 8-1: 4	Table 8-1: 40 CFR 90.103 Table 1 - Phase Exhaust Emission Standards (grams per kilowatt-hour)									
Engine displacement class	Hydrocarbons + oxides of nitrogen (HC + NOX)	Hydrocarbons	Carbon monoxide	Oxides of nitrogen (NOX)						
II	13.4		519	II						

## Table 8-1: 40 CFR 90.103 Table 1 - Phase Exhaust Emission Standards (grams per kilowatt-hour)

## Table 8-2: 40 CFR 90.103 Table 3 - Phase 2 Class II Engine Exhaust Emission Standards by Model Year (grams per kilowatt-

11001)							
	Emission	Model Year					
Engine class	requirement	2001	2002	2003	2004	2005 and later	
	HC + NOX	18.0	16.6	15.0	13.6	12.1	
II	NMHC + NOX	16.7	15.3	14.0	12.7	11.3	
	CO	610	610	610	610	610	

## 40 CFR 60.4233 - What emission standards must I meet if I am an owner or operator of a stationary SI internal combustion engine?

Owners and operators of emergency stationary SI ICE with a maximum engine power greater than 19 KW (25 HP) and less than 75 KW (100 HP) (except gasoline and rich burn engines that use LPG) must comply with the emission standards in Table 1 to this subpart for their emergency stationary SI ICE.

Owners and operators of emergency stationary SI ICE with a maximum engine power greater than 19 KW (25 HP) that are gasoline engines or rich burn engines that use LPG, must comply with the same emission standards as those specified in CFR 60.4231.

Owners and operators of stationary SI natural gas and lean burn LPG emergency engines greater than or equal to 130 HP must meet a nitrogen oxides (NOX) emission standard of 3.0 grams per HP-hour (g/HP-hr), a CO emission standard of 4.0 g/HP-hr, and a volatile organic compounds (VOC) emission standard of 1.0 g/HP-hr, or a NOX emission standard of 250 ppmvd at 15 percent oxygen (O2), a CO emission standard 540 ppmvd at 15 percent O2, and a VOC emission standard of 86 ppmvd at 15

percent O2, where the date of manufacture of the engine is prior to January 1, 2009, for emergency engines.

## 40 CFR 60.4237 - What are the monitoring requirements if I am an owner or operator of an emergency stationary SI internal combustion engine?

- Starting on July 1, 2010, if the emergency stationary SI internal combustion engine that is greater than or equal to 500 HP that was built on or after July 1, 2010, does not meet the standards applicable to non-emergency engines, the owner or operator must install a nonresettable hour meter.
- Starting on January 1, 2011, if the emergency stationary SI internal combustion engine that is greater than or equal to 130 HP and less than 500 HP that was built on or after January 1, 2011, does not meet the standards applicable to non-emergency engines, the owner or operator must install a non-resettable hour meter.
- If you are an owner or operator of an emergency stationary SI internal combustion engine that is less than 130 HP, was built on or after July 1, 2008, and does not meet the standards applicable to non-emergency engines, you must install a non-resettable hour meter upon start-up of your emergency engine.

## 40 CFR 60.4243 - What are my compliance requirements if I am an owner or operator of a stationary SI internal combustion engine?

For the engine to be considered an emergency stationary ICE, any operation other than emergency operation, maintenance and testing, emergency demand response, and operation in non-emergency situations for 50 hours per year, is prohibited.

There is no time limit on the use of emergency stationary ICE in emergency situations.

You may operate your emergency stationary ICE for any combination of the purposes below for a maximum of 100 hours per calendar year.

- + Emergency stationary ICE may be operated for maintenance checks and readiness testing
- Emergency stationary ICE may be operated for emergency demand response for authorised periods
- Emergency stationary ICE may be operated for periods where there is a deviation of voltage or frequency of 5 percent or greater below standard voltage or frequency

Emergency stationary ICE may be operated for up to 50 hours per calendar year in non-emergency situations. The 50 hours of operation in non-emergency situations are counted as part of the 100 hours per calendar year for maintenance and testing and emergency demand response. The 50 hours per year for non-emergency situations cannot be used for peak shaving or non-emergency demand response, or to generate income for a facility to an electric grid or otherwise supply power as part of a financial arrangement with another entity.

The 50 hours per year for non-emergency situations can be used to supply power as part of a financial arrangement with another entity if all the following conditions are met:

- The engine is dispatched by the local balancing authority or local transmission and distribution system operator;
- The dispatch is intended to mitigate local transmission and/or distribution limitations so as to avert potential voltage collapse or line overloads that could lead to the interruption of power supply in a local area or region.
- The dispatch follows reliability, emergency operation or similar protocols that follow specific NERC, regional, state, public utility commission or local standards or guidelines.
- The power is provided only to the facility itself or to support the local transmission and distribution system.
- The owner or operator identifies and records the entity that dispatches the engine and the specific NERC, regional, state, public utility commission or local standards or guidelines that are being followed for dispatching the engine. The local balancing authority or local transmission and distribution system operator may keep these records on behalf of the engine owner or operator.

Owners and operators of stationary SI natural gas fired engines may operate their engines using propane for a maximum of 100 hours per year as an alternative fuel solely during emergency operations but must keep records of such use. If propane is used for more than 100 hours per year in an engine that is not certified to the emission standards when using propane, the owners and operators are required to conduct a performance test to demonstrate compliance with the emission standards of CFR 60.4233.

## 40 CFR 60.4245 - What are my notification, reporting, and recordkeeping requirements if I am an owner or operator of a stationary SI internal combustion engine?

The owner or operator must document how many hours are spent for emergency operation, including what classified the operation as emergency and how many hours are spent for non-emergency operation. The operator of the following engines must keep records of the hours of operation of the engine through a non-resettable hour meter:

- For all stationary SI emergency ICE greater than or equal to 500 HP manufactured on or after July 1, 2010, that do not meet the standards applicable to non-emergency engines
- For all stationary SI emergency ICE greater than or equal to 130 HP and less than 500 HP manufactured on or after July 1, 2011 that do not meet the standards applicable to nonemergency engines
- For all stationary SI emergency ICE greater than 25 HP and less than 130 HP manufactured on or after July 1, 2008, that do not meet the standards applicable to non-emergency engines

### Table 1 to Subpart JJJJ of Part 60

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Engine type and fuel	Maximum	Manufactura	Emissions standards					
	engine power date	data		g/HP-hr		ppmvd at 15% O		
		uate	NOx	СО	VOC	NOx	СО	VOC
Emorgonou	25 <hp<130< td=""><td>1/1/2009</td><td>c 10</td><td>387</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></hp<130<>	1/1/2009	c 10	387	N/A	N/A	N/A	N/A
Emergency	HP≥130		2.0	4.0	1.0	160	540	86

Table 8-3: NOX, CO, and VOC Emission Standards for Stationary Emergency Engines >25 HP

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## **Appendix B**

40 CFR Part 63 Subpart ZZZZ National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines

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The relevant parts of 40 CFR Part 63 Subpart ZZZZ have been summarised in the sections below.

### 40 CFR 63.6585 - Am I subject to this subpart?

The emergency stationary RICE listed below are not subject to this subpart:

- Existing residential, commercial and institutional emergency stationary RICE located at an area source of HAP emissions that do not operate or are not contractually obligated to be available for more than 15 hours per calendar year for the purposes specified in 40 CFR 63.6640.
- + Existing emergency stationary RICE with a site rating of more than 500 brake HP located at a major source of HAP emissions that does not operate or is not contractually obligated to be available for more than 15 hours per calendar year for the purposes specified in 40 CFR 63.6640.
- + A new or reconstructed emergency or limited use stationary RICE with a site rating of less than or equal to 500 brake HP located at a major source of HAP emissions

# 40 CFR 63.6600 - What emission limitations and operating limitations must I meet if I own or operate a stationary RICE with a site rating of more than 500 brake HP located at a major source of HAP emissions?

If you own or operate an emergency stationary RICE with a site rating of more than 500 brake HP located at a major source of HAP emissions, you do not need to comply with the emission limitations in Tables 1a, 2a, 2c, and 2d to this subpart or operating limitations in Tables 1b and 2b to this subpart.

## 40 CFR 63.6603 - What emission limitations, operating limitations, and other requirements must I meet if I own or operate an existing stationary RICE located at an area source of HAP emissions?

If you own or operate an emergency stationary RICE with a site rating of more than 500 brake HP located at a major source of HAP emissions, you do not need to comply with the emission limitations in Tables 1a, 2a, 2c, and 2d to this subpart or operating limitations in Tables 1b and 2b to this subpart:

#### 40 CFR 63.6604 - What fuel requirements must I meet if I own or operate a stationary CI RICE?

If you own or operate an existing emergency CI stationary RICE with a site rating of more than 100 brake HP and a displacement of less than 30 litres per cylinder that uses diesel fuel or with a site rating of more than 500 brake HP and a displacement of less than 30 litres per cylinder located at a major source of HAP that uses diesel fuel and operates or is contractually obligated to be available for more than 15 hours per calendar year for the purposes specified in 40 CFR 63.6640, you must use diesel fuel that meets the requirements in 40 CFR 80.510.

40 CFR 80.510 indicates that diesel fuel can have a maximum sulfur content of 15ppm and a minimum cetane index of 40 or a maximum aromatic content of 35 volume percent.

## 40 CFR 63.6625 - What are my monitoring, installation, collection, operation, and maintenance requirements?
If you are operating a new or reconstructed emergency 4SLB stationary RICE with a site rating of greater than or equal to 250 and less than or equal to 500 brake HP located at a major source of HAP emissions, you must install a non-resettable hour meter prior to the start-up of the engine.

If you own or operate any of the following stationary RICE, you must operate and maintain the stationary RICE and after-treatment control device (if any) according to the manufacturer's emission-related written instructions or develop your own maintenance plan which must provide to the extent practicable for the maintenance and operation of the engine in a manner consistent with good air pollution control practice for minimizing emissions:

- An existing emergency or black start stationary RICE with a site rating of less than or equal to 500 HP located at a major source of HAP emissions
- + An existing emergency or black start stationary RICE located at an area source of HAP emissions

# 40 CFR 63.6640 - How do I demonstrate continuous compliance with the emission limitations, operating limitations, and other requirements?

If you own or operate an existing emergency stationary RICE with a site rating of less than or equal to 500 brake HP located at a major source of HAP emissions or an existing emergency stationary RICE located at an area source of HAP emissions, you must install a non-resettable hour meter if one is not already installed.

For the engine to be considered an emergency stationary RICE, any operation other than emergency operation, maintenance and testing, emergency demand response, and operation in non-emergency situations for 50 hours per year is prohibited.

There is no time limit on the use of emergency stationary RICE in emergency situations.

You may operate your emergency stationary RICE for any combination of the purposes below for a maximum of 100 hours per calendar year.

- Emergency stationary RICE may be operated for maintenance checks and readiness testing, provided that the tests are recommended by federal, state or local government, the manufacturer, the vendor, the regional transmission organization or equivalent balancing authority and transmission operator, or the insurance company associated with the engine.
- Emergency stationary RICE may be operated for emergency demand response for authorised periods
- Emergency stationary RICE may be operated for periods where there is a deviation of voltage or frequency of 5 percent or greater below standard voltage or frequency.

Emergency stationary RICE located at major sources and area sources of HAP may be operated for up to 50 hours per calendar year in non-emergency situations. The 50 hours of operation in non-emergency situations are counted as part of the 100 hours per calendar year for maintenance and testing and emergency demand response. The 50 hours per year for non-emergency situations cannot be used for

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peak shaving or non-emergency demand response, or to generate income for a facility to supply power to an electric grid or otherwise supply power as part of a financial arrangement with another entity.

The 50 hours per year for non-emergency situations can be used to supply power as part of a financial arrangement with another entity if all the following conditions are met:

- The engine is dispatched by the local balancing authority or local transmission and distribution system operator.
- The dispatch is intended to mitigate local transmission and/or distribution limitations so as to avert potential voltage collapse or line overloads that could lead to the interruption of power supply in a local area or region.
- The dispatch follows reliability, emergency operation or similar protocols that follow specific NERC, regional, state, public utility commission or local standards or guidelines.

### 40 CFR 63.6655 - What records must I keep?

You must keep records of the maintenance conducted on an existing stationary emergency RICE in order to demonstrate that you operated and maintained the stationary RICE and after-treatment control device (if any) according to your own maintenance plan.

You must keep records of the hours of operation of the engine that is recorded through the nonresettable hour meter. The owner or operator must document how many hours are spent for emergency operation, including what classified the operation as emergency and how many hours are spent for nonemergency operation. The owner or operator must keep records of the notification of the emergency, and the date, start time, and end time of engine operation for these purposes.

### Table 1a to Subpart ZZZZ of Part 63

 Table 8-4: Emission Limitations for Existing, New, and Reconstructed Spark Ignition, 4SRB Stationary RICE >500 HP

 Located at a Major Source of HAP Emissions

For each	You must meet the following emission limitation, except during periods of start-up	During periods of start-up you must .
1. 4SRB stationary RICE	a. Reduce formaldehyde emissions by 76 percent or more. If you commenced construction or reconstruction between December 19, 2002 and June 15, 2004, you may reduce formaldehyde emissions by 75 percent or more until June 15, 2007 or	Minimize the engine's time spent at idle and minimize the engine's start- up time at start-up to a period needed for appropriate and safe loading of the engine, not to exceed 30 minutes, after which time the non- start-up emission limitations apply
	b. Limit the concentration of formaldehyde in the stationary RICE exhaust to 350 pobyd or less at 15	
	percent O2	

### Table 1b to Subpart ZZZZ of Part 63

## Table 8-5: Operating Limitations for Existing, New, and Reconstructed SI 4SRB Stationary RICE >500 HP Located at a Major Source of HAP Emissions

For each	You must meet the following operating limitation, except during periods of start-up .
<ol> <li>1. existing, new and reconstructed 4SRB stationary RICE &gt;500 HP located at a major source of HAP emissions complying with the requirement to reduce formaldehyde emissions by 76 percent or more (or by 75 percent or more, if applicable) and using NSCR; or</li> <li>2. existing, new and reconstructed 4SRB stationary RICE &gt;500 HP located at a major source of HAP emissions complying with the requirement to limit the concentration of formaldehyde in the stationary RICE exhaust to 350 ppbvd or less at 15 percent O2 and using NSCR;</li> </ol>	<ul> <li>a. maintain your catalyst so that the pressure drop across the catalyst does not change by more than 2 inches of water at 100 percent load plus or minus 10 percent from the pressure drop across the catalyst measured during the initial performance test; and</li> <li>b. maintain the temperature of your stationary RICE exhaust so that the catalyst inlet temperature is greater than or equal to 750 °F and less than or equal to 1250 °F.</li> </ul>
2. existing, new and reconstructed 4SRB stationary RICE >500 HP	
located at a major source of HAP emissions complying with the	Comply with any operating limitations
requirement to reduce formaldehyde emissions by 76 percent or	approved by the Administrator.
more (or by 75 percent or more, if applicable) and not using NSCR; or	
existing, new and reconstructed 4SRB stationary RICE >500 HP located	
at a major source of HAP emissions complying with the requirement	
to limit the concentration of formaldehyde in the stationary RICE	
exhaust to 350 ppbvd or less at 15 percent O2 and not using NSCR.	

### Table 2a to Subpart ZZZZ of Part 63

#### Table 8-6: Emission Limitations for New and Reconstructed 2SLB and Compression Ignition Stationary RICE >500 HP and New and Reconstructed 4SLB Stationary RICE ≥250 HP Located at a Major Source of HAP Emissions

For each	You must meet the following emission limitation, except during periods of start-up	During periods of start-up you must .
1. 2SLB stationary RICE	a. Reduce CO emissions by 58 percent or more; or b. Limit concentration of formaldehyde in the stationary RICE exhaust to 12 ppmvd or less at 15 percent O2. If you commenced construction or reconstruction between December 19, 2002 and June 15, 2004, you may limit concentration of formaldehyde to 17 ppmvd or less at 15 percent O2 until June 15, 2007	Minimize the engine's time spent at idle and minimize the engine's start- up time at start-up to a period needed for appropriate and safe loading of the engine, not to exceed 30 minutes, after which time the non- start-up emission limitations apply.
2. 4SLB stationary RICE	a. Reduce CO emissions by 93 percent or more; or	
	b. Limit concentration of formaldehyde in the stationary RICE exhaust to 14 ppmvd or less at 15 percent O2	
3. CI stationary RICE	a. Reduce CO emissions by 70 percent or more; or	
	b. Limit concentration of formaldehyde in the stationary RICE exhaust to 580 ppbvd or less at 15 percent O2	

### Table 2b to Subpart ZZZZ of Part 63

 Table 8-7: Operating Limitations for Existing, New, and Reconstructed SI 4SRB Stationary RICE >500 HP Located at a

 Major Source of HAP Emissions

For each	You must meet the following operating limitation, except during periods of start-up

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<ol> <li>New and reconstructed 2SLB and CI stationary RICE &gt;500 HP located at a major source of HAP emissions and new and reconstructed 4SLB stationary RICE ≥250 HP located at a major source of HAP emissions complying with the requirement to reduce CO emissions and using an oxidation catalyst; and New and reconstructed 2SLB and CI stationary RICE &gt;500 HP located at a major source of HAP emissions and new and reconstructed 4SLB stationary RICE ≥250 HP located at a major source of HAP emissions complying with the requirement to limit the concentration of formaldehyde in the stationary RICE exhaust and using an oxidation catalyst.</li> </ol>	<ul> <li>a. maintain your catalyst so that the pressure drop across the catalyst does not change by more than 2 inches of water at 100 percent load plus or minus 10 percent from the pressure drop across the catalyst that was measured during the initial performance test; and</li> <li>b. maintain the temperature of your stationary RICE exhaust so that the catalyst inlet temperature is greater than or equal to 450 °F.</li> </ul>
2. Existing CI stationary RICE >500 HP complying with the requirement to limit or reduce the concentration of CO in the stationary RICE exhaust and using an oxidation catalyst	<ul> <li>a. maintain your catalyst so that the pressure drop across the catalyst does not change by more than 2 inches of water from the pressure drop across the catalyst that was measured during the initial performance test; and</li> <li>b. maintain the temperature of your stationary RICE exhaust so that the catalyst inlet temperature is greater than or equal to 450 °F and less than or equal to 1350 °F.</li> </ul>
3. New and reconstructed 2SLB and CI stationary RICE >500 HP located at a major source of HAP emissions and new and reconstructed 4SLB stationary RICE ≥250 HP located at a major source of HAP emissions complying with the requirement to reduce CO emissions and not using an oxidation catalyst; and New and reconstructed 2SLB and CI stationary RICE >500 HP located at a major source of HAP emissions and new and reconstructed 4SLB stationary RICE ≥250 HP located at a major source of HAP emissions and new and reconstructed 4SLB stationary RICE ≥250 HP located at a major source of HAP emissions and new and reconstructed 4SLB stationary RICE ≥250 HP located at a major source of HAP emissions complying with the requirement to limit the concentration of formaldehyde in the stationary RICE exhaust and not using an oxidation catalyst; and existing CI stationary RICE >500 HP complying with the requirement to limit or reduce the concentration of CO in the stationary RICE exhaust and not using an oxidation catalyst.	Comply with any operating limitations approved by the Administrator.

### Table 2c to Subpart ZZZZ of Part 63

Table 8-8: Requirements for Existing Compression Ignition Stationary RICE Located at a Major Source of HAP Emissions and Existing Spark Ignition Stationary RICE ≤500 HP Located at a Major Source of HAP Emissions

	You must meet the following emission limitation, except	During periods of start-up you must .
For each	during periods of start-up	·· ··
1. Emergency	a. Change oil and filter every 500 hours of operation or	Minimize the engine's time spent at
stationary CI RICE	annually, whichever comes first.	idle and minimize the engine's start-
and black start	b. Inspect air cleaner every 1,000 hours of operation or	up time at start-up to a period
stationary Cl	annually, whichever comes first, and replace as	needed for appropriate and safe
RICE1	necessary;	loading of the engine, not to exceed
	c. Inspect all hoses and belts every 500 hours of	30 minutes, after which time the non-
	operation or annually, whichever comes first, and replace	start-up emission limitations apply
	as necessary.	
6. Emergency	a. Change oil and filter every 500 hours of operation or	
stationary SI RICE	annually, whichever comes first;	
and black start	b. Inspect spark plugs every 1,000 hours of operation or	
stationary SI RICE.	annually, whichever comes first, and replace as	
	necessary;	
	c. Inspect all hoses and belts every 500 hours of	
	operation or annually, whichever comes first, and replace	
	as necessary.	

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If an emergency engine is operating during an emergency and it is not possible to shut down the engine in order to perform the work practice requirements on the schedule required in Table 2c of this subpart, or if performing the work practice on the required schedule would otherwise pose an unacceptable risk under federal, state, or local law, the work practice can be delayed until the emergency is over or the unacceptable risk under federal, state, or local law has abated. The work practice should be performed as soon as practicable after the emergency has ended or the unacceptable risk under federal, state, or local law has abated. Sources must report any failure to perform the work practice on the schedule required and the federal, state or local law under which the risk was deemed unacceptable.

### Table 2d to Subpart ZZZZ of Part 63

Table 8-9: Requirements for Existing Stationary RICE Located at Area Sources of HAP Emissions									
For each	You must meet the following emission limitation, except during periods of start-up	During periods of start- up you must							
4. Emergency stationary CI RICE and black start stationary CI RICE.	<ul> <li>a. Change oil and filter every 500 hours of operation or annually, whichever comes first;</li> <li>b. Inspect air cleaner every 1,000 hours of operation or annually, whichever comes first, and replace as necessary; and</li> <li>c. Inspect all hoses and belts every 500 hours of operation or annually, whichever comes first, and replace as necessary.</li> </ul>								
5. Emergency stationary SI RICE; black start stationary SI RICE; non- emergency, non-black start 4SLB stationary RICE >500 HP that operate 24 hours or less per calendar year; non-emergency, non-black start 4SRB stationary RICE >500 HP that operate 24 hours or less per calendar year.	<ul> <li>a. Change oil and filter every 500 hours of operation or annually, whichever comes first;</li> <li>b. Inspect spark plugs every 1,000 hours of operation or annually, whichever comes first, and replace as necessary; and</li> <li>c. Inspect all hoses and belts every 500 hours of operation or annually, whichever comes first, and replace as necessary.</li> </ul>								

If an emergency engine is operating during an emergency and it is not possible to shut down the engine in order to perform the management practice requirements on the schedule required in Table 2d of this subpart, or if performing the management practice on the required schedule would otherwise pose an unacceptable risk under federal, state, or local law, the management practice can be delayed until the emergency is over or the unacceptable risk under federal, state, or local law has abated. The management practice should be performed as soon as practicable after the emergency has ended or the unacceptable risk under federal, state, or local law has abated. Sources must report any failure to perform the management practice on the schedule required and the federal, state or local law under which the risk was deemed unacceptable.

### Appendix C

BAAQMD Rule 96.1.5, BACT Determination for Diesel Back-Up Engines Greater than or equal to 1,000 Brake Horsepower

DOCKETED	
Docket Number:	19-SPPE-04
Project Title:	SJ2
TN #:	236089
Document Title:	BAAQMD letter Re BACT Determination For Diesel Back-up Engines Greater Than or Equal to 1,000 Break Horsepower
Description:	From Jack P. Broadbent, Executive Officer, APCO, Bay Area Quality
Filer:	Lisa Worrall
Organization:	Bay Area Quality Management District
Submitter Role:	Public Agency
Submission Date:	12/22/2020 1:22:37 PM
Docketed Date:	12/22/2020



# Bay Area Air Quality

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Jack P. Broadbent EXECUTIVE OFFICER/APCO

Connect with the Bay Area Air District:



### 12/21/2020

Mr. Richard Corey Executive Officer California Air Resources Board 1001 I Street, Sacramento, CA 95814

Mr. Drew Bohan Executive Director California Energy Commission 1516 Ninth Street Sacramento, CA 95814

# RE: BACT Determination for Diesel Back-Up Engines Greater than or equal to 1,000 Brake Horsepower

Dear Mr. Corey and Mr. Bohan,

The purpose of this letter is to inform your agencies that the Bay Area Air Quality Management District (Air District) has established a best available control technology (BACT) guideline for large (greater or equal to 1,000 brake horsepower) diesel engines used for emergency standby power that requires them to meet the U. S. EPA's Tier 4 emissions standards. This determination will apply to any new and open permit application with a diesel backup engine  $\geq$  1000 bhp that is deemed complete after 1/1/2020.

The Air District is the entity charged with permitting for stationary sources of air pollution in the nine-county region surrounding the San Francisco bay. Air District permits are required by law for:

- Any stationary equipment that may cause air pollution;
- · Modifications to existing permitted equipment or their permit conditions;
- Permitted equipment that is moved to a new location;
- Transfer of permitted equipment to new owners; and
- Installation of equipment used to control emissions.

As part of our permitting processes, The Air District's New Source Review Rule -Regulation 2, Rule 2 (Regulation 2, Rule 2) - requires that new or modified sources of air pollutants undergo permit review for Best Available Control Technology (BACT). BACT2 "Achieved-In-Practice", applies to the most effective emission controls already in use or the most stringent emission limit achieved in the field for the type and capacity of equipment comprising the source under review and operating under similar conditions.

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Regulation 2, Rule 2, states that any new or modified source which results in an increase in emissions of precursor organic compounds (POC), non-precursor organic compounds (NPOC), nitrogen oxides (NOx), sulfur dioxide (SO2), particulate matter (PM10), or carbon monoxide (CO) in excess of 10 pounds per highest day must be reviewed for possible application of BACT. California Health and Safety Code Section 42300 authorizes delegation of stationary source permitting authority from the state to the local air pollution control districts, including the setting of rules and definitions.

For the BACT Guideline, the Air District relied on its evaluations of the following projects, which are both emergency standby engines that are installed and operating in compliance with the U.S. EPA Tier 4 emissions standards:

- Air District Permit Application 27020 (San Jose Santa Clara Regional Wastewater Facility, Four Emergency Diesel Standby Engines, each 4,376 BHP)
- Air District Permit Application 25115 (Sutro Tower, Inc., Emergency Diesel Standby Engine, 1,881 BHP).

The Air District also relied on an evaluation of the permit and source test results of the Microsoft – MWH Data Center, in Quincy, Washington. The permit limits that Microsoft complies with are in units of g/bhp-hr: 0.5 NOx, 0.14 NMHC, 0.02 PM filterable, 2.6 CO. These emergency diesel standby engines ranged from 0.75 MWe to 3.0 MWe.

Thank you for your attention and If you have any questions regarding this letter, please contact Damian Breen, Senior Deputy Executive Officer at (415) 749-5041.

Sincerely,

Jouh P. Burochur

Jack/P. Broadbent Executive Officer/APCO

### BAY AREA AIR QUALITY MANAGEMENT DISTRICT Best Available Control Technology (BACT) Guideline

### **Source Category**

Source:	IC Engine-Compression Ignition: Stationary Emergency, non- Agricultural, non-direct drive fire pump	Revision: Document #:	0 96.1.5
Class:	$\geq$ 1000 BHP Output	Date:	12/22/2020*

### Determination

Pollutant	BACT 1. Technologically Feasible/ Cost Effective 2. Achieved in Practice 3. TBACT	TYPICAL TECHNOLOGY
POC (NMHC)	1. n/s <sup>a</sup> 2. 0.14 g/bhp-hr <sup>b</sup>	<ol> <li>n/s<sup>a</sup></li> <li>Any engine certified or verified to achieve the applicable standard</li> </ol>
NOx	1. n/s <sup>a</sup> 2. 0.5 g/bhp-hr <sup>b</sup>	<ol> <li>n/s<sup>a</sup></li> <li>Any engine certified or verified to achieve the applicable standard</li> </ol>
SO₂	<ol> <li>n/s<sup>a</sup></li> <li>Fuel sulfur content not to exceed 0.0015% (wt) or 15 ppm (wt)</li> </ol>	<ol> <li>n/s<sup>a</sup></li> <li>CARB Diesel Fuel (Ultra Low Sulfur Diesel)</li> </ol>
со	1. n/s <sup>a</sup> 2. 2.6 g/bhp-hr <sup>b</sup>	<ol> <li>n/s<sup>a</sup></li> <li>Any engine certified or verified to achieve the applicable standard</li> </ol>
PM <sub>10</sub>	<ol> <li>n/s<sup>a</sup></li> <li>0.02 g/bhp-hr<sup>b</sup></li> <li>0.02 g/bhp-hr</li> </ol>	<ol> <li>n/s<sup>a</sup></li> <li>Any engine or technology demonstrated, certified or verified to achieve the applicable standard</li> <li>Any engine or technology demonstrated, certified or verified to achieve the applicable standard</li> </ol>
NPOC	1. n/s 2. n/s	1. n/s 2. n/s

\* Applies to open permit applications with a complete date on or after 1/1/2020.

### References

a.	Cost effectiveness analysis must be based on lesser of 50 hr/yr or non-emergency operation as limited by District bealth risk screen analysis
b.	1. BAAQMD Application 27020 San Jose/Santa Clara Water Pollution Control
	3. Microsoft MWH Data Center, Quincy, Washington
	Tier 4-Compliant (Tier 2 engines abated by catalyzed diesel particulate filter and selective catalytic
	reduction) https://ecology.wa.gov/Air-Climate/Air-guality/Data-Centers
	4. Comments by the California Air Resources Board on the California Energy Commission's
	Proposed Decision for the Proposed Sequoia Data Center project (19-SPPE-03), Attachment 2: Tier 4 Diesel Emergency Generator Engines

https://ecology.wa.gov/Air-Climate/Air-quality/Data-Centers



### **Appendix D**

Cumulative NO<sub>2</sub> concentrations for Tier 2 and Tier 4 Diesel Generators at Different Separation Distances

### Tier 2 and Tier 4 cumulative NO<sub>2</sub> concentrations

The results below present the cumulative  $NO_2$  concentrations for Tier 2 and Tier 4 standby emergency diesel generators.

**Table C-1** and **Table C-2** present the predicted cumulative NO<sub>2</sub> levels for the Tier 2 and Tier 4 standby emergency diesel generators.



s ef	Distance from facility (m)																			
Number o generator	100	200	300	400	500	600	700	800	006	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
1	190.5	181.6	139.4	113.9	113.8	113.8	113.7	113.4	113	113	112.8	112.6	112.5	112.3	112.2	112.2	112.2	112.2	112.2	112.2
2	364.4	295.5	203.3	138	137.8	137.4	136.9	135.2	128	119.6	119.6	114.4	114.3	113.7	113.7	113.7	113.7	113.7	113.6	113.6
3	519.2	418.1	255.9	146.7	140.8	140.2	139.4	138.3	137.7	136.8	136.8	136.3	136.3	128.5	128.5	118.6	118.6	115.1	115.1	115.1
4	697.8	667.6	313.9	165.9	147.6	144.6	142.6	141.1	140	139	139	138.4	138.4	137.5	137.5	136.6	136.6	134.9	134.9	122.8
5	856.4	820.3	361.7	187.7	165.8	148.3	146.1	142.2	141	139.8	139.8	139.2	139.2	138.2	138.2	137.2	137.2	136.7	136.7	129.8
6	1018.8	974.4	425.3	210.4	181.1	156.9	148.3	146.2	145.8	145.8	145.8	145.8	145.8	145.8	145.8	145.8	145.8	145.5	145.5	136.3
7	1146.9	1097.3	494.4	234.6	203.1	165.5	156	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147	147	145.2
8	1330.3	1272.6	553.3	257.8	204.7	198	160.6	150.7	149.1	149.1	149.1	149.1	149.1	149.1	149.1	149.1	149.1	148.5	148.5	146.5
9	1485.5	1421	613.2	260.4	217.1	186.5	165.9	160.5	151.5	150.8	150.8	150.8	150.8	150.8	150.8	150.8	150.8	150.2	150.2	147.9
10	1664.2	1590.8	676.3	262.2	227.9	205.9	176.4	162.9	154.1	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	151.9	151.9	149.3
11	1823.9	1743.5	745.9	264.7	252	204.3	193.2	172	160.8	154.3	154.3	154.3	154.3	154.3	154.3	154.3	154.3	153.7	153.7	150.8
12	1986.3	1897.6	802.9	267.2	259.4	217.5	203.5	186.2	166.8	156.1	156.1	156.1	156.1	156.1	156.1	156.1	156.1	155.5	155.5	152.4
13	2114.4	2020.5	872.1	269.2	260.8	223.5	204.5	198.5	172.8	162.1	157.8	157.8	157.8	157.8	157.8	157.8	157.8	157	157	153.7
14	2297.9	2195.8	945.4	270.8	262	236.6	205.5	203.6	182.9	165.6	159.5	159.5	159.5	159.5	159.5	159.5	159.5	158.6	158.6	154.9
15	2453	2344.2	1007.2	273	263.5	252.2	212.5	204.6	194.9	167.8	161.2	161.2	161.2	161.2	161.2	161.2	161.2	160.2	160.2	156.3
16	2631.7	2514	1072	274.8	264.8	258.8	217.6	205.5	203.3	176.9	162.9	162.9	162.9	162.9	162.9	162.9	162.9	161.9	161.9	157.8
17	2791.5	2666.6	1123.9	277.3	266.5	260	229.2	206.5	204.2	171.5	165.2	164.7	164.7	164.7	164.7	164.7	164.7	163.7	163.7	159.3
18	2953.9	2820.7	1180.6	279.7	268.1	261.2	242.5	211.9	205	181.8	170.2	166.5	166.5	166.5	166.5	166.5	166.5	165.5	165.5	160.8
19	3082	2943.7	1250.2	281.7	269.5	262.2	254.1	217.4	205.7	190.7	175.7	168.1	168.1	168.1	168.1	168.1	168.1	167.1	167.1	162.1
20	3265.4	3118.9	1324.5	283.4	270.7	263.1	258.7	218.1	206.5	194.8	181.5	172.9	169.8	169.8	169.8	169.8	169.8	168.6	168.6	163.4
21	3420.6	3267.3	1386.2	285.6	272.2	264.2	259.5	227.2	207.3	203.2	186.5	180.7	171.5	171.5	171.5	171.5	171.5	170.3	170.3	164.8
22	3599.2	3437.2	1450.6	287.4	273.5	265.2	260.3	236.2	211.6	203.7	192	187.7	173.2	173.2	173.2	173.2	173.2	172	172	166.2
23	3759	3589.8	1504	291.3	275.2	266.4	261.3	246.7	217.4	209.6	196.7	195.6	175	175	175	175	175	173.8	173.8	167.7
24	3921.4	3743.9	1559.4	299.8	276.9	267.6	262.2	257.1	224.9	216.9	203.1	203.1	177.4	176.8	176.8	176.8	176.8	175.6	175.6	169.3
25	4049.5	3866.9	1630.3	310.2	280.9	268.6	263	258.8	233.1	224.7	207.4	203.6	183	179.4	178.5	178.5	178.5	177.1	177.1	170.6
26	4233	4042.1	1704.6	321.3	290.4	273.5	263.7	259.4	241.6	232.9	213.8	204.1	188.7	184.3	180.2	180.2	180.2	178.6	178.6	171.8
27	4388.1	4190.5	1766.3	330.2	298.3	282.6	271.9	260.1	249.4	240.4	220.3	210.1	194.2	189.1	181.9	181.9	181.9	180.3	180.3	173.3
28	4566.8	4360.3	1830.7	340.2	307	291.8	280.7	268.5	257.5	248.1	227	216.7	199.8	194.1	183.6	183.6	183.6	182	182	174.7
29	4726.6	4513	1884.1	347.3	313.3	300.1	288.7	276.1	264.8	255.1	232.7	223.3	205	200.1	190	190	185.4	183.8	183.8	176.2
30	4889	4667.1	1939.5	362.7	321.7	308.6	296.8	283.8	272.4	262.4	239.8	229.8	210.4	203.4	192.5	191.8	188.6	188.6	188.6	178.5
31	5017.1	4790	2010.4	366.2	331.9	318.3	306.1	292.6	280.6	270.3	246.7	236.5	216.1	208.8	197.9	192.3	191.7	191.7	191.7	183.9
32	5200.5	4965.3	2084.7	377.3	341.9	328.3	315.6	301.6	289.2	278.4	253.5	243.3	221.8	213.6	203.1	193.1	192.1	192.1	192.1	189.3
33	5355.7	5113.7	2146.4	386.1	352.3	337.3	324.3	309.9	297	285.9	260.5	249.9	227.3	218.4	205	196.8	192.9	192.5	192.5	191.8
34	5534.3	5283.5	2210.8	396.2	362.4	346.6	333.1	318.3	305.1	293.6	267.5	256.6	232.9	223.4	209.5	200.6	197.7	192.9	192.9	192.1

Table C-1: Cumulative NO<sub>2</sub> concentrations at different separation distances for Tier 2 standby emergency diesel generators (µg/m<sup>3</sup>) – Criteria 246µg/m<sup>3</sup>



35	5694.1	5436.2	2264.2	403.3	372.5	355.3	341.1	325.9	312.5	300.7	274.5	263.1	238.1	228.3	214	203.4	203	193.8	193.8	192.6
36	5856.5	5590.3	2319.6	425.5	382.4	364.7	349.2	333.6	320.5	307.9	281.6	269.6	243.5	227.8	218.6	208.2	205.3	195.6	195.6	193
37	5984.6	5713.2	2390.5	422.2	392.6	374.5	358.5	342.4	328.6	315.8	288.5	276.4	249.1	238.1	222.9	213.1	209.3	197.2	197.2	193.4
38	6168.1	5888.5	2464.8	433.3	402.6	384	368	351.4	336.7	323.9	295.4	283.1	254.9	243	227.4	218.1	213.5	201	201	193.7
39	6323.2	6036.9	2526.5	442.1	412.9	393.8	376.7	359.7	344.7	331.4	302.3	289.7	260.4	247.8	231.8	223	217.5	204.7	204.7	195.7
40	6501.9	6206.7	2590.9	452.2	423.1	403.3	385.6	368.1	352.9	339.2	309.3	296.4	266	252.8	236.4	228	221.7	208.6	208.6	199.3
41	6661.7	6359.3	2644.3	459.3	433.1	413	393.5	375.7	360.8	346.2	316.3	302.9	271.2	257.6	240.8	232.8	225.8	212.3	212.3	202.9
42	6824	6513.5	2699.7	488.4	443	422.4	401.6	383.4	368.8	353.5	323.5	309.5	276.6	257.9	245.4	237.8	230	216.1	216.1	206.6
43	6952.2	6636.4	2770.6	478.2	453.2	432.2	410.9	392.2	376.9	361.3	330.3	316.2	282.2	267.4	249.8	242.7	234	219.9	219.9	210.6
44	7135.6	6811.7	2844.9	489.3	463.2	441.7	420.4	401.2	385	369.4	337.2	322.9	287.9	272.3	254.3	247.7	238.1	223.7	223.7	214.8
45	7290.8	6960	2906.6	498.1	473.5	451.5	429.1	409.5	393	376.9	344.1	329.5	293.4	277.1	259.1	252.6	242.2	227.4	227.4	218.9
46	7469.4	7129.9	2971	508.2	483.7	461	438	417.9	401.2	384.7	351.1	336.2	299	282.1	264.4	257.6	246.3	231.2	231.2	223.2
47	7629.2	7282.5	3024.4	515.3	493.8	470.7	445.9	425.5	409.1	391.7	358.1	342.7	304.2	287	267.7	262.4	250.4	235	235	227.3
48	7791.6	7436.6	3079.8	551.2	503.7	480.1	454	433.2	417.1	399	365.3	349.3	309.6	288.1	272.3	267.4	254.6	238.8	238.8	231.6
49	7919.7	7559.6	3150.7	534.2	513.8	489.9	463.3	442.1	425.2	406.8	372.1	356	315.3	296.8	276.8	272.3	258.6	242.5	242.5	235.7
50	8103.2	7734.8	3225	545.3	523.9	499.4	472.8	451	433.3	415	379	362.7	321	301.6	282	277.3	262.8	246.3	246.3	239.9
51	8258.3	7883.2	3286.7	554.3	534.2	509.2	481.5	459.3	441.4	422.5	385.9	369.4	326.5	306.4	287.2	282.1	266.8	250.1	250.1	244
52	8437	8053.1	3351.1	564.4	544.3	518.7	490.4	467.7	449.5	430.2	392.9	376	332.4	311.4	292.4	287.1	271	253.9	253.9	248.3
53	8596.8	8205.7	3404.5	572.8	554.4	528.4	498.3	475.3	457.4	437.2	400	382.5	338.3	316.3	295.6	292	275.1	257.7	257.7	252.4
54	8759.1	8359.8	3459.9	614.1	564.3	537.8	506.5	483.1	465.4	444.5	407.1	389.1	344.3	318.2	299.6	297	279.3	261.5	261.5	256.7
55	8887.3	8482.7	3530.8	592.7	574.5	547.6	515.7	491.9	473.5	452.3	414	395.8	350	326.5	304.8	301.8	283.3	265.2	265.2	260.8
56	9070.7	8658	3605.1	604	584.5	557.1	525.2	500.8	481.6	460.5	420.8	402.6	355.6	331.6	310.1	306.8	287.4	269	269	265
57	9225.9	8806.4	3666.9	613.6	594.8	566.9	533.9	509.1	489.7	468	427.7	409.2	361.4	336.6	315.2	311.7	291.5	272.8	272.8	269.1
58	9404.5	8976.2	3731.2	623.7	605	576.4	542.8	517.5	497.8	475.7	434.8	415.8	367.2	341.8	320.5	316.7	295.7	276.6	276.6	273.4
59	9564.3	9128.9	3784.7	632.1	615	586.1	550.7	525.1	505.7	482.8	441.8	422.4	373.2	346.9	323.7	321.6	299.7	280.3	280.3	277.5
60	9726.7	9283	3840	676.9	624.9	595.5	558.9	532.9	513.7	490	448.9	428.9	379.2	348.3	327.7	326.5	303.9	284.2	284.2	281.8
61	9891.3	9432.5	3925.4	653.8	634.8	604.9	568.8	542.3	521.8	498.5	455.7	435.7	384.7	357	333	331.5	308	287.9	287.9	285.9
62	9967.6	9503.8	4006.6	665.1	645	614.7	578.5	551.5	529.6	506.6	462.2	442.4	390	361.8	338.2	336.4	311.9	291.6	291.6	290
63	10083.9	9601.5	4104.7	673.8	654.8	624.3	588.9	561.3	537.6	513.5	468.8	449.2	395.4	366.5	342.4	341.3	315.8	295.2	295.2	294.1
64	10110.5	9624.5	4059.5	685.2	664.6	634.1	598.9	570.9	545.2	520	475.1	455.9	400.5	371.1	346.4	346.1	319.7	298.9	298.9	298.1
65	10157.7	9660.2	4163.6	699.4	673.8	643.3	605.5	577.1	553	525.5	481.6	462.8	405.8	375.4	351	351	323.5	302.4	302.4	302
66	10158.8	9661.1	4255.9	712.1	682.9	652.5	616.1	585	560.4	532.1	487.7	469.5	411.2	380.1	355.7	355.7	327.2	305.9	305.9	305.9
67	10167.2	9667.1	4363.6	726.2	691.1	660.9	622.6	591.2	568	529.2	494	476.4	415.9	385.9	360.4	360.4	330.9	309.8	309.8	309.8
68	10167.2	9667.1	4457.6	738.8	699.2	669.3	626.7	595	575.1	535.1	500	483.1	420.8	391.5	365.1	365.1	334.5	334.5	313.7	313.6
69	10331.8	9816.6	4539.7	751.4	709.1	678.7	636.7	604.4	583.2	542.2	506.7	489.9	426.3	397	370	370	338.5	338.5	317.8	317.8
70	10408.2	9887.9	4615.2	762.7	719.2	688.5	646.4	613.7	591	549.1	513.3	496.6	432.1	402.3	374.9	374.9	342.5	342.5	321.8	321.8
71	10524.5	9985.7	4708.4	776	729.1	698.1	656.8	623.5	599	556.6	519.9	503.4	438.1	407.8	379.8	379.8	346.4	346.4	325.9	325.9
72	10551.1	10008.6	4794.5	788.3	738.8	707.9	666.8	633.1	606.6	563.9	526.2	510	443.9	413.3	384.7	384.7	350.2	350.2	329.9	329.9
73	10598.2	10044.4	4898.6	802.5	748	717	673.4	639.3	614.4	571.4	532.6	516.9	450	418.9	389.5	389.5	354	354	333.9	333.9
74	10599.4	8614.4	4990.8	815.1	757.2	726.3	684	647.2	621.8	578.6	538.8	523.6	455.9	424.4	394.3	394.3	357.8	357.8	337.8	337.8



75	10607.8	8728.2	5098.6	829.2	765.4	734.7	690.5	653.4	629.4	586.1	545.1	530.6	460.6	430.2	399	399	361.4	361.4	341.7	341.7
76	10607.8	8817	5198	841.9	773.5	743.1	694.6	657.2	636.6	593.2	551.1	537.3	465.2	435.9	403.6	403.6	365	365	345.5	345.5
77	10772.4	8950	5282	854.4	783.4	752.4	704.5	666.6	644.6	600.7	557.8	544.1	471	441.3	408.6	408.6	369.1	369.1	349.6	349.6
78	10848.7	9066	5359.1	865.7	793.5	762.2	714.2	675.9	652.5	608.1	564.4	550.7	476.8	446.7	413.5	413.5	373	373	353.7	353.7
79	10965	9195.5	5457.8	879	803.4	771.9	724.6	685.7	660.4	615.6	570.9	557.6	482.8	452.2	418.4	418.4	376.9	376.9	357.7	357.7
80	10991.6	9306.3	5548.6	891.3	813.1	781.6	734.7	695.3	668	622.9	577.3	516.3	488.6	457.6	423.2	423.2	380.8	380.8	361.7	361.7
81	11038.8	9428.5	5663.5	905.5	822.3	790.8	741.2	701.5	675.8	630.4	584.1	522.7	494.7	463.3	428	428	384.6	384.6	365.7	365.7
82	11039.9	9529.4	5765.1	918.2	831.4	800.1	751.8	709.4	683.3	637.6	591.5	528.7	500.6	468.8	432.8	432.8	388.3	388.3	369.6	369.6
83	11048.3	9643.1	5889.6	894.9	839.7	808.4	758.4	715.6	690.8	645.1	599.2	535.2	505.3	474.6	437.5	437.5	392	392	373.5	373.5
84	11048.3	9731.9	3597.1	908.1	847.7	816.9	762.5	719.4	698	652.2	606.8	541.9	509.9	480.2	442.2	442.2	395.6	395.6	377.3	377.3
85	11212.9	9865	3646.5	920.2	857.6	826.2	772.4	728.8	706.1	659.7	613.9	548.3	515.7	485.6	447.1	447.1	399.6	399.6	381.4	381.4
86	11289.3	9980.9	3693.3	931.5	867.7	836	782.1	738	713.9	667.1	621	554.5	521.5	491	452	452	403.6	403.6	385.5	385.5
87	11405.6	10110.4	3751.5	945.4	877.6	845.7	792.5	747.9	721.8	674.6	628.3	561	527.5	496.5	456.9	456.9	407.5	407.5	389.6	389.6
88	11432.2	10221.3	3806.9	957.4	887.4	855.4	802.5	757.5	729.5	681.8	635.5	567.4	533.3	502	461.7	461.7	411.4	411.4	393.6	393.6
89	11479.3	10343.4	3875	972.1	896.6	864.6	809.1	763.6	737.3	689.3	643	574.1	539.4	507.6	466.6	466.6	415.1	415.1	397.5	397.5
90	11480.5	10444.4	3938.5	985.1	905.7	873.9	819.7	771.6	744.7	696.6	650.4	580.7	545.3	513.1	471.3	471.3	418.9	418.9	401.5	401.5
91	11488.9	10581.3	4013.5	1000.3	913.9	882.2	826.3	778.6	752.3	704	658.2	587.6	550	518.9	476.1	476.1	422.5	422.5	405.3	405.3
92	11488.9	10700.8	4082.7	1013.5	922	890.6	830.3	786.9	759.4	711.1	665.7	594.4	554.6	524.5	480.7	480.7	426.1	426.1	409.1	409.1
93	11653.4	10825.1	4132	1025.6	931.9	900	840.3	795.5	767.5	718.7	672.8	600.7	560.4	530	485.7	485.7	430.2	430.2	413.3	413.3
94	11729.8	10936.3	4178.8	1036.9	942	909.8	850	803.9	775.3	726	679.9	607	566.2	535.4	490.5	490.5	434.1	434.1	417.3	417.3
95	11846.1	11076.2	4237	1050.8	951.9	919.4	860.4	812.7	783.3	733.5	687.2	613.4	572.2	540.9	495.5	495.5	438	438	421.4	421.4
96	11872.7	11190.4	4292.5	1062.8	961.6	929.2	870.4	821.1	790.9	740.8	694.4	619.8	578	546.3	500.3	500.3	441.9	441.9	425.4	425.4
97	11920.3	11345.7	4360.6	1077.5	970.8	938.4	877	829.9	798.7	748.3	702	626.5	584.1	551.9	505.1	505.1	446.4	445.7	429.4	429.4
98	12018.9	11461.1	4424.1	1090.5	980	947.6	887.6	838.3	806.1	755.5	709.3	633.1	590	557.5	509.9	509.9	450.8	449.4	433.3	433.3
99	12167.2	11630.7	4499.1	1105.7	988.2	956	894.1	847	813.7	763	717.1	640.1	594.7	563.3	514.6	514.6	455.5	453.1	437.2	437.2
100	12293.9	11750.1	4568.2	1118.9	996.3	964.4	898.2	855.4	820.9	770.1	724.6	646.8	599.3	568.9	519.3	519.3	460.2	456.7	441	441
101	12425.6	11874.5	4617.6	1131	1006.2	973.8	908.1	864	828.9	777.7	731.8	653.1	605.1	574.3	524.2	524.2	464.5	460.7	445.1	445.1
102	12541	11985.7	4664.4	1142.3	1016.3	983.6	917.9	872.4	836.8	785	738.8	659.4	610.9	579.7	529.1	529.1	468.8	464.7	449.2	449.2
103	12689	12125.5	4722.6	1156.2	1026.2	993.2	928.2	881.1	844.7	792.5	746.1	665.9	616.9	585.2	534	534	473.2	468.6	453.2	453.2
104	12807.2	12239.8	4778	1168.2	1035.9	1002.9	938.3	889.6	852.3	799.8	753.3	672.3	622.7	590.7	538.8	538.8	477.5	472.5	457.2	457.2
105	12972.1	12395.1	4846.1	1182.9	1045.1	1012.1	944.8	898.3	860.1	807.3	760.9	679	628.8	596.3	543.7	543.7	482.1	476.2	461.2	461.2
106	13092.2	12510.5	4909.6	1166.4	1054.2	1021.4	955.4	906.8	867.5	814.5	768.2	685.6	634.7	601.8	548.4	548.4	486.6	480	465.1	465.1
107	13272.6	12680	4242.9	1179.8	1062.5	1029.8	962	915.5	875.1	822	776	692.5	639.4	607.6	553.2	553.2	491.3	483.6	469	469
108	13399.3	12799.5	4294.7	1192	1070.5	1038.2	966.1	923.9	882.3	829.1	783.5	699.3	644	613.2	557.8	557.8	495.9	487.3	472.8	472.8
109	13531	12923.9	4338.3	1203.8	1080.4	1047.5	976	932.5	890.4	836.6	790.7	705.6	649.8	618.7	562.8	562.8	500.2	491.3	477	477
110	13646.4	13035.1	4376.7	1214.5	1090.5	1057.3	985.7	940.9	898.2	844	797.7	711.8	655.6	624.1	567.6	567.6	504.5	495.2	481	481
111	13794.4	13174.9	4426	1227	1100.4	1067	996.1	949.6	906.1	851.5	805.1	718.3	661.6	629.6	572.5	572.5	508.9	499.1	485.1	485.1
112	13912.6	13289.2	4469.5	1238.6	1110.2	1051.7	1006.2	958.1	913.8	858.8	812.3	724.7	667.4	635	577.4	577.4	513.2	503.4	489.1	489.1
113	14077.5	13444.5	4524.9	1252.1	1119.4	1058.7	1012.7	966.8	921.5	866.3	819.8	731.4	673.5	640.6	582.2	582.2	517.8	507.7	493.1	493.1
114	14197.6	13559.9	4572.9	1264.1	1128.5	1069.6	1023.3	975.2	929	873.5	827.2	738	679.4	646.2	587	587	522.3	512	497	497



115	14378	13729.4	4631.4	1277.6	1136.7	1076.5	1029.9	984	936.5	880.9	834.9	745	684.1	652	591.7	591.7	527	516.3	500.8	500.8
116	14504.7	13848.9	4683.2	1289.7	1135.6	1080.9	1034	992.4	943.7	888.1	842.5	751.7	688.7	657.6	596.3	596.3	531.6	520.5	504.7	504.7
117	14636.4	13973.3	4726.9	1301.5	1146.6	1091.3	1043.9	1000.9	951.8	895.6	849.6	758	694.5	663	601.3	601.3	535.9	525	508.8	508.8
118	14751.8	14084.5	4765.3	1312.2	1157.1	1101.4	1053.6	1009.4	959.6	903	856.7	764.3	700.3	668.4	606.2	606.2	540.2	529.5	512.9	512.9
119	14899.8	14224.3	4814.6	1324.7	1168.8	1112.4	1064	1018.1	967.6	910.5	864	770.8	706.3	673.9	611.1	611.1	544.6	533.9	516.9	516.9
120	15018	14338.5	4858.1	1336.4	1180	1122.9	1074	1026.5	975.2	917.7	871.2	777.2	712.1	679.3	615.9	615.9	549	538.3	520.9	520.9
121	15182.9	14493.8	4913.4	1349.8	1187.6	1129.9	1080.6	1035.3	983	925.2	878.7	783.9	718.2	685	620.8	620.8	553.5	542.7	524.9	524.9
122	15303	14609.3	4961.4	1361.9	1198.9	1140.8	1091.2	1043.7	990.4	932.4	886.1	790.5	724.1	690.5	625.5	625.5	558	547	528.8	528.8
123	15483.4	14778.8	5019.9	1375.3	1206.4	1147.8	1097.7	1052.5	998	939.9	893.9	797.4	728.8	696.3	630.2	630.2	562.7	551.2	532.7	532.7
124	15610.1	14898.2	5071.7	1387.5	1211.1	1152.1	1101.8	1060.8	1005.2	947	901.4	804.2	733.4	701.9	634.9	634.9	567.3	555.4	536.5	536.5
125	15741.8	15022.6	5115.4	1399.3	1222.1	1162.5	1111.8	1069.4	1013.2	954.6	908.5	810.5	739.2	707.4	639.8	639.8	571.6	560	540.6	540.6
126	15857.2	15133.9	5153.8	1410	1232.6	1172.6	1121.5	1077.8	1021	961.9	915.6	816.7	745	712.8	644.7	644.7	575.9	564.4	544.7	544.7
127	16005.2	15273.6	5203.1	1422.5	1244.4	1183.6	1131.9	1086.6	1029	969.4	922.9	823.2	751	718.3	649.6	649.6	580.3	568.9	548.8	548.8
128	16123.5	15387.9	5246.6	1434.1	1255.5	1194.1	1141.9	1095	1036.6	976.7	930.1	829.6	756.8	723.7	654.5	654.5	584.7	573.2	552.8	552.8
129	16288.4	15543.2	5302	1447.5	1263.1	1201.1	1148.5	1103.8	1044.4	984.2	937.7	836.3	739	729.3	659.3	659.3	589.2	577.6	556.7	556.7
130	16408.4	15658.6	5350	1459.6	1274.4	1212	1159.1	1112.2	1051.8	991.4	945	842.9	744	734.9	664.1	664.1	593.7	581.9	560.6	560.6
131	16588.9	15828.2	5411.9	1473.1	1281.9	1219	1165.6	1121	1059.4	998.9	952.8	849.8	749.2	740.6	668.8	668.8	598.4	586.2	564.5	564.5
132	16715.5	15947.6	5471.2	1485.2	1286.8	1223.3	1169.7	1129.3	1066.6	1006	960.3	856.6	755.2	746.3	673.4	673.4	603	590.4	568.3	568.3
133	16847.2	16072	5513	1497	1297.7	1233.7	1179.6	1137.9	1074.6	1013.5	967.5	862.9	760.7	751.7	678.4	678.4	607.3	594.9	572.5	572.5
134	16962.6	16183.2	5551.6	1507.7	1308.1	1243.8	1189.3	1146.3	1082.5	1020.9	974.5	869.2	766.3	757.1	683.3	683.3	611.6	599.3	576.5	576.5
135	17110.6	16323	5602.3	1520.2	1319.9	1254.8	1199.7	1155.1	1090.4	1028.4	981.8	875.7	772	762.6	688.2	688.2	616	603.8	580.6	580.6
136	17228.9	16437.3	5647.9	1531.9	1331	1265.3	1209.8	1163.5	1098	1035.7	989	882.1	777.8	768	693	693	620.4	608.2	584.6	584.6
137	17393.8	16592.6	5707.9	1545.3	1338.6	1272.3	1216.3	1172.3	1105.8	1043.2	996.6	888.8	783.8	773.7	697.8	697.8	624.9	612.5	588.6	588.6
138	17513.9	16708	5760.9	1557.4	1349.9	1283.2	1226.9	1180.7	1113.3	1050.4	1003.9	895.3	789.8	779.2	702.6	702.6	629.4	616.8	592.5	592.5
139	17694.3	16877.5	5827.8	1570.8	1359.4	1290.2	1233.5	1189.4	1120.8	1058.6	1011.7	902.3	796.2	785	707.3	707.3	634.1	621.1	596.4	596.4
140	17820.9	16997	5887.2	1583	1369.6	1294.5	1237.6	1197.8	1128	1066.8	1019.2	909.1	802.5	790.6	712	712	638.7	625.3	600.2	600.2
141	18016.4	17180.2	5955.9	1595.3	1379.5	1298.7	1241.5	1206.5	1135.7	1075.5	1027.2	916.2	809.3	796.6	716.5	716.5	643.6	629.4	603.9	603.9
142	18156.7	17313	6018.9	1606.8	1389	1304.8	1241.6	1214.9	1143.6	1083.9	1035	923.2	815.9	802.5	721	721	648.5	633.5	607.6	607.6
143	18362.9	17505.1	6077.1	1617	1396.7	1316.2	1244.7	1223.5	1152.2	1088.4	1043.1	930.5	823	808.5	725.4	725.4	653.5	637.4	611.2	611.2
144	18516.3	16460.8	6132.8	1626.8	1404.6	1327.2	1244.7	1231.5	1160.4	1094.4	1050.9	937.8	830	814.5	729.7	729.7	658.5	641.3	614.7	614.7
145	18723.5	16529.9	6162.9	1633.3	1409.4	1338.4	1244.8	1239.7	1169	1101.6	1018.5	945.3	837.4	820.6	733.8	733.8	663.7	645	618.2	618.2
146	18886.1	16586.8	6162.9	1639.8	1414	1349.2	1247.3	1247.3	1177.1	1108.3	1018.5	952.7	826.7	826.7	737.8	737.8	668.9	648.7	621.5	621.5
147	19081.5	16685.4	6231.6	1652.1	1423.9	1361	1255.9	1255.9	1185.8	1116	1024.8	959.8	832.7	832.7	742.4	742.4	673.7	652.8	625.3	625.3
148	19221.8	16762.8	6294.6	1663.7	1433.4	1372.7	1264.4	1264.4	1194.2	1123.5	1032.9	966.9	838.6	838.6	746.9	746.9	678.6	656.9	628.9	628.9
149	19428	16845.4	6352.8	1673.9	1441	1384.1	1273	1273	1202.8	1130.9	1033.4	974.2	844.6	844.6	751.3	751.3	683.6	660.8	632.5	632.5
150	19581.5	16910.9	6408.5	1683.7	1449	1395.1	1280.9	1280.9	1211	1137.8	1040.1	981.4	850.5	850.5	755.5	755.5	688.6	664.7	636.1	636.1
151	19788.6	17059.3	6438.7	1690.1	1453.8	1406.3	1290.2	1289.1	1219.6	1145	1047.1	988.9	856.7	856.7	759.7	759.7	693.9	668.5	639.5	639.5
152	19951.2	17199.5	6438.7	1696.7	1458.4	1417.1	1302	1296.7	1227.7	1151.7	1053.7	996.3	862.7	862.7	763.7	763.7	699	672.1	642.8	642.8
153	20146.7	17367.9	6507.3	1709	1468.3	1428.9	1313.8	1305.4	1236.3	1159.3	1060.9	1003.5	868.7	868.7	768.3	768.3	703.9	676.2	646.6	646.6
154	20287	17488.9	6570.4	1720.5	1477.8	1440.6	1325.8	1313.8	1244.8	1166.8	1067.9	1010.5	874.6	874.6	772.8	772.8	708.8	680.3	650.3	650.3



155	20493.1	17666.5	6628.6	1730.7	1485.4	1452	1337.5	1322.4	1253.4	1174.2	1074.9	1017.8	880.6	880.6	777.1	777.1	713.8	684.2	653.9	653.9
156	20646.6	17799	6684.2	1740.5	1493.4	1463	1349.5	1330.4	1261.6	1181.1	1081.7	1025	886.6	886.6	781.4	781.4	718.8	688.1	657.4	657.4
157	20853.8	17977.4	6714.4	1747	1498.1	1474.2	1361.2	1338.6	1270.1	1188.3	1088.6	1032.5	892.7	892.7	785.6	785.6	724	691.9	660.8	660.8
158	21016.3	18117.6	6714.4	1753.5	1502.8	1485	1373.1	1346.2	1278.3	1195	1095.3	1039.9	898.8	898.8	789.6	789.6	729.2	695.5	664.2	664.2
159	21211.8	18286	6783.1	1765.8	1512.7	1496.9	1384.8	1354.9	1286.9	1202.6	1102.4	1047.1	904.7	904.7	794.2	794.2	734.1	699.7	667.9	667.9
160	21352.1	18407	6846.1	1777.3	1522.2	1508.6	1396.9	1363.3	1295.4	1210.1	1109.4	1054.1	910.7	910.7	798.6	798.6	738.9	703.7	671.6	671.6
161	21558.3	18584.6	6904.3	1787.6	1529.8	1519.9	1408.5	1371.9	1303.9	1217.5	1116.4	1061.4	916.7	916.7	803	803	744	707.7	675.2	675.2
162	21711.7	18717.1	6960	1797.3	1537.8	1530.9	1420.5	1379.8	1312.2	1224.4	1123.2	1068.6	922.6	922.6	807.3	807.3	748.9	711.5	678.7	678.7
163	21918.9	18895.5	6990.1	1803.8	1545.2	1542.2	1432.2	1388.1	1320.7	1231.6	1130.1	1076.2	928.8	928.8	811.4	811.4	754.2	715.3	682.1	682.1
164	22081.5	19035.7	6990.1	1810.4	1553	1552.9	1444.1	1395.6	1328.9	1238.3	1136.8	1083.5	934.8	934.8	815.5	815.5	759.3	719	685.5	685.5
165	22277	19204.1	7058.8	1822.7	1564.8	1564.8	1455.8	1404.3	1337.5	1246	1144	1090.7	940.8	940.8	820.1	820.1	764.2	723.1	689.2	689.2
166	22417.3	19325.1	7121.8	1834.2	1576.5	1576.5	1467.9	1412.8	1346	1253.5	1151	1097.7	946.7	946.7	824.5	824.5	769.1	727.1	692.9	692.9
167	22623.4	19502.7	7180	1844.4	1587.9	1587.9	1479.6	1421.4	1354.5	1260.8	1158	1105	952.7	952.7	828.9	828.9	774.1	731.1	696.5	696.5
168	22776.9	19635.2	7235.7	1854.2	1598.8	1598.8	1491.6	1429.3	1362.8	1267.8	1164.7	1112.2	958.7	958.7	833.2	833.2	779.1	734.9	700.1	700.1
169	22984.1	19813.6	7265.9	1803.1	1610.1	1610.1	1503.3	1437.5	1371.3	1275	1171.7	1119.8	964.8	964.8	837.3	837.3	784.3	738.7	703.5	703.5
170	23146.6	19953.9	6126.6	1809.8	1620.8	1620.8	1515.2	1445.1	1379.5	1281.7	1178.4	1127.2	970.9	970.9	841.4	841.4	789.5	742.4	706.8	706.8
171	23342.1	20122.3	6175	1822.3	1632.7	1632.7	1526.9	1453.8	1388.1	1289.9	1185.5	1134.3	976.8	976.8	845.9	845.9	794.4	746.5	710.6	710.6
172	23482.4	20243.3	6219.2	1833.9	1644.4	1644.4	1538.9	1462.2	1396.5	1298.3	1192.5	1141.3	982.8	982.8	850.4	850.4	799.2	750.5	714.3	714.3
173	23688.5	20420.9	6256	1844	1655.8	1655.8	1550.6	1470.8	1405.1	1307.3	1199.5	1148.6	988.8	988.8	854.8	854.8	804.3	754.5	717.9	717.9
174	23842	20553.4	6290	1853.3	1666.7	1666.7	1562.6	1478.8	1413.4	1316.1	1206.3	1155.9	994.7	994.7	859	859	809.2	758.4	721.4	721.4
175	24049.2	20731.8	6317.8	1860.6	1678	1678	1574.3	1487	1421.9	1325.5	1213.2	1163.4	1000.9	1000.9	863.2	863.2	814.5	762.1	724.8	724.8
176	24211.7	20872	6346.6	1867.3	1688.8	1688.8	1586.2	1494.6	1430.1	1334.6	1219.9	1170.8	1006.9	1006.9	867.2	867.2	819.6	765.8	728.2	728.2
177	24407.2	21040.4	6395	1879.8	1700.6	1700.6	1597.9	1503.2	1438.7	1343.2	1227	1177.9	1012.9	1012.9	871.8	871.8	824.5	769.9	731.9	731.9
178	24547.5	21161.4	6439.2	1891.4	1712.3	1712.3	1610	1511.7	1447.1	1351.6	1234.1	1185	1018.8	1018.8	876.3	876.3	829.4	773.9	735.6	735.6
179	24753.7	21339	6475.9	1901.5	1723.7	1723.7	1621.6	1520.3	1455.7	1360.6	1241.1	1192.3	1024.8	1024.8	880.7	880.7	834.4	777.9	739.2	739.2
180	24907.1	21471.5	6510	1910.8	1734.6	1734.6	1633.6	1528.2	1464	1369.4	1247.8	1199.5	1030.7	1030.7	884.9	884.9	839.4	781.8	742.7	742.7
181	25114.3	21649.9	6537.8	1918.2	1745.9	1745.9	1645.4	1536.4	1472.5	1378.8	1254.8	1207	1036.9	1036.9	889.1	889.1	844.6	785.5	746.1	746.1
182	25276.9	21790.1	6566.5	1924.9	1756.7	1756.7	1657.2	1544	1480.7	1387.9	1261.4	1214.4	1043	1043	893.1	893.1	849.8	789.2	749.5	749.5
183	25472.4	21958.5	6615	1937.4	1768.5	1768.5	1669	1552.7	1489.3	1396.5	1268.6	1221.6	1048.9	1048.9	897.7	897.7	854.7	793.3	753.2	753.2
184	25612.7	22079.5	6659.1	1949	1780.2	1780.2	1681	1561.2	1497.7	1404.9	1275.6	1228.6	1054.9	1054.9	902.2	902.2	859.6	797.4	756.9	756.9
185	25818.8	22257.1	6695.9	1959.1	1791.6	1791.6	1692.7	1569.7	1506.3	1413.9	1282.6	1235.9	1060.9	1060.9	906.5	906.5	864.6	801.3	760.5	760.5
186	25972.3	22389.6	6730	1968.4	1802.6	1802.6	1704.7	1577.7	1514.6	1422.7	1289.4	1243.1	1066.8	1066.8	910.8	910.8	869.6	805.2	764.1	764.1
187	26179.5	22568	6757.7	1975.7	1813.8	1813.8	1716.4	1585.9	1523.1	1432.1	1296.3	1250.6	1073	1073	915.5	915.5	874.8	808.9	767.5	767.5
188	26342	22708.2	6786.5	1982.4	1824.6	1728.3	1635	1593.5	1531.3	1441.1	1303	1258	1079	1079	920	920	879.9	812.6	770.8	770.8
189	26537.5	22876.7	6834.9	1994.9	1836.4	1740	1644.6	1602.2	1539.9	1449.8	1310.1	1265.2	1085	1085	925	925	884.8	816.7	774.6	774.6
190	26677.8	22997.7	6879.1	2006.5	1848.1	1752.1	1653.8	1610.6	1548.3	1458.2	1317.1	1272.2	1090.9	1090.9	929.9	929.9	889.7	820.8	778.3	778.3
191	26883.9	23175.2	6915.9	2016.6	1859.5	1763.7	1663.6	1619.2	1556.9	1467.2	1324.1	1279.5	1096.9	1096.9	934.7	934.7	894.7	824.7	781.9	781.9
192	27037.4	23307.7	6949.9	1962.3	1870.5	1775.7	1672.7	1627.2	1565.2	1476	1330.9	1286.7	1102.8	1102.8	939.3	939.3	899.7	828.6	785.4	785.4
193	27244.6	23486.2	6977.7	1967.7	1881.7	1787.4	1682.2	1635.4	1573.7	1485.4	1337.8	1294.3	1109	1109	944.1	944.1	904.9	832.3	788.8	788.8
194	27407.1	23626.4	7006.5	1973	1892.5	1799.3	1691	1642.9	1581.9	1494.4	1344.5	1301.6	1115	1115	948.7	948.7	910.1	836	792.2	792.2



195	27602.6	23794.8	7054.9	1984.1	1904.3	1811	1700.6	1651.6	1590.5	1503.1	1351.7	1308.8	1121	1121	953.7	953.7	915	840.1	795.9	795.9
196	27742.9	23915.8	7099.1	1994.8	1916	1823.1	1709.8	1660.1	1598.9	1470.1	1358.7	1315.8	1126.9	1126.9	958.9	958.6	919.9	844.2	799.6	799.6
197	27949.1	24093.4	7135.8	2003.5	1927.4	1834.7	1719.6	1668.7	1607.5	1477.5	1365.7	1323.1	1133	1133	964.8	963.4	924.9	848.1	803.2	803.2
198	28102.5	24225.9	7169.9	2012.3	1938.4	1846.8	1728.7	1676.6	1615.8	1484.4	1372.4	1330.3	1138.9	1138.9	970.6	968	929.9	852	806.7	806.7
199	28309.7	24404.3	7197.7	2017.6	1949.6	1858.5	1738.2	1684.8	1624.3	1491.6	1379.4	1337.9	1145	1145	975.9	972.8	935.1	855.8	810.1	810.1
200	28472.3	24544.5	7226.4	2022.9	1960.4	1870.3	1747	1692.4	1632.5	1498.3	1386.1	1345.3	1151.1	1151.1	982	977.4	940.3	859.4	813.5	813.5

s ef									Dist	ance fro	m facility	(m)								
Number o generatoi	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
1	116.4	109.3	108.8	108.5	108.4	108.3	108.2	107.9	107.4	107.4	107.1	106.9	106.8	106.5	106.4	106.4	106.4	106.4	106.4	106.4
2	122.8	112.3	111.8	111.6	111.6	111.6	111.6	111.2	110.3	110.2	109.5	109.1	109	108.3	108.3	108.3	108.2	108.2	108.1	108.1
3	126.9	112.9	112.2	112.2	112.1	112.1	112	111.9	111.9	111.7	111.6	111.4	111	110.2	110.1	110.1	110.1	110	110	110
4	146.4	141.9	116.1	112.7	112.5	112.5	112.4	112.3	112.3	112.1	111.9	111.8	111.8	111.6	111.6	111.6	111.6	111.6	111.6	111.6
5	169.7	164.4	123.2	113.1	112.9	112.9	112.8	112.6	112.6	112.4	112.2	112.1	112	111.9	111.8	111.8	111.8	111.8	111.8	111.8
6	193.6	187.1	130.5	113.6	113.3	113.3	113.2	113	113	112.7	112.5	112.4	112.2	112.1	112.1	112.1	112.1	112	112	112
7	212.4	205.2	139.4	114.1	113.8	113.8	113.6	113.4	113.4	113	112.8	112.6	112.5	112.3	112.3	112.3	112.3	112.2	112.2	112.2
8	239.4	230.9	148.8	114.6	114.2	114.2	114.1	113.8	113.8	113.4	113.1	112.9	112.8	112.6	112.5	112.5	112.5	112.4	112.4	112.4
9	262.3	252.8	156.8	115.1	114.6	114.6	114.5	114.1	114.1	113.7	113.4	113.2	113	112.8	112.7	112.7	112.7	112.7	112.7	112.7
10	288.6	277.8	165.2	115.6	115.1	115.1	114.9	114.5	114.5	114	113.7	113.5	113.3	113	113	113	113	112.9	112.9	112.9
11	312.1	300.2	171.7	116	115.5	115.5	115.3	114.9	114.9	114.3	114	113.7	113.5	113.2	113.2	113.2	113.2	113.1	113.1	113.1
12	336	322.9	179	116.5	115.9	115.9	115.7	115.2	115.2	114.6	114.3	114.1	113.8	113.5	113.4	113.4	113.4	113.3	113.3	113.3
13	354.8	341	187.9	117	116.3	116.3	116.1	115.6	115.6	115	114.6	114.3	114	113.7	113.6	113.6	113.6	113.5	113.5	113.5
14	381.8	366.8	197.3	117.5	116.8	116.8	116.5	116	116	115.3	114.9	114.5	114.3	113.9	113.8	113.8	113.8	113.7	113.7	113.7
15	404.7	388.6	205.2	118	117.2	117.2	117	116.4	116.4	115.6	115.2	114.8	114.5	114.2	114.1	114.1	114.1	113.9	113.9	113.9
16	430.9	413.6	213.7	118.5	117.7	117.7	117.4	116.8	116.8	116	115.5	115.1	114.8	114.4	114.3	114.3	114.3	114.2	114.2	114.2
17	454.5	436.1	220.2	120	118.1	118.1	117.8	117.1	117.1	116.3	115.8	115.4	115	114.6	114.5	114.5	114.5	114.4	114.4	114.4
18	478.4	458.8	227.5	126.6	118.5	118.5	118.2	117.5	117.5	116.6	116.1	115.8	115.3	114.9	114.7	114.7	114.7	114.6	114.6	114.6
19	497.2	476.9	236.4	129.9	118.9	118.9	118.6	117.9	117.9	116.9	116.4	115.9	115.5	115.1	115	115	115	114.8	114.8	114.8
20	524.2	502.6	245.8	130.3	119.4	119.4	119	118.3	118.3	117.3	116.6	116.2	115.8	115.3	115.2	115.2	115.2	115	115	115
21	547	524.5	253.7	136.4	119.8	119.8	119.4	118.7	118.7	117.6	116.9	116.5	116	115.5	115.4	115.4	115.4	115.2	115.2	115.2
22	573.3	549.5	262.2	137.1	121.5	120.2	119.9	119	119	117.9	117.2	116.7	116.3	115.8	115.6	115.6	115.6	115.4	115.4	115.4
23	596.8	571.9	268.6	137.9	124.5	120.6	120.2	119.4	119.4	118.2	117.5	117	116.5	116	115.8	115.8	115.8	115.7	115.7	115.7
24	620.7	594.6	276	142.4	126.2	121.6	120.6	119.8	119.8	118.5	117.8	117.4	116.8	116.2	116.1	116.1	116.1	115.9	115.9	115.9
25	639.6	612.7	284.9	146	130.2	126.4	121.1	120.1	120.1	118.9	118.1	117.7	117	116.5	116.3	116.3	116.3	116.1	116.1	116.1
26	666.6	638.5	294.3	149.9	135.7	131.7	125.8	120.5	120.5	119.2	118.4	117.8	117.3	116.7	116.5	116.5	116.5	116.3	116.3	116.3
27	689.4	660.3	302.2	152.4	139.4	135.1	128.9	120.9	120.9	119.5	118.7	118.1	117.6	116.9	116.7	116.7	116.7	116.5	116.5	116.5
28	715.7	685.3	310.7	152.9	142	139.2	132.8	121.8	121.3	119.9	119	118.4	117.8	117.1	117	117	117	116.7	116.7	116.7
29	739.2	707.8	317.1	153.6	142.2	140.9	134.4	125.6	125.6	120.2	119.3	118.8	118	117.4	117.2	117.2	117.2	116.9	116.9	116.9
30	763.1	730.5	325.5	154.4	142.4	141.9	136.2	127.8	127.8	120.5	119.6	119.1	118.3	117.6	117.4	117.4	117.4	117.2	117.2	117.2
31	782	748.6	335.6	154.9	143	142.5	140.7	131.4	131.4	120.8	119.9	119.4	118.6	117.8	117.6	117.6	117.6	117.4	117.4	117.4
32	809	774.3	346.4	155.3	144.5	143.1	142.2	134.9	134.9	121.2	120.2	119.7	118.8	118.1	117.9	117.9	117.9	117.6	117.6	117.6
33	831.8	796.2	355.5	155.8	147.7	143.5	142.6	139.1	139.1	121.5	120.5	119.7	119.1	118.3	118.1	118.1	118.1	117.8	117.8	117.8
34	858.1	821.2	365.1	156.3	151	144	143.1	139.5	139.5	121.8	120.8	120.2	119.3	118.5	118.3	118.3	118.3	118	118	118

Table C. 2. Cumulative NO concentrations at differen	t concretion distances for Tion A	atomathy, and an an average of the set	concretere (us/m3) Criterie 24Cu	/
Table C-2: Cumulative NO <sub>2</sub> concentrations at differen	it separation distances for filer 4	standby emergency diese	generators (ug/m <sup>2</sup> ) – Criteria 2460	16/III.
				.0,



35	881.6	843.6	372.7	157.1	152.6	144.2	143.3	140.7	140	123.2	121.1	120.5	119.6	118.7	118.5	118.5	118.5	118.2	118.2	118.2
36	905.5	866.3	381	157.8	153.2	144.4	143.5	141.8	140.3	125	121.4	120.8	119.8	119	118.8	118.8	118.8	118.4	118.4	118.4
37	924.3	884.4	391.2	160.1	153.5	145	144	142.3	140.7	127.9	124.8	121.1	120.5	119.2	119	119	119	118.7	118.7	118.7
38	951.3	910.2	402	163.4	153.9	145.6	144.6	142.9	141.1	131	128.5	123.9	123.9	119.4	119.2	119.2	119.2	118.9	118.9	118.9
39	974.2	932	411.1	164	154.3	146.1	145	143.2	141.6	134.4	130.8	126.1	126.1	119.7	119.4	119.4	119.4	119.1	119.1	119.1
40	1000.5	957	420.6	164.4	154.7	146.5	145.5	143.6	142.1	137.1	133.4	128.6	128.6	119.9	119.6	119.6	119.6	119.3	119.3	119.3
41	1024	979.5	428.2	165	155.2	146.7	145.7	143.8	142.5	139.3	134.4	129.6	129.6	120.2	120.2	119.9	119.9	119.5	119.5	119.5
42	1047.9	1002.2	436.6	165.7	155.8	147.6	145.9	144	142.8	139.5	135.5	130.8	130.8	121.2	121.2	120.1	120.1	119.7	119.7	119.7
43	1066.7	1020.3	446.8	166.9	156.2	150	146.4	144.4	143.2	139.8	138.9	133.9	133.9	124	124	120.3	120.3	119.9	119.9	119.9
44	1093.7	1046.1	457.6	169.2	156.5	152.2	147	145	143.7	141.9	141.9	137.4	137.4	127.2	127.2	120.5	120.5	120.2	120.2	120.2
45	1116.6	1067.9	466.7	169.7	156.9	152.5	147.4	145.3	144.2	142.1	142.1	139.5	139.5	129.1	129.1	120.8	120.8	120.4	120.4	120.4
46	1142.8	1092.9	476.2	172.4	157.3	152.8	147.8	145.7	144.6	142.5	142.5	141.8	141.8	131.4	131.4	121.1	121.1	120.6	120.6	120.6
47	1166.4	1115.3	483.8	176.2	157.9	153.3	148	145.9	145.1	142.6	142.6	141.9	141.9	132.3	132.3	121.9	121.9	120.8	120.8	120.8
48	1190.3	1138	492.2	179.9	158.5	153.7	148.3	146.1	145.3	142.7	142.7	142.1	142.1	133.3	133.3	122.8	122.8	121	121	121
49	1209.1	1156.1	502.4	182.9	158.8	154	148.8	146.5	145.8	143.1	143.1	142.4	142.4	136.1	136.1	125.3	125.3	121.2	121.2	121.2
50	1236.1	1181.9	513.2	185.9	160.2	154.3	149.4	147.1	146.2	143.6	143.6	142.9	142.9	139.2	139.2	128.1	128.1	122.3	122.3	121.4
51	1258.9	1203.7	522.3	189.2	162.8	154.6	149.8	147.4	146.7	143.8	143.8	143.1	143.1	141.1	141.1	129.8	129.8	123.9	123.9	121.7
52	1285.2	1228.7	531.8	192.6	163.8	154.9	150.2	147.8	147.1	144.2	144.2	143.4	143.4	142	142	131.8	131.8	125.9	125.9	121.9
53	1308.7	1251.2	539.4	195.7	164.3	155.3	150.4	148	147.6	144.3	144.3	143.5	143.5	142.1	142.1	132.6	132.6	126.6	126.6	122.1
54	1332.6	1273.9	547.8	196.1	165.1	155.7	150.6	148.2	147.9	144.4	144.4	143.7	143.7	142.2	142.2	133.5	133.5	127.5	127.5	122.3
55	1351.5	1292	558	196.5	167.2	156	151.2	148.6	148.3	144.8	144.8	144	144	142.5	142.5	136	136	129.8	129.8	122.5
56	1378.5	1317.8	568.7	196.8	169.4	156.3	152.3	149.2	148.7	145.3	145.3	144.5	144.5	142.9	142.9	138.8	138.8	132.4	132.4	122.7
57	1401.3	1339.6	577.8	197.2	171.6	156.6	152.6	149.5	149.2	145.5	145.5	144.7	144.7	143.1	143.1	140.5	140.5	134	134	122.9
58	1427.6	1364.6	587.4	197.6	172.8	156.9	152.8	149.9	149.6	145.8	145.8	145	145	143.4	143.4	141.9	141.9	135.9	135.9	123.2
59	1451.1	1387	595	198.1	173.2	157.3	153.1	150.1	150.1	146	146	145.1	145.1	143.5	143.5	142	142	136.7	136.7	123.4
60	1475	1409.7	603.4	198.5	173.5	157.8	153.5	150.4	150.4	146.1	146.1	145.3	145.3	143.6	143.6	142.1	142.1	137.6	137.6	124
61	1499.2	1431.7	615.5	200.1	173.7	158	153.7	150.9	150.8	146.6	146.6	145.7	145.7	144.1	144.1	143.3	143.3	140.4	140.4	126.5
62	1510.5	1442.2	626.8	202.2	174	158.4	154.3	151.4	151.3	147.1	147.1	146.7	146.7	146.7	146.7	146.7	146.7	142.2	142.2	128.9
63	1527.6	1456.6	640.3	204.1	174.2	158.6	154.9	152	151.7	148.5	148.5	148.5	148.5	148.5	148.5	148.5	148.5	143.6	143.6	131.5
64	1531.5	1460	636	206	174.4	158.9	155.5	152.6	152.1	151.9	151.9	151.9	151.9	151.9	151.9	151.9	151.9	146.7	146.7	134
65	1538.4	1465.2	651.3	207.7	174.6	160.1	156.2	153.1	152.5	152.1	152.1	152.1	152.1	152.1	152.1	152.1	152.1	148	148	136.6
66	1538.6	1465.4	664.9	209.4	174.8	161.7	156.7	153.7	152.9	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	150.9	150.9	139
67	1539.8	1466.3	680.7	211	175	163.2	157.3	154.2	153.3	152.7	152.7	152.7	152.7	152.7	152.7	152.7	152.7	152	152	141.6
68	1539.8	1466.3	694.5	212.5	175.2	163.7	157.9	154.7	153.7	153.1	153.1	153.1	153.1	153.1	153.1	153.1	153.1	152.3	152.3	142
69	1564.1	1488.2	706.6	213.3	175.5	164	158.5	155.3	154.2	153.3	153.3	153.3	153.3	153.3	153.3	153.3	153.3	152.5	152.5	142.3
70	1575.3	1498.7	717.7	213.6	175.8	164.2	159.1	155.9	154.6	153.7	153.7	153.7	153.7	153.7	153.7	153.7	153.7	152.9	152.9	142.6
71	1592.4	1513.1	731.5	213.8	177.6	164.4	159.8	156.5	155	154	154	154	154	154	154	154	154	153.1	153.1	142.9
72	1596.3	1516.5	744.1	214	179.4	164.6	160.4	157	155.4	154.4	154.4	154.4	154.4	154.4	154.4	154.4	154.4	153.4	153.4	143.2
73	1603.3	1521.8	759.4	214.2	181.1	164.8	161	157.6	155.8	154.6	154.6	154.6	154.6	154.6	154.6	154.6	154.6	153.6	153.6	143.5
74	1603.4	1299.2	773	214.4	182.8	165	161.6	158.1	156.3	155	155	155	155	155	155	155	155	153.9	153.9	143.8



75	1604.7	1315.9	788.9	214.6	184.4	165.2	162.2	158.7	156.6	155.2	155.2	155.2	155.2	155.2	155.2	155.2	155.2	154.1	154.1	144.1
76	1604.7	1329	802.7	216.3	186	166.2	162.7	159.2	157.1	155.5	155.5	155.5	155.5	155.5	155.5	155.5	155.5	154.4	154.4	144.4
77	1628.9	1348.5	814.8	217	187.8	167.9	163.4	159.8	157.5	155.8	155.8	155.8	155.8	155.8	155.8	155.8	155.8	154.6	154.6	145.6
78	1640.1	1365.6	825.9	217.3	189.8	169.5	164	160.3	158	156.2	156.2	156.2	156.2	156.2	156.2	156.2	156.2	155	155	147.9
79	1657.2	1384.7	839.8	218	191.5	171.2	164.6	160.9	158.6	156.4	156.4	156.4	156.4	156.4	156.4	156.4	156.4	155.2	155.2	149
80	1661.2	1401	853.2	219.9	193.4	172.8	165.2	161.4	159.2	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	155.5	155.5	151.2
81	1668.1	1418.9	870.1	221.6	195	174.3	165.8	162	159.7	157	157	157	157	157	157	157	157	155.7	155.7	152
82	1668.3	1433.8	885.1	223.3	196.8	174.8	166.4	162.6	160.3	157.4	157.4	157.4	157.4	157.4	157.4	157.4	157.4	156	156	152.2
83	1669.5	1450.5	903.4	225	198.3	175	167	163.1	160.8	157.6	157.6	157.6	157.6	157.6	157.6	157.6	157.6	156.2	156.2	152.3
84	1669.5	1463.6	567.8	226.5	199.9	175.2	167.5	163.6	161.4	158.1	158.1	158	158	158	158	158	158	156.5	156.5	152.6
85	1693.7	1483.2	575.1	228.5	201.8	175.8	168.2	164.2	161.9	158.6	158.6	158.2	158.2	158.2	158.2	158.2	158.2	156.7	156.7	152.8
86	1705	1500.2	582	228.7	203.7	177.4	168.8	164.7	162.5	159.1	159.1	158.6	158.6	158.6	158.6	158.6	158.6	157.1	157.1	153
87	1722.1	1519.3	590.5	228.9	205.5	178.8	169.4	165.3	163.1	159.6	159.6	158.8	158.8	158.8	158.8	158.8	158.8	157.3	157.3	153.2
88	1726	1535.6	598.7	229.2	207.3	180.3	170	165.9	163.6	160.1	160.1	159.2	159.2	159.2	159.2	159.2	159.2	157.6	157.6	153.4
89	1732.9	1555.4	608.7	230.9	209	181.6	170.7	166.5	164.2	160.6	160.6	159.4	159.4	159.4	159.4	159.4	159.4	157.8	157.8	153.5
90	1733.1	1572.4	618	232.5	210.7	183	171.3	167	164.7	161.1	161.1	159.8	159.8	159.8	159.8	159.8	159.8	158.2	158.2	153.8
91	1734.3	1597.4	629.1	233.9	212.3	184.2	171.9	167.5	165.3	161.6	161.6	160	160	160	160	160	160	158.3	158.3	153.9
92	1734.3	1615	639.3	235.4	213.2	185.5	172.4	168	165.8	162.1	162.1	160.4	160.4	160.4	160.4	160.4	160.4	158.6	158.6	154.2
93	1758.5	1633.3	646.5	237.3	213.5	187	173	168.6	166.4	162.6	162.6	160.6	160.6	160.6	160.6	160.6	160.6	158.8	158.8	154.3
94	1769.8	1649.6	653.4	239.5	213.7	188.6	173.6	169.2	166.9	163.1	163.1	161	161	161	161	161	161	159.2	159.2	154.6
95	1786.9	1670.2	662	241.2	213.9	190	174.3	169.8	167.5	163.6	163.6	161.3	161.3	161.3	161.3	161.3	161.3	159.4	159.4	154.7
96	1790.8	1687	670.1	254	214.1	191.5	174.9	170.3	168.1	164.1	164.1	161.7	161.7	161.7	161.7	161.7	161.7	159.8	159.8	155
97	1797.8	1709.9	680.1	256	214.3	192.8	175.5	170.9	168.6	164.6	164.6	162.2	162.2	161.9	161.9	161.9	161.9	159.9	159.9	155.1
98	1807.1	1726.9	689.5	257.9	214.5	194.2	176.1	171.4	169.2	165.1	165.1	162.6	162.6	162.2	162.2	162.2	162.2	160.3	160.3	155.4
99	1825.5	1751.8	700.5	259.7	214.7	195.4	176.7	172	169.8	165.6	165.6	163.1	163.1	162.4	162.4	162.4	162.4	160.4	160.4	155.5
100	1844.1	1769.4	710.7	261.4	214.9	196.7	177.2	172.5	170.3	166.1	166.1	163.5	163.5	162.8	162.8	162.8	162.8	160.8	160.8	155.7
101	1863.5	1787.7	718	263.5	215.1	198.2	177.9	173.1	170.9	166.6	166.6	164	164	163	163	163	163	161	161	155.9
102	1880.5	1804	724.9	265.8	215.4	199.8	178.5	173.6	171.4	167.1	167.1	164.4	164.4	163.5	163.5	163.5	163.5	161.3	161.3	156.2
103	1902.3	1824.6	733.4	267.9	215.6	201.3	179.1	174.2	172	167.6	167.6	164.9	164.9	163.7	163.7	163.7	163.7	161.5	161.5	156.3
104	1919.7	1841.4	741.6	269.8	215.8	202.7	180.2	175.1	172.5	168.1	168.1	165.4	165.4	164.1	164.1	164.1	164.1	161.9	161.9	156.6
105	1943.9	1864.3	751.6	271.5	216	204.1	181.5	176.2	173.1	168.6	168.6	165.8	165.8	164.3	164.3	164.3	164.3	162	162	156.7
106	1961.6	1881.3	760.9	271.7	216.2	205.4	182.6	177.3	173.7	169.1	169.1	166.3	166.3	164.7	164.7	164.7	164.7	162.4	162.4	156.9
107	1988.1	1906.2	661	271.9	216.4	206.7	183.9	178.4	174.2	169.6	169.6	166.8	166.8	164.9	164.9	164.9	164.9	162.5	162.5	157
108	2006.8	1923.8	668.7	272.1	217.4	207.9	185.1	179.4	174.8	170.1	170.1	167.2	167.2	165.2	165.2	165.2	165.2	162.9	162.9	157.3
109	2026.2	1942.1	675.1	272.4	218.9	209.5	186.2	180.5	175.3	170.6	170.6	167.7	167.7	165.5	165.5	165.5	165.5	163.1	163.1	157.5
110	2043.1	1958.5	680.7	272.6	220.3	211	187.3	181.5	175.9	171.1	171.1	168.1	168.1	165.9	165.9	165.9	165.9	163.4	163.4	157.7
111	2064.9	1979	688	272.9	221.9	212.5	188.4	182.6	176.4	171.7	171.6	168.6	168.6	166.1	166.1	166.1	166.1	163.6	163.6	157.9
112	2082.3	1995.9	694.4	273.1	223.3	213.2	189.6	183.7	177	172.7	172.1	169	169	166.5	166.5	166.5	166.5	164	164	158.1
113	2106.6	2018.7	702.5	273.4	225	213.4	190.8	184.8	177.6	173.7	172.6	169.5	169.5	166.7	166.7	166.7	166.7	164.1	164.1	158.2
114	2124.3	2035.7	709.6	273.6	226.5	213.6	192	185.9	178.2	174.7	173.1	169.9	169.9	167.1	167.1	167.1	167.1	164.5	164.5	158.5



115	2150.8	2060.6	718.2	273.8	243.4	213.7	193.3	187	179.2	175.7	173.6	170.4	170.4	167.3	167.3	167.3	167.3	164.6	164.6	158.6
116	2169.5	2078.2	725.8	274	244.9	213.9	194.4	188	180.1	176.7	174.1	170.8	170.8	167.7	167.7	167.7	167.7	165	165	158.9
117	2188.8	2096.5	732.3	274.3	246.6	214	195.6	189.1	181.1	177.6	174.6	171.3	171.3	167.9	167.9	167.9	167.9	165.2	165.2	159
118	2205.8	2112.9	737.9	274.5	248.4	214.2	196.6	190.1	182.1	178.5	175.1	171.7	171.7	168.3	168.3	168.3	168.3	165.6	165.6	159.3
119	2227.6	2133.5	745.2	274.8	250.1	214.4	197.8	191.2	183.1	179.5	175.6	172.2	172.2	168.5	168.5	168.5	168.5	165.7	165.7	159.4
120	2245	2150.3	751.6	275	251.6	214.6	198.9	192.2	184	180.5	176.1	172.7	172.7	168.9	168.9	168.9	168.9	166.1	166.1	159.7
121	2269.3	2173.1	759.7	275.2	253.2	214.7	200.2	193.4	185.1	181.5	176.6	173.1	173.1	169.1	169.1	169.1	169.1	166.3	166.3	159.8
122	2286.9	2190.1	766.8	275.5	254.7	214.9	201.4	194.4	186.1	182.5	177.1	173.6	173.6	169.5	169.5	169.5	169.5	166.6	166.6	160.1
123	2313.5	2215.1	775.4	275.7	256.2	215.1	202.6	195.5	187.1	183.5	177.6	174.1	174.1	169.7	169.7	169.7	169.7	166.8	166.8	160.3
124	2332.1	2232.6	783	275.9	257.6	215.2	203.8	196.6	188.1	184.5	178.1	174.5	174.5	170.1	170.1	170.1	170.1	167.1	167.1	160.6
125	2351.5	2250.9	789.4	276.2	259.3	215.4	204.9	197.6	189	185.4	178.6	175	175	170.4	170.4	170.3	170.3	167.3	167.3	160.7
126	2368.5	2267.3	795.1	276.4	261.2	215.6	206	198.7	190	186.3	179.1	175.4	175.4	170.8	170.8	170.8	170.8	167.7	167.7	161
127	2390.3	2287.9	802.4	276.7	262.8	215.8	207.2	199.8	191	187.3	179.6	175.9	175.9	171.3	171.3	171	171	167.8	167.8	161.2
128	2407.7	2304.7	808.7	276.9	264.4	215.9	208.3	200.8	192	188.2	180.1	176.3	176.3	171.7	171.7	171.4	171.4	168.2	168.2	161.5
129	2431.9	2327.6	817.2	277.7	265.9	216.1	209.6	202	193	189.3	180.6	176.8	176.8	172.1	172.1	171.6	171.6	168.4	168.4	161.7
130	2449.6	2344.5	825	279.4	267.4	216.3	210.7	203	194	190.3	181.1	177.2	177.2	172.5	172.5	172	172	168.7	168.7	162
131	2476.2	2369.5	834.8	281.4	268.9	216.5	212	204.1	195	191.3	181.6	177.7	177.7	172.9	172.9	172.2	172.2	168.9	168.9	162.1
132	2494.8	2387.1	843.6	283.2	270.3	217.6	213.2	205.2	196	192.3	182.1	178.1	178.1	173.3	173.3	172.5	172.5	169.2	169.2	162.4
133	2514.2	2405.4	849.7	284.9	271.5	219	214.3	206.2	197	193.2	182.6	178.6	178.6	173.7	173.7	172.8	172.8	169.4	169.4	162.6
134	2531.2	2421.7	855.4	286.5	271.7	220.4	215.4	207.2	197.9	194.1	183.1	179	179	174.1	174.1	173.2	173.2	169.8	169.8	162.9
135	2552.9	2442.3	862.9	288.4	271.9	221.7	216.6	208.3	198.9	195.1	183.6	179.5	179.5	174.6	174.6	173.4	173.4	170	170	163.1
136	2570.3	2459.1	869.6	290.1	272.1	223	217.7	209.4	199.9	196	184.1	180	180	175	175	173.8	173.8	170.3	170.3	163.4
137	2594.6	2482	878.4	292.1	272.3	224.2	219	210.5	200.9	197.1	184.6	180.4	180.4	175.4	175.4	174	174	170.5	170.5	163.5
138	2612.3	2499	886.2	293.8	272.5	225.4	220.1	211.6	201.9	198	185.1	180.9	180.9	175.8	175.8	174.4	174.4	170.8	170.8	163.8
139	2638.8	2523.9	896.1	295.8	272.6	226.5	221.4	212.7	202.9	199.1	185.8	181.4	181.4	176.2	176.2	174.6	174.6	171	171	164
140	2657.5	2541.5	904.8	297.6	272.8	227.7	222.6	213.7	203.9	200.1	186.7	181.8	181.8	176.6	176.6	175	175	171.3	171.3	164.2
141	2686.2	2568.4	914.9	299.4	273	228.8	223.7	214.7	204.8	201	187.6	182.2	182.2	177	177	175.2	175.2	171.5	171.5	164.4
142	2706.9	2588	924.2	301.1	273.1	229.8	224.8	215.7	205.7	202	188.5	182.3	182.3	177	177	175.5	175.5	171.8	171.8	164.7
143	2737.2	2616.3	932.7	302.6	273.3	230.9	225.6	216.3	206.4	202.9	189.2	182.7	182.7	177.4	177.4	175.7	175.7	171.9	171.9	164.8
144	2759.8	2453.8	940.9	304.1	273.4	231.9	226.6	217.1	207.2	203.7	190	182.7	182.7	177.4	177.4	176.1	176.1	172.3	172.3	165.1
145	2790.3	2464	945.4	305	273.6	232.9	227.2	217.5	207.6	204.4	190.6	183.1	183.1	177.8	177.8	176.4	176.4	172.6	172.6	165.3
146	2814.2	2472.3	945.4	306	273.7	233.8	227.7	215.7	208	204.9	191.1	183.1	183.1	177.8	177.8	176.7	176.7	172.9	172.9	165.6
147	2843	2486.8	955.5	307.8	274.2	234.9	228.8	216.7	208.9	205.9	192	183.6	183.6	178.2	178.2	176.9	176.9	173	173	165.7
148	2863.6	2498.2	964.8	309.5	275.6	236	230	217.8	209.8	206.9	192.9	183.6	183.6	178.3	178.3	177.3	177.3	173.4	173.4	166
149	2893.9	2510.4	973.3	311	276.7	237.1	230.8	218.7	210.5	207.7	193.6	184	184	178.7	178.7	177.5	177.5	173.5	173.5	166.2
150	2916.5	2520	981.5	312.4	277.9	238.1	231.7	219.7	211.3	208.6	194.4	184.4	184.1	178.7	178.7	177.8	177.8	173.8	173.8	166.4
151	2947	2545.4	985.9	313.4	278.6	239.1	232.3	220.2	211.7	209.3	195	184.7	184.5	179.1	179.1	178.2	178.2	174.1	174.1	166.7
152	2970.9	2566	985.9	314.3	279.3	240	232.8	220.7	212.1	209.8	195.6	185.1	184.5	179.1	179.1	178.5	178.5	174.4	174.4	167
153	2999.7	2590.8	996.1	316.1	280.7	241.1	234	221.8	213	210.8	196.4	185.8	184.9	179.5	179.5	178.7	178.7	174.6	174.6	167.1
154	3020.4	2608.6	1005.3	317.8	282.1	242.2	235.1	222.8	213.9	211.7	197.3	186.6	185	179.5	179.5	179.1	179.1	174.9	174.9	167.4



155	3050.7	2634.7	1013.9	319.3	283.2	243.2	235.9	223.7	214.6	212.6	198.1	187.1	185.4	179.9	179.9	179.2	179.2	175.1	175.1	167.5
156	3073.3	2654.2	1022.1	320.8	284.4	244.3	236.9	224.7	215.4	213.5	198.9	187.7	185.4	179.9	179.9	179.6	179.6	175.4	175.4	167.8
157	3103.8	2680.5	1026.5	321.7	285.1	245.2	237.4	225.2	215.8	214.1	199.5	190.5	185.8	180.3	180.3	179.9	179.9	175.7	175.7	168
158	3127.7	2701.1	1026.5	322.7	285.8	246.2	238	225.7	216.2	214.7	200	190.5	185.8	180.3	180.3	180.3	180.3	176	176	168.3
159	3156.4	2725.9	1036.6	324.5	287.3	247.3	239.1	226.8	217.1	215.6	200.8	191	186.3	180.7	180.7	180.5	180.5	176.2	176.2	168.5
160	3177.1	2743.7	1045.9	326.2	288.7	248.4	240.2	227.8	218	216.6	201.7	191	186.3	186.3	180.8	180.8	180.8	176.5	176.5	168.7
161	3207.4	2769.8	1054.5	327.7	289.8	249.4	241	228.7	218.7	217.4	202.5	191.5	186.7	186.7	181.1	181	181	176.6	176.6	168.9
162	3230	2789.3	1062.7	329.1	290.9	250.4	242	229.7	219.5	218.3	203.3	191.5	186.8	186.8	181.4	181.4	181.4	177	177	169.1
163	3260.5	2815.6	1067.1	330.1	291.6	251.4	242.6	230.5	220.5	219	203.9	192	187.2	187.2	181.7	181.7	181.7	181.7	177.3	169.4
164	3284.4	2836.2	1067.1	331.1	292.3	252.4	243.1	231.6	221.8	219.5	204.4	192	187.2	187.2	182	182	182	182	177.6	177.6
165	3313.2	2861	1077.2	332.9	293.8	253.5	244.3	232.8	223	210.9	205.3	192.6	187.6	187.6	182.2	182.2	182.2	182.2	177.7	177.7
166	3333.8	2878.8	1086.5	334.6	295.2	254.6	245.4	234.1	224.3	211.7	206.1	193.3	187.7	187.7	182.6	182.6	182.6	182.6	178.1	178.1
167	3364.2	2904.9	1095	336.1	296.3	261.9	246.2	235.4	225.5	212.4	206.9	193.8	188.1	188.1	182.8	182.8	182.8	182.8	178.2	178.2
168	3386.8	2924.4	1103.2	337.5	297.5	262.9	247.2	236.5	226.7	213.2	207.7	194.5	188.1	188.1	183.1	183.1	183.1	183.1	178.5	178.5
169	3417.2	2950.7	1107.7	324.8	298.2	263.8	247.7	237.7	228	213.8	208.3	194.8	188.5	188.5	183.5	183.5	183.5	183.5	178.8	178.8
170	3441.2	2971.3	942.7	325.6	298.9	264.8	248.2	238.8	229.2	214.8	208.8	195.2	188.5	188.5	183.8	183.8	183.8	183.8	179.1	179.1
171	3469.9	2996.1	949.8	327.2	300.3	265.8	249.4	240.1	230.5	216	209.7	195.9	189	189	184	184	184	184	179.3	179.3
172	3490.6	3013.9	956.3	328.8	301.7	266.9	250.5	241.4	231.7	217.3	210.6	196.7	189	189	184.4	184.4	184.4	184.4	179.6	179.6
173	3520.9	3040.1	961.7	330.1	302.8	267.9	251.3	242.6	233	218.6	211.3	197.2	189.4	189.4	184.5	184.5	184.5	184.5	179.8	179.8
174	3543.5	3059.5	966.7	331.4	304	268.9	252.3	243.8	234.2	219.9	212.1	197.8	189.5	189.5	184.9	184.9	184.9	184.9	180.1	180.1
175	3574	3085.8	970.8	332.2	304.7	269.9	252.9	245	235.4	221.2	212.7	198.2	189.9	189.9	185.2	185.2	185.2	185.2	180.4	180.4
176	3597.9	3106.4	975.1	332.9	305.4	270.8	253.4	246.1	236.6	222.6	213.2	198.5	189.9	189.9	185.6	185.6	185.6	185.6	180.7	180.7
177	3626.7	3131.2	982.2	334.6	301.6	271.5	254.5	247.4	237.9	223.9	214.1	199.5	190.3	190.3	185.7	185.7	185.7	185.7	180.8	180.8
178	3647.3	3149	988.7	336.2	303.1	271.6	255.7	248.6	239.1	225.1	215	200.6	190.4	190.4	186.1	186.1	186.1	186.1	181.2	181.2
179	3677.6	3175.2	994.1	337.4	304.4	271.7	256.4	249.9	240.4	226.4	215.7	201.6	190.8	190.8	186.3	186.3	186.3	186.3	181.3	181.3
180	3700.2	3194.7	999.1	338.7	305.6	271.8	257.4	251.1	241.6	227.7	216.6	202.7	190.8	190.8	186.6	186.6	186.6	186.6	181.6	181.6
181	3730.7	3220.9	1003.2	339.5	306.5	272.7	258	252.3	242.9	229.1	217.2	203.8	191.2	191.2	187	187	187	187	181.9	181.9
182	3754.6	3241.5	1007.4	340.3	307.3	274.3	259.7	253.4	244.1	230.4	217.7	204.9	191.2	191.2	187.3	187.3	187.3	187.3	182.3	182.3
183	3783.4	3266.3	1014.6	341.9	308.8	276.1	261.4	254.7	245.4	231.7	218.5	206	191.7	191.7	187.5	187.5	187.5	187.5	182.4	182.4
184	3804.1	3284.1	1021.1	343.5	310.3	277.8	263.2	255.9	246.6	232.9	219.4	207	192.4	191.7	187.9	187.9	187.9	187.9	182.7	182.7
185	3834.4	3310.3	1026.5	344.8	311.5	279.5	264.9	257.2	247.9	234.3	220.2	208.1	192.8	192.1	188.1	188.1	188.1	188.1	182.9	182.9
186	3857	3329.8	1031.5	346.1	312.8	281.1	266.7	258.4	249.1	235.6	221	209.1	193.5	192.8	188.4	188.4	188.4	188.4	183.2	183.2
187	3887.5	3356	1035.6	346.9	313.7	282.7	268.4	259.6	250.3	236.9	221.6	210.2	193.8	193.3	188.8	188.8	188.8	188.8	183.5	183.5
188	3911.4	3376.7	1039.8	347.6	296.5	272.8	266.8	260.7	251.5	238.3	222.1	211.3	194.1	193.7	189.1	189.1	189.1	189.1	183.8	183.8
189	3940.1	3401.4	1046.9	349.3	297.7	272.9	268.2	262	252.8	239.5	222.9	212.4	194.8	194.4	189.3	189.3	189.3	189.3	184	184
190	3960.8	3419.2	1053.4	350.8	298.8	273.7	269.6	263.2	254	240.8	223.8	213.4	195.5	195.1	189.6	189.6	189.6	189.6	184.3	184.3
191	3991.1	3445.4	1058.8	352.1	299.6	275.4	271	264.5	255.3	242.1	224.6	214.5	196	195.8	189.8	189.8	189.8	189.8	184.4	184.4
192	4013.7	3464.9	1063.8	353.4	300.6	277.1	272.3	265.6	256.5	243.4	225.4	215.5	196.6	196.4	190.2	190.2	190.2	190.2	184.8	184.8
193	4044.2	3491.1	1067.9	354.2	301.1	278.8	273.7	266.8	257.8	244.8	226	216.7	197	197	190.5	190.5	190.5	190.5	185.1	185.1
194	4068.1	3511.8	1072.2	355	301.6	280.6	275	268	259	246.1	226.5	217.7	197.4	197.4	190.9	190.9	190.9	190.9	185.4	185.4



195	4096.9	3536.5	1079.3	356.6	302.8	282.3	276.4	269.2	260.2	247.4	227.4	218.8	198.1	198.1	191	191	191	191	185.5	185.5
196	4117.5	3554.3	1085.8	358.2	304	284.1	277.8	270.5	261.5	242.5	228.2	219.8	198.8	198.8	191.4	191.4	191.4	191.4	185.9	185.9
197	4147.9	3580.5	1091.2	359.5	304.8	285.8	279.2	271.7	262.7	243.6	229	220.9	199.4	199.4	191.6	191.6	191.6	191.6	186	186
198	4170.5	3600	1096.2	360.8	305.7	287.6	280.6	272.9	264	244.6	229.8	222	200.1	200.1	191.9	191.9	191.9	191.9	186.3	186.3
199	4200.9	3626.2	1100.3	361.6	303.2	289.3	282	274.1	265.2	245.7	230.4	223.1	200.6	200.6	192.3	192.3	192.3	192.3	186.6	186.6
200	4224.9	3646.9	1104.5	362.3	304.3	291	283.3	275.2	266.4	246.7	230.9	224.2	201.1	201.1	192.6	192.6	192.6	192.6	187	187