Implementation of Non-Road Mobile Machinery (NRMM) Diesel Engine Emissions Control on Crossrail

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Contents

Glossary

CECE	Committee for the European Construction Equipment
CFA	Continuous Flight Auger
DPF	Diesel Particulate Filter
EC	European Commission
EIC	Environment Industries Commission
EMP	Environmental Management Plane
EMR	Environmental Minimum Requirements
EU	European Union
FPS	Federation of Piling Specialists
kW	Kilowatt
LEZ	Low Emission Zone
NRMM	Non Road Mobile Machinery
US EPA	United States Environmental Protection Agency

1 Introduction

The document is intended as internal reference and guidance for the Sustainability and Consents team and Delivery Environmental Advisors. It provides:

- A description of the approach to diesel emissions controls for NRMM
- A summary of the research and consultation undertaken by Crossrail and the findings
- A description of the current processes used by Crossrail to implement diesel emissions controls.

This document can also be read in conjunction with Contractor Guidance document CRL-XRL-T1-GUI-CR001-50001 and amended versions *"Guidance on Emissions from Non-Road Mobile Machinery (NRMM) and Retrofitting with Diesel Particulate Filters"* which has been issued as a guidance communication document to contractors.

Annex 1 of this document provides a.

A Field Guide to Identification of Engine Compliance, can also be read in conjunction with this document, which can to be used by Crossrail Environmental advisors, construction managers and site engineers; document CR-XRL-T1-GUI-CR001-50005*" Non-Road Mobile Machinery (NRMM) Diesel Engine Emissions Field Guide to Identification of Diesel Engine Emission Compliance'.*

2 London Air Pollution and Crossrail

The notorious sulphur smog's of the 1950's are a thing of the past but air pollution is still a real issue across the capital. Pollution from engine emissions, and particularly from diesel fumes, is the most significant cause of London's poor air quality.

Air pollution contributes to a myriad of health problems across London and it is estimated that 4,300[1] people die prematurely in London every year because of air pollution, a similar number to the smogs of the 1950's.

The UK has legally binding limits on levels of harmful air pollution[2]. One or more of these limits has been broken in London in every year since they came into effect in 2005. The two pollutants of most concern are microscopic airborne particles, known as particulate matter (PM_{10}), and Nitrogen Dioxide (NO_2), a toxic gas.

Diesel exhaust emissions emit these pollutants and in addition have also be classified as being carcinogenic to humans, based on sufficient evidence that exposure is associated with an increased risk for lung cancer by The International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO)[3].

Once operational, Crossrail should offer significant benefits in reducing private car journeys across the Capital and therefore contribute to improving London's air. During the long construction period however, there will be many sites spread out across London, with each site having a range of large and medium size diesel engines working throughout the day. Crossrail

[1] Mayor of London (2010)
[2] Her Majesties Stationary Office (HMSO) (2010) The Air Quality Standards Regulations, Statutory Instrument No. 1001
[3] IARC (2012) Press Release No. 213, Diesel Engine Exhaust Carcinogenic

can, therefore give rise to significant amounts of pollution from diesel engines if not adequately controlled.

It is difficult to quantify the emissions contribution from construction sites in London. However, the latest version of the London Atmospheric Emissions Inventory estimates that construction and non-road mobile machinery account for around 15% of PM_{10} and 12% of nitrogen oxide (NOx) emissions[4]. For example; if every off-road plant used on Crossrail construction sites during November 2011 was equipped with the latest emissions controls, it would remove the equivalent PM_{10} emissions of 8,500 cars, or 1 km of Oxford Street or Tottenham Court Road, for each hour of operational working[5]. While construction and demolition sites can have a wide array of sources of emissions and subsequent effects upon air quality, this document focusses solely on those associated with tailpipe emissions from diesel engines and in particular, that of PM_{10}.

3 Definition of Non-Road Mobile Machinery and Emissions Standards

Diesel engine emissions control is traditionally at the manufacturer stage, through international and national legislative requirements. All new construction machinery or 'Non-Road Mobile Machinery' (NRMM) sold in the European Union (EU), since 1997, must conform to EU Directive 97/68 its amendments[6] and the subsequent member state transposed regulations. This Directive requires that, in order for NRMM to be first placed on the EU market for sale, engines (for use in NRMM) must be approved to demonstrate compliance with pollutant emission standards.

Emissions standards state the gaseous and particulate pollutant levels which can be emitted from NRMM and are staged to allow continual improvements. There are several staged reductions for different pollutants at each EU Standard. The largest staged reduction in PM_{10} emissions is between Stage IIIA and Stage IIIB engines; this reduction is the focus of this document and the Crossrail requirement on NRMM.

Full details of EU Standards, their reference directives and approval to market timeline can be found in Appendix 1.

In the UK, the legislation governing emissions produced by engines fitted in NRMM is the Non-Road Mobile Machinery (Emission of Gaseous and Particulate Pollutants) Regulations 1999 and subsequent amendments[7]. These regulations transpose Directive 97/68 and subsequent amendments into national legislation.

The UK NRMM Regulations and EU Directive are intended ultimately to cover almost all engines used for mobile applications which are not subject to national or international vehicle approval requirements.

The UK Vehicle Certification Agency (VCA)[8] defines NRMM as any mobile machine, transportable industrial equipment or vehicle with or without body work not intended for carrying

[4] Greater London Authority (2013) Control of dust and emissions during construction and demolition SPG – Draft for consultation

[6] For full details of the EU Directive see Appendix 1.

[7] The Non-Road Mobile Machinery (Emission of Gaseous and Particulate Pollutants) (Amendment) Regulations 2013 Statutory Instrument No. 1687

8 VCA (2013) http://www.dft.gov.uk/vca/enforcement/non-road-mobile-mach.asp

passengers or goods on the road, which has an internal combustion engine as specified in Annex 1 of Directive 97/68.

This includes any equipment brought onto site to carry out operations for the purpose of construction and is not considered a permanent installation (i.e. it does not require planning permission) In addition, vehicle registration of NRMM as 'road legal' does not make the NRMM exempt from NRMM emission standards and as such is not exempt from the Crossrail stated requirements. Examples of non-road mobile machinery include, but are not limited to: Generators; Bulldozers; Pumps; Construction machinery; Industrial trucks; Fork Lifts and Mobile cranes.

4 Construction Emissions Controls in London

In addition to emissions standards placed at the point of manufacture some authorities have placed local requirements to ensure NRMM used conforms to certain emissions standards or have a certain minimum emission limit.

4.1 Greater London Authority Best Practice Guidance

London based NRMM requirements can be traced back to the Mayor of London's Best Practice Guidance (BPG) on the control of dust on construction sites[9].

The specific best practice guidance relating to NRMM and controlling diesel engine emissions is as follows:

- *Grant access for an officer from the local authority or conformity inspector and provide a safe area to test NRMM if needed.*
- *All NRMM should comply with either the current or immediately previous EU Directive Staged Emission Standards (97/68/EC,2002/88/EC, 2004/26/EC); now transposed into UK regulations. As new emission standards are introduced the acceptable standards will be updated to the new current and immediately previous standard.*
- *NRMM with power outputs of over 37kW should be fitted with suitable after-treatment devices stated on the approved list managed by the Energy Saving Trust. The devices included on this list conform to a filtration efficiency of over 85 per cent.*
- *The ongoing conformity of plant retrofitted with suitable after treatment devices, to a defined performance standard, should be ensured through a programme of on-site checks.*

These requirements were originally intended to be written into planning conditions through 'Environmental Management Plans (EMP)' or similar and enforceable through the planning regime. There is limited evidence to suggest that this requirement has been up taken or indeed enforced across London. This is despite the wording being often included into EMP's and other planning documentation.

The BPG makes reference to a list of 'after-treatment devices' for the control of emissions through retrofitting engines. This list, published by the Energy Saving Trust in 2008, is a list of accredited devices known collectively as Diesel Particulate Filters (DPF).

[9] Mayor of London; (2006). The control of dust and emissions from construction and demolition Best Practice Guidance.

4.1 Greater London Authority Proposed Supplementary Planning Guidance

The Greater London Authority (GLA) has proposed, in draft form, a replacement to the 'Best Practice Guidance (BPG) for the control of dust and emissions from construction and demolition'.

The proposed SPG 'The control of dust and emissions during construction and demolition' was published for consultation in September 201.

Within this SPG the GLA is considering proposals for controlling NRMM emissions on construction sites through a requirement for 'Cleaner Construction Machinery' for London. This is likely to be enforced though the planning regime and will restrict use of certain NRMM within central London and the wider Greater London areas. It is also anticipated these requirements will be phased in over 2015-2020 and based on EU emission standards (though retrofit will be a compliance option).

Crossrail has worked with the GLA to ensure that the current Crossrail requirements do not conflict and only support the proposals of the SPG.

4.1 City of London Code of Practice for Deconstruction and Construction Sites

The City of London's Pollution Control Team have development a Code of Practice for Deconstruction and Construction Sites10 , to encourage the use of the best environmental options in planning and managing construction and deconstruction (demolition) in the City of London.

Within this code there is a requirement which mirrors Crossrail emissions requirements:

"All Non-Road Mobile Machinery (NRMM) should meet Stage IIIB emission criteria, unless it can be demonstrated that Stage IIIB equipment is not available. If Stage IIIB equipment is not available, NRMM must be fitted with particle traps and / or catalytic exhaust treatment wherever possible. An inventory of all NRMM must be kept on site and all machinery should be regularly serviced and service logs kept on site for inspection. Records should be kept on site which details proof of emission limits for all equipment".

Crossrail has also worked with the City of London's Pollution Control Team to ensure that the current Crossrail requirements do not conflict and only support their code.

4.2 Olympic Development Authority

In 2010, The Olympic Development Authority (ODA), commissioned a report to assess the cost effectiveness of using DPFs on NRMM within the Olympic Park[11]. This study looked at total emissions of pollutants and dispersion modelling of sources. The study used this data to produce a cost benefit analysis of potential emissions controls scenarios.

The results of the cost benefit analysis concluded that the incremental benefits of retro-fitting DPFs were approximately half of the annual incremental costs (benefits were monetised based on a health impact assessment). As a result of the study the ODA took the decision not to implement the requirement to retrofit DPFs to NRMM.

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[10] City of London Department of Markets and Consumer Protection (Seventh Edition – May 2013) Code of Practice for Deconstruction and Construction Sites

[11] Entec UK Limited (2010). Cost-Benefit Analysis of Reducing Particulate Emissions from Non-Road Mobile Machinery on the Olympic Park Construction Site Final Report.

4.3 Energy Saving Trust Non-Road Mobile Machinery Register

The Energy Saving Trust's NRMM Register is an independent certification and register service for manufacturers of pollution abatement equipment for construction machinery. It can be found on the EST website[12].

The 'Energy Saving Trust Non-Road Mobile Machinery Register' of accredited devices was not updated between 2008 and 2012, plausibly as a consequence of a lack of market demand for NRMM retrofit created from a low enforcement of the BPG requirement. DPF technology has however moved on since 2008, generated from an active non-UK demand and other on-road fields such as the London Low Emissions Zones (LEZ). The EST register has subsequently been re-opened and a new version published in March 2013. A smaller number of companies have re-accredited to the 2013 register, possibly due to lack of confidence in the market demand.

There are several programmes globally which offer similar processes of control for NRMM retrofit and verified DPF's including;

- The Swiss Federal Ordinance on Air Pollution Control (OAPC) FOEN Particulate Filter List, (VFT3).
    - http://www.vert-dpf.eu/
    - http://www.bafu.admin.ch/partikelfilterliste/index.html?lang=en
- Californian ARB Verification Classifications for Diesel Emission Control Strategies, Retrofit Device Verification Database Off-road Level 3.
    - http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm
- Transport for London (TfL) Low Emissions Certification (LEC) process, Emission Stage Phase 4 achieving PM emissions limits Standard The Energy Savings Trust Energy Savings Trust Non-Road Mobile Machinery Register
    - http://www.tfl.gov.uk/assets/downloads/roadusers/lez/LEZ/lez-approved-filter-device-list.pdf

(note NRMM is not subject to the TfL LEZ which covers on-road engines, though the technology is similar).

The EST NRMM Register is the current and sole UK/London equivalent to these other schemes and acts as a third party assurance scheme to help contractors/plant hire/developers choose the correct solutions. The EST NRMM Register provides a list of certified companies and devices and ensures that companies have the appropriate background to provide installation of DPF including:

- Knowledge and compliance with Health & Safety requirements;
- Knowledge and compliance with Provision and Use of Work Equipment Regulations 1998 (PUWER);
- Provision of training for installation and maintenance;
- Supply of DPF 'data logger'; and
- Provide appropriate warranties and insurance of their products
- Requirement for the DPF to comply with at least an 85% mass reduction of total PM.

[12] http://www.energysavingtrust.org.uk/england/Organisations/Certification/Non-Road-Mobile-Machinery-NRMM-certification.

4.4 Construction Emissions Controls in London Summary

The historical perspective outlined in this section emphasises the lack of availability and maturity in both the retrofit market and adoption of diesel emissions controls across the construction industry as a whole.

The ODA study was a desk based assessment of a large but localised construction site, with limited nearby 'sensitive' receptors. It is considered that the ODA report is not reflective of Crossrail's spatial disparity. In contrast to the Olympics, Crossrail operate 25 separate construction sites across the whole of London, throughout some of the worst urban air pollution in the UK and within close proximity to a multitude of sensitive receptors, for example; Bond Street and Whitechapel are very close to residential properties and schools.

Since the release of the original GLA BPG and the ODA study, more stringent emissions standards have come into force through EU legislation and NRMM with these more stringent standards have been made available to the market. Despite this, a combination of; natural life cycle of NRMM, high procurement costs, a period of economic recession, and other market pressures on the construction industry, have resulted in older, more polluting, NRMM remaining in wide spread circulation across London during 2012 and 2013.

5 Crossrail Approach to Diesel Engine Emissions Controls

The use of advanced emissions control technology in construction machinery has been used extensively across Europe and the US over the last ten years, it is a relatively new requirement in the UK.

Crossrail is the first UK infrastructure project to enforce emissions control on construction machinery to bring about environmental benefits (as opposed to occupational health benefits in underground settings).

This section details the key aspects of the diesel engines exhaust emissions requirements and how they are disseminated through the project.

5.1 Environmental Minimum Requirements

The standards and procedures that have been agreed with local authorities and statutory agencies to control and manage environmental impacts are contained in a set of documents known as the Crossrail Environmental Minimum Requirements (EMR).

Annex 1 to the EMR, Section 6.2.1; states the requirements to control adverse impacts of vehicle and plant emissions where:

"The nominated undertaker will ensure that the adverse impacts of vehicle and plant emissions are controlled. Measures to be considered for limiting emissions and avoiding nuisance will include one or more of the following as appropriate and as far as reasonably practicable:

> *(a) ensuring that the engines of all vehicles and plant on site are not left running unnecessarily;*
>
> *(b) using low emission vehicles and plant fitted with catalysts, diesel particulate filters or similar devices;*
>
> *(c) using ultra low sulphur fuels in plant and vehicles;*

(d) requiring that plant will be well maintained, with routine servicing of plant and vehicles to be completed in accordance with the manufacturers' recommendations and records maintained for the work undertaken

5.2 Contractual Works Information

These EMR have been passed through individual contracts as stated within the 'Works Information' Volume 2B - General Requirements, Part 21 - Environmental Management, Section 21.10.2 Vehicle and Equipment Emissions and subsequent amendments where:

"The Contractor shall implement the following measures to limit emissions and avoid nuisance…

all non-road mobile machinery shall:

− comply with the current or immediately previous EU Directive Staged Emission Standards; and

− if power output is over 37kW, be fitted with an after-treatment device(s) stated on the approved list managed by the Energy Saving Trust, and ongoing conformity to a performance standard to be defined by the Project Manager shall be ensured through a programme of on-site checks which shall be recorded."

This contractual requirements and subsequent amendments translate to the following requirement for Contractors:

- The Works Information requires all NRMM to meet with the current or immediately previous European Union (EU) NRMM Emission Directive, staged emissions standards.
- NRMM with a type approval engine Stage IIIA or below, with a power output greater than (or equal to) 37kW, should be fitted with a Diesel Particulate Filter (DPF).
- Any NRMM that is compliant with Stage IIIB emissions standards will not need to be retrofitted with a DPF (because emissions of PM are already controlled).
- NRMM with a power output below 37kW does not need to comply with these requirements.

Note that Stage IV introduces additional extensive controls on NOx emissions. Stage IV is still in industry development and is unlikely to be available for the duration of the Crossrail construction period and as such NOx abatement technology is not required.

As started previously the largest staged reduction in PM_{10} emissions is between Stage IIIA and Stage IIIB engines; this reduction is the focus of this document and the Crossrail requirement on NRMM.

For clarity within this document this Works Information Volume 2B, Part 20.10.2 is referred to as the 'Crossrail NRMM Diesel Engine Emissions Requirements' or simply 'The NRMM Requirements' where an implied reference is made.

5.3 Crossover with Existing Regulations

Aside from being a public health issue and contributing to the improvement of London's Air, adopting emissions controls also allows a reduction of a known carcinogen for all workers across Crossrail sites and helps contractors comply with existing Health and Safety requirements.

Regulations already exist for the control of diesel engine emissions in the workplace (occupational exposure). The NRMM Requirements do not and should not supplant these

occupational regulations; instead the highlighted issues and methods of controls available for both occupational regulations and The NRMM Requirements can support one another. Existing occupational regulations which support The NRMM Requirements are detailed in this section.

5.3.1 Control of diesel engine exhaust emissions in the workplace (HSG187)

HSG187 tackles emissions from diesel engines which tend to occur within an enclosed or 'internal' environment (such as a bus depot) and states that; Diesel engine exhaust emissions (DEEE) are generated from stationary power sources which may be used in tunnels, alongside railway lines during maintenance work and on construction sites. DEEE is covered under the Control of Substances Hazardous to Health Regulations 2002 (as amended) (COSHH), as such the employer should make a suitable and sufficient assessment of the risks to health if exposed to diesel fumes. The employer should take the necessary steps to prevent or adequately control exposure in the workplace.

Where exposure cannot be prevented, the employer will need to consider the use of a combination of specific control measures including:

- workplace air extraction fans;
- tailpipe exhaust extraction systems;
- the use of filters attached to tailpipes;
- catalytic converters.

5.3.2 Provision and Use of Work Equipment Regulations 1998

These Provision and Use of Work Equipment Regulations often abbreviated to PUWER, place duties on people and companies who own, operate or have control over work equipment.

PUWER also places responsibilities on businesses and organisations whose employees use work equipment, whether owned by them or not.

Any modification to NRMM through the retrofit should be carried out without compromise to the PUWER regulations.

PUWER requires that equipment provided for use at work is:

- suitable for the intended use
- safe for use, maintained in a safe condition and inspected to ensure it is correctly installed and does not subsequently deteriorate
- used only by people who have received adequate information, instruction and training
- accompanied by suitable health and safety measures, such as protective devices and controls.

5.3.3 Code of practice for health and safety in tunnelling in the construction industry (BS6164)

The NRMM Requirements cover all NRMM used on-site and as such also apply to equipment used during and for the purpose of tunnelling and therefore crossover with BS6164

Section 24.4.1 of BS 6164 covers internal combustion engines and specifically diesel engines. The stated details which crossovers with The NRMM Requirements are repeated here (type approvals for diesel engines refereed to in BS6164 refer back to EC Directive 97/68/EC).

- In order to meet stringent limits on atmospheric concentrations of nitrogen oxides, the guidance in the BTS publication, "Occupational Exposure to Nitrogen Monoxide in a

Tunnel Environment: Best Practice Guide" should be followed. Where Nitrogen Oxide emissions from diesel-powered plant should be minimised by:

- *Selecting plant of a size capable of minimising unnecessary vehicle movements*.
- *Using new plant wherever possible.*
- *Using engines that comply with the latest EU Tier standards.*
- *Maintaining plant regularly to help maintain operating efficiency.*
- *Monitoring engine emissions.*
- *Using ultra low sulphur grade diesel or other clean fuels.*
- *Operating a plant-idling policy whereby equipment should be turned off when not in use.*
- *Ensuring that plant operators are trained properly.*

- Engines of more than 37 kW-rated output should conform to BS EN 1679-1. This should prevent the emission of exhaust gases likely to cause excessive levels of particulates in the tunnel, and ensure that the engines are designed to minimize fire hazards.
- Ventilating air should be sufficient to dilute toxic gases to safe levels, and reduce smoke and odours to acceptable levels.
- To avoid local concentrations of dangerous levels of contaminants, some form of exhaust conditioning should be used on engines not complying with Euro III or higher.
- NOTE 1 Conditioning can take the form of a fume diluter or catalytic converter. Advice on correct matching should be sought from the suppliers of any conditioning device.
- NOTE 2 Diesel particulate filters can be incorporated, but the duty cycles on locomotives can cause fouling up.
- NOTE 3 Engines conforming to Euro III or higher already incorporate exhaust conditioning.
- Engines for underground use should be "clean burn" types, which produce minimum particulate emissions, with virtually no visible exhaust emissions.

6 Consultation

To understand the contractual compliance progress and establish methods of enforcement of The NRMM Requirements, Crossrail Sustainability & Consents team engaged in a period of consultation during the Spring/Summer of 2012.

Several known companies active in the NRMM supply market and retrofit DPF supply market were contacted as part of the consultation process. Crossrail also communicated with the Environment Industries Commission (EIC) 'Transport Working Group' which represents the interests of the DPF industry. Formal communique to the EIC is presented in Appendix 2. Full details of correspondence and meeting minutes are not detailed in this report though a list of companies and organisations contacted throughout the consultation process is provided in Appendix 3.

6.1 Crossrail Fleet

A request was made to the Tier 1 Contractors to provide details of NRMM currently on site and forecast to be used across active sites in order to provide an understanding of the total Crossrail fleet. The following information was requested:

- NRMM Type.
- Model.
- Engine Size/Power Output.

- Period/Duration on Site.
- Engine Emission Standard Stage.
- Details of any retrofitted NRMM with Diesel Particulate Filters.
- Model/Type of Filter Proposed/Fitted.
- Fitter and date of fitting or timeline for fitting.
- Comments/Evidence/Position/Timeline on why NRMM compliance.

As site activity and NRMM use undergoes frequent changes, the data obtained provided a snapshot into the fleet composition for the period Jan-April 2012.

From the data received a total of 213 individual NRMM were recorded with full details on engine standards for total of 139. The break down of this 139 NRMM was:

- EU Stage II - 16 (12%)
- EU Stage IIIA - 82 (59%)
- EU Stage IIIB - 39 (28%)
- EU Stage IV - 0 (0%)

The data showed that over 70% of the NRMM did not comply with The NRMM Requirements. Estimates from Tier 1 contractors indicated 80% of NRMM was hired in and the rest owned by Tier 1 contractors purchased specifically for the contract, though procurement of NRMM often took place before the market availability of EU Stage IIIB engines.

6.2 Consultation Findings

Each Crossrail Contract operates under different on-site conditions and operating restrictions with a wide array of NRMM. As such, each contractual arrangement required a unique plan of action to adhere to The NRMM Requirements. This site action would involve a combination of both procuring NRMM to site with the required EU emissions standards as well as retrofitting with DPF. This could include ensuring all plant procured through purchase or hire came with suitable engine standards or retrofit or adopting to use a service and maintenance package with a DPF supplier to retrofit entire fleets of plant.

Seven contractors demonstrated part compliance of their NRMM or a plan was set in place to achieve compliance before the end of 2012. Some contractors chose to ensure all NRMM hired in or as part of a planned purchase meet Stage IIIB emissions standards. Other contractors choose to adopt a service and maintenance package with a DPF supplier to retrofit entire fleets of NRMM.

The NRMM Requirements appeared to be driving the demand across the industry for retrofit and uptake of higher EU Staged engines. Within the consultation period the majority of NRMM hire companies working on Crossrail were in the process of upgrading supply fleet; towards offering both NRMM with either EU Stage IIIB engines or EU Stage IIIA/II engines retrofitted with DPF.

This process of upgrade is complicated by the life cycle of different NRMM and not purely because of market demands. For example; Large Cranes tend to remain in the market for upwards of 10-15 years, unlike smaller excavators which tend to remain for no more than 5-10 years. Additionally, some NRMM supply companies market their NRMM as being no older than four years old. Hire purchase agreements between Tier 1 Contractors and NRMM hire companies also vary between days, weeks and years. It is more typical that larger or specialist

equipment have longer hire purchase periods while more commonly available NRMM have hire purchase arrangements at very short notice and can be for days and weeks.

Stage IIIB NRMM started being released to the market at the beginning of 2012, as such the availability of NRMM before the project and up to spring 2012 was naturally quite low. Certain other factors are also set to influence the natural uptake of newer NRMM. Under the EU regulations a flexibility scheme exists where older equipment can be placed on the market post 'market placement' date. This was increased to 37.5% of the engines released per engine or equipment manufacturer in 2012[13].This flexibility only applies during the transition of EU Stage IIIA to IIIB, though the construction industry has a lobbying group for relaxation of EU regulations, which may well influence uptake of Stage IV.

Stage IV type approval dates are also devised to match the United States Environmental Protection Agency (US EPA) emissions requirements. To avoid competitive disadvantage in different markets some Original Equipment Manufactures (OEM) are trying to by-pass EU Stage IIIB (US Interim Stage 4i) altogether and developing straight to EU/US Stage IV. The availability of Stage IV, whist almost non-existent in London in 2012 and 2013, is therefore set to increase during 2014.

According to the type approval dates constant speed engines (generators) are on a slightly different timeframe and thus are not available with Stage IIIB engines during 2012 and 2013. There appearance on the market is anticipated to be in 2014.

None of the Continuous Flight Augering (CFA) piling rigs or diaphragm-wall cranes on site were compliant with The NRMM Requirements during the Consultation period. Both Stage II and Stage IIIA equipment was being used on site and there was limited availability of Stage IIIB piling rigs on the market.

With regards to the possibility of retrofitting piling rigs with DPF; The Federation of Piling Specialists (FPS) provided a statement in 2011[14] that sets out that due to technical issues, undertaking DPF retrofit of piling rigs is not currently feasible. These technical issues also apply to diaphragm-wall crane bases. Further clarification on this position statement was requested by Crossrail in June 2012. The Chairman of the FPS Plant Group responded to email correspondence that; *"to our knowledge since the FPS statement was issued last Jul, none of the engine or equipment manufacturers have made any further progress/investigation into modifying existing engines to meet the requirements of Stage IIIB. Their efforts have been channelled into the development of the Stage 4 engines due in 2014. During the intervening period a number of third party companies have come forward offering to modify engines but without any consultation with engine or equipment manufacturers."*

Most of the crawler cranes within the consultation period were Stage IIIA engine equipped, but there are also examples of Stage II cranes being used on site. There were two examples of use of Stage IIIB cranes on site but overall there was again a low market availability of Stage IIIB equipment. None of the cranes were retrofitted with DPF.

A retrofit case study was supplied to Crossrail for a between Crane Supplier 'Weldex' and DPF supplier 'Cawdell' for a Stage IIIA 80 tonne crane see Appendix 4. There was also information from the consultation process suggesting such a retrofit is not technically feasible for a crawler

[13] http://www.cece.eu/publicationsDetail.php?id=625&mem=0

[14] http://www.fps.org.uk/fps/FPS%20Statement%20Emission%20Standards%20for%20Non-Road%20Diesel%20Engines.pdf

crane with a Stage II equipped engine. The consultation revealed that while the technical feasibility to retrofit Stage IIIA cranes with DPF is possible, the costs reported were considerable and often quoted to be between £20-30,000 which was deemed by contractors to be both financially and time prohibitive. There also appeared to be a lack of maturity with DPF supply within the supply chain with no clear agreements on how to pass the cost on between the supplier and contractor.

For other NRMM, which generally have lower powered engine ranges, the consultation of the supply chain suggested technical feasibility was better. There was conflicting anecdotal evidence on NRMM performance following DPF retrofit with additional concerns over very specialist equipment and low powered equipment where exhaust temperatures was not suitable for many retrofit types.

Major NRMM hire companies were offering supply of some Stage IIIA NRMM fitted with DPF with limited delay, although the overall availability of Stage IIIB NRMM was set to increase over the course of 2012.. It was also understood that some Stage IIIB NRMM such as telehandlers and dumpers would not come to market until mid 2013.

6.3 Diesel Particulate Filters Retrofit Market

The retrofit market was also consulted through approaching companies listed on the EST NRMM register (also members of the EIC transport working group). Findings of these consultations are summarised here:

- A Diesel Particulate Filter (DPF) is a post-exhaust diesel emission control system that is intended to reduce the emissions of particulate matter (PM) from the engine.
- The 'approved' DPFs on the EST NRMM register are all 'wall-flow' or 'full-flow' filters which means all exhaust is forced through a filter membrane reducing total particulate mass emitted to the atmosphere.
- DPFs differ to catalytic convertor or a diesel oxidation catalyst (DOC) which convert emissions of Carbon Monoxide (CO) and Hydrocarbons (HC) into Carbon Dioxide (CO_2) and Water (H_2O) but do not reduce emissions of particulates to an EU Stage IIIB equivalent level. These systems are typically termed 'through-flow' which means the exhaust gases flow though the unit only partially restricted.
- There are many different types of DPFs and different ways they operate.
- Some DPF designs combine the use of a 'pre-catalyst' or have a catalyst coating to help the removal process but a catalytic convertor on its own will not reduce PM to the same level of a DPF.
- DPF do require on-going maintenance and cleaning or 're-generation' to ensure they are working affectively, though this can be tied in to existing maintenance schedules.
- Some DPF simply 'trap' particulates and after a while become full and require periodic removal for regeneration or cleaning, either through high pressure or heat treatment. The common method is to have replacement filters on site to replace while others are undergoing cleaning.
- Other DPF can regenerate 'activity' whilst in-situ on the NRMM and require a dose of fuel or heating coil to regenerate.
- This process can lead to a small increase in fuel consumption. The EST Register requires that DPF do not give rise to more than 5% increase in CO_2 emissions; which can be assessed by measurement of CO_2 or reference to the change in brake specific fuel consumption.

- Poor engine maintenance practices can lead to increased particulate production and engine oil consumption resulting in more frequent DPF regeneration and cleaning.
- The correct retrofit should not lead to operational issues. Improper choice of DPF or a one-size fits all approach, along with a lack of understanding and operational training can lead to poor engine performance and problems with using a DPF.
- In practice, fuel consumption is kept to a minimum through correct maintenance and operation of NRMM and more affected by this than any additional increase in fuel consumption utilised by the DPF.
- DPFs that have US and EU certifications have already undergone rigorous programmes to "verify" emissions performance and product reliability before they enter the marketplace.
- DPF which use a disposable filter medium are not approved by the EST NRMM Register.
- Typically the DPF replaces the exhaust silencer and does not affect noise attenuation.
- The DPF supplier should provide warranty on the actual DPF along with operator instructions and any training required along with a data logger/back pressure monitoring system. This will help ensure that the DPF is maintained correctly and operates within the range of the engine requirements and therefore should not affect engine performance or compromise the engine warranty.
- Engines ranged below 65kW experience difficulties for retrofit including low exhaust temps and availability of space, though is limited to specific cases and equipment.

A series of costs were supplied by some DPF suppliers. The costs supplied were representative of the purchase price of passive DPF and were considered indicative and not provided as commercially fixed for Crossrail or any third party. These indicative costs are presented in Table 1.

Table 1 Indicative Retrofit Financial Costs

Power Range - Low (kW)	Power Range –High (kW)	Price Range – Low	Price Range - High	Price Range - Median
37	80	£3,000	£3,200	£3,100
60	140	£3,200	£3,700	£3,450
110	180	£3,800	£4,200	£4,000
140	210	£4,200	£4,600	£4,400
160	260	£4,600	£4,800	£4,700
170	300	£4,800	£5,700	£5,250
250	360	£5,700	£6,300	£6,000

The DPF retrofit costs medium range come in at around £4,500 per DPF unit, with additional installation and on-going maintenance costs. The consultation also revealed that larger excavators (in excess of 20 tonne lifting capacity) have DPF costs in excess of £10,000 while piling rigs and cranes; 80 tonne and upwards, the costs were between £20,000-£30,000 per DPF unit and fitting.

Typical NRMM (i.e. excavators, telehandlers, and dumpers) purchase prices ranges between £30,000-£150,000 depending on size and age of machine. DPF costs can therefore represent a considerable percentage of purchase costs, especially for larger plant. Full market analysis was

not performed and no single solution or costs for a fleet retrofit approach was available that can allow for complete cost analysis.

Selection of an appropriate DPF for a NRMM indicates that the DPF would become a permanent fixture of the equipment for its entire lifetime and therefore a theoretical cost could be spread over the duration of the NRMM lifetime. Despite this the consultation revealed there was a significant lack of maturity in the hire market for commercial costs of retrofit to be distributed throughout the lifetime of the equipment and/or across the hire purchase periods.

6.4 Alternatives to Retrofit

Several alternatives have been developed in the construction industry which may offer certain advantages over traditional diesel engines namely; Hybrid Engines (such as the Komatsu HB Excavator series), Compressed Natural Gas (CNG) and Full Electric motors. There may also be additional benefits in pollutant emissions by changing to fuel from diesel to certain Biofuels.

These alternatives were uncommon at the time of consultation and a full investigation on their availability, suitability and financial costs was not undertaken.

6.5 Summary of Consultation

Table 2 provides a summary of the NRMM position across 11 active contracts and the supply chain during the consultation period.

Table 2 Summary of NRMM from Consultation

	Mini Excavator /Dumper / Telehandler / Roller / Generator / Pump / Tractor / Loader / Excavator / Articulated Dump Truck	**Crawler Crane (lifting only)**	**Piling Equipment / Diaphragm Wall Equipment / Hydraulic Crawler Drills**
Availability of 3B	Supply chain, availability reasonably high and predicted to increase over 2012-2014. EU flexibility provision on 3A and longevity of equipment mean some low availability. Generators/Dumpers/Telehandlers not available at 3B.	Low availability in the market place. Some 80T and 100T only. EU flexibility provision on 3A and longevity of equipment mean availability low.	3B generally not available in the market. EU flexibility provision on 3A and longevity of equipment mean availability low.
Evidence of Retrofit	Wide selections of plant hire availability/ DPF suppliers offering both stock and service agreements.	Evidence of a single crane supply company offering 3A engine with DPF.	No seen retrofit. Supplier statements of retrofit in other countries, no UK experience. No supplier case studies with details.
Downtime for replace/retrofit	Most Plant hire can/are supply with limited delay. 4-6 Weeks lead, additional day of training	Some downtime required before hire, 1 month to 15 week lead time (dependant on availability of DPF).	Testing on BG40 and small rigs under way by Federation of Piling Specialist members (Bachy).

Accessibility to Site/Risk to project delay	Availability of equipment high and options for replacement with small lead times.	Special load/Section 61 deviations (out-of-hours)/Road closures/removal of hording etc. required. Some Cranes required to be craned in and out of location On-going maintenance may also be increased	Special load/Section 61 deviations (out-of-hours)/Road closures/removal of hording etc. required. Some Cranes required to be craned in and out of location On-going maintenance may also be increased
Capital Expense	Dependant on contract details and approach DPF costs range between £3,000-£5,000 per unit, plus additional maintenance costs. Expenses typically increase through plant hire charge, possibility of one off charge to pay for entire retrofit. Most plant hire companies spreading the costs of retrofit i.e. increase of £100-150pw in hire charge. Alternative options include entering into service agreement with specialist DPF supplier for retrofit and on-going maintenance	Dependant on contract details and approach No details of costs increase through plant hire obtained. Possibility of one off charge to pay for entire retrofit. Retrofit anticipated in be in-excess of £10,000-20,000	No details of costs obtained, retrofit anticipated in be in-excess of £20,000 per Rig

7 Options Appraisal

7.1 Issues and Engagement

Following the consultation period it was apparent that compliance to The NRMM Requirements was not being achieved and was unlikely to be achieved without further Crossrail engagement. An options appraisal was carried out to understand practical options and establish a timeframe for achieving compliance.

There were various reasons as to why compliance was not being achieved the main issues are outlined below:

- Difficulty in procuring latest emission standards engines:
  - Manufactures desire to sell old engine fleet first so a lack of availability.
  - Stage IIIA, II and Pre-EU Stage engines are still in wide circulation in the market.
  - CECE[15] recommending an increase in the EU flexibility provision.

- Hesitation in construction industry to embrace retrofit options:
  - Concerns over technical operation.
  - Concerns over operational safety.
  - Position paper from influential bodies like Federation of Piling Specialists rejecting retrofit.
  - Pre-EU engines not suitable for DPF.

- Financial Costs and lack of understanding where the costs will be incurred

[15] CECE position about the application of the amending directive on enlargement of flexibility http://www.cece.eu

- Capital costs to procurement.
- On-going maintenance of fleet costs.
- Lack of outside funding arrangements (i.e. government incentives).
- Unknown cost share relationships between project/contracts/subcontractors/supplier.

- Legacy of non-enforcement of previous similar requirements stated in:
  - GLA Best Practice Guidance.
  - Olympic Development Authority.
  - Local Authority Action Plans and Code(s) of Construction.

In order to overcome these obstacles and establish potential options a process of engagement was established with the entire supply chain with Crossrail offering communication and assistance in both contacts and technical information to Tier 1,2, 3 and 4 contractors and suppliers. This engagement adopted no formal arrangement instead Crossrail Sustainability and Consents team maintained channels of communication with major supply routes as well as working to create relationships as detailed in Figures 1 and 2.

Figure 1 Crossrail Supply Chain Structure

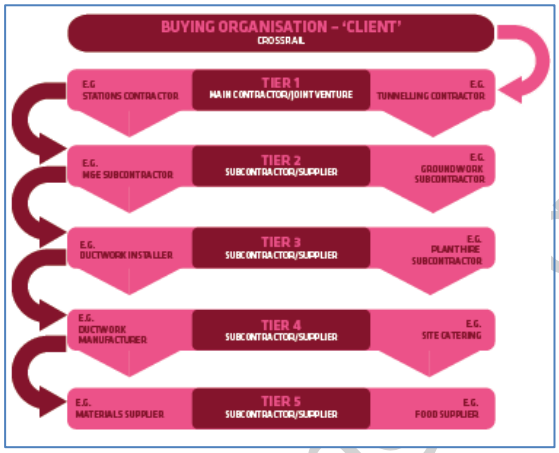
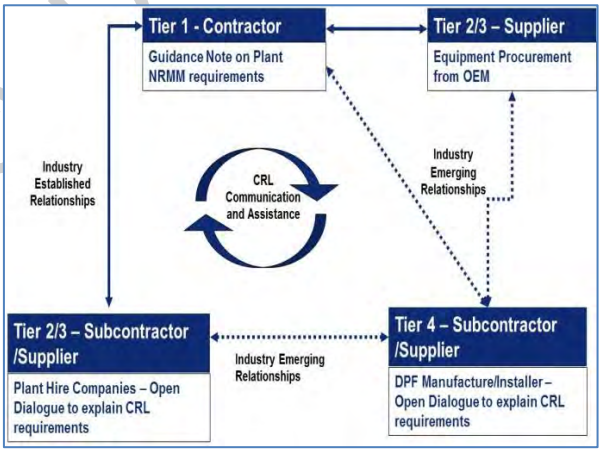


Figure 2 NRMM Supply Chain Engagements



7.2 Cost and Emissions Analysis

It was considered prohibitively expensive and time consuming to establish a contract-by-contract cost-benefit analysis and detailed emissions forecast for the entirety of the Crossrail Project. Any such approach would require details of all projected equipment on each contract for the duration of the contract including the running hours and typical loading profiles of each NRMM. An analysis of the cost and engine data provided from the consultation process was however undertaken. It is noted that considerable limitations exist for this analysis including the changing nature of the Crossrail fleet over time and lack of data relating to engine utilisation, though the analysis was undertaken with the data available.

The 139 recorded NRMM are presented in Figure 3 according to engine size within several categories of NRMM. These distinct NRMM categories along with average engine size were used to calculate averaged total emissions and averaged total costs of retrofit for each category.

Figure 3 Consultation Fleet Average Engine Size.

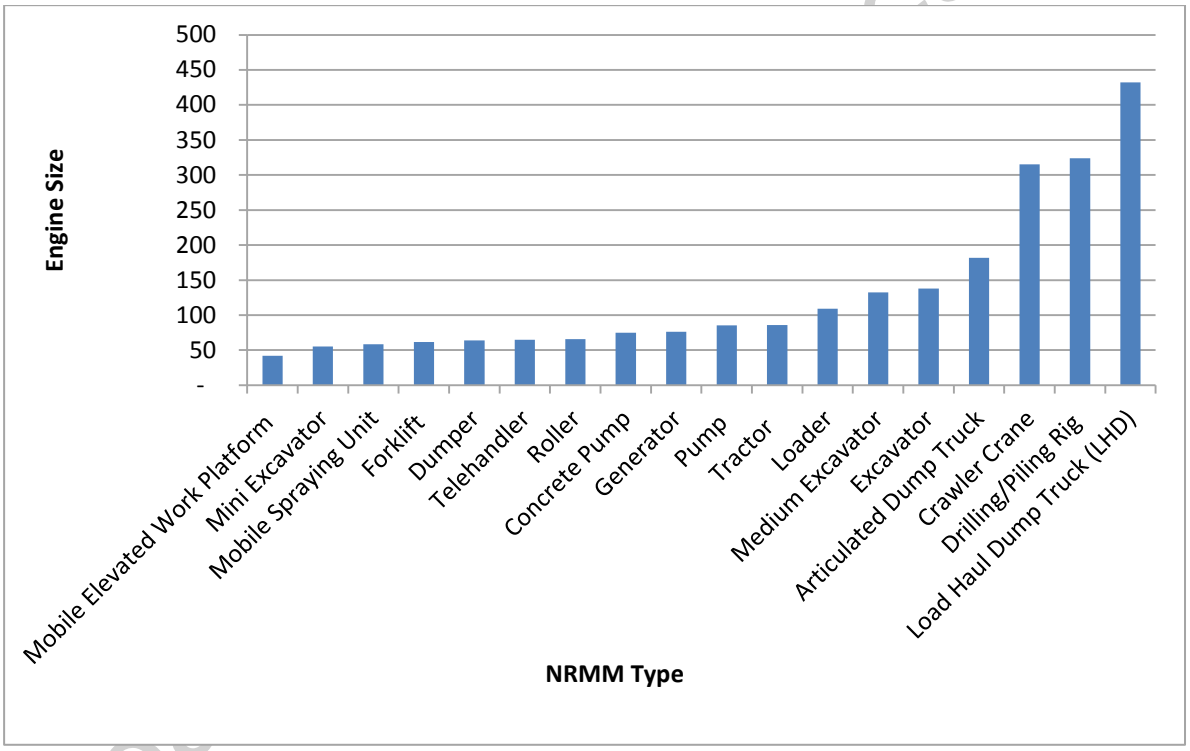
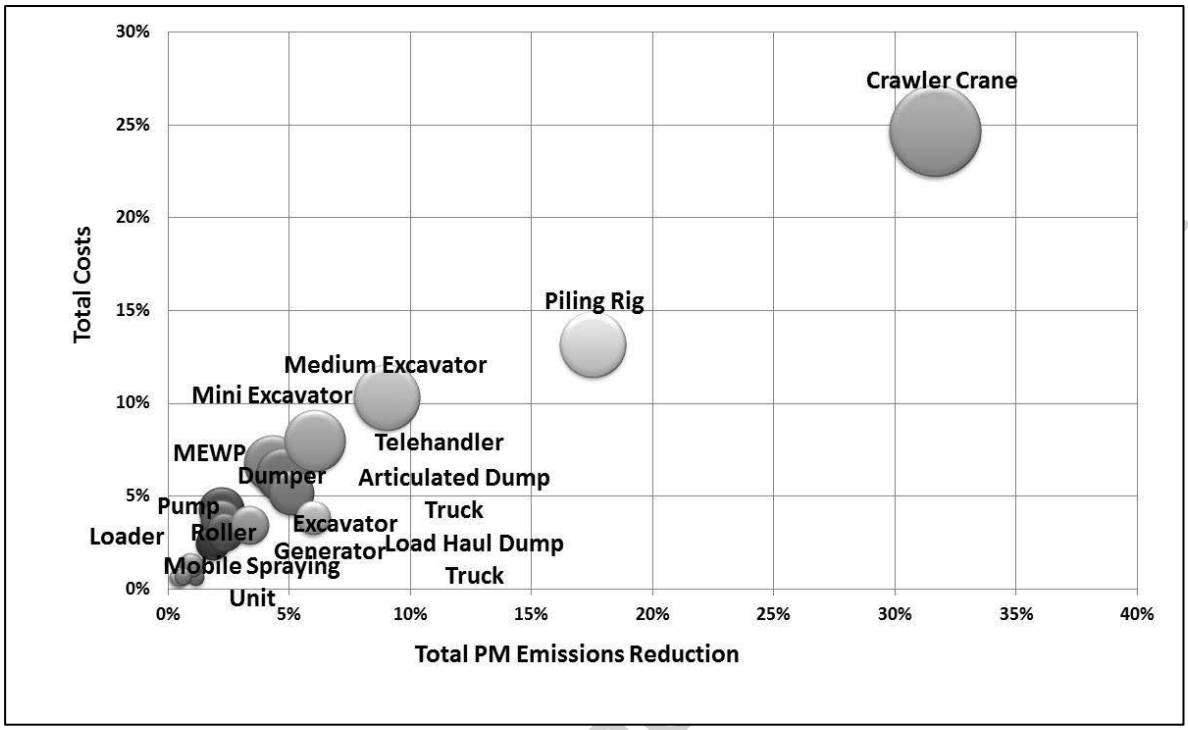


Figure 4 presents these NRMM categories incorporating number of units within each group presented as proportional total emissions reductions if DPF retrofit was achieved[16] against proportional costs for each category.

Figure 4 indicates that the NRMM categories with larger engine sizes, Cranes and Piling rigs have the highest potential for proportional emissions savings though retrofit, though incur the highest percentage of the total costs for the fleet.

[16] Based on Stage IIIA PM emission factors for no retrofit and Stage IIIB emission factors with retrofit

Figure 4 Consultation Fleet Percentage of Total Costs against Total PM Emissions Reduction potential per NRMM Type*



7.3 Option Scenarios

Based on the consultation fleet data findings, potential options where narrowed down to a few scenarios, these option scenarios are presented in Table 3 and discussed below.

Table 3 NRMM Options Scenarios from Consultation Fleet Data (11contracts /130 NRMM)

	Total PM Emissions (kg/hr)	PM Percentage Reduction	Estimated Retrofit Costs	Equivalent PM Emissions (kg/hr)	
				Car*	HGV
1. Do nothing (no NRMM)	5.65	0%	£ 0	8,557	1,510
2. Do everything (all NRMM)	0.59	-90%	£834,450	7,661	1,352
3a. Do something (exclude NRMM <56kW)	1.04	-82%	£711,700	6,987	1,233
3b. Do something (exclude NRMM <75kW)	1.88	-67%	£527,400	5,713	1,008
4a. Do something (exclude Pilling Rigs)	1.48	-74%	£724,450	6,319	1,115
4b. Do something (exclude NRMM <56kW and Piling Rigs)	1.93	-66%	£601,700	5,633	197

**Emission factor for Cars based on EURO IV engine standards 0.03g/km travelling at 20km/h. **Emission factor for HGV based on EURO III engine standards 0.1g/kWhr*

1. Do nothing – This approach would render The NRMM Requirements obsolete and would not deliver success in the form of project delivery.
2. Do Everything – Enforce retrofit on all NRMM, regardless of costs, time and industry position. This approach was ruled out due to lack of confidence in the supply market that this demand can be met. In addition it was deemed to require a large amount of time and costs to negotiate with industry, which might lead to non action within the time frame of the project.
3. Do something –
    a. Focus on larger engines first, with the largest emitting engines; and take no action on the smaller engines. This could deliver the second highest level of emission savings but also the second highest level of costs. This option would again require further negotiations with the industry which might lead to non action within the time frame of the project.
    b. Similar to option 'a', though a large portion of the low powered fleet are removed from the requirement. This option presents second poorest PM reduction to cost ratio.
4. Do Something –
    a. Relaxing requirement for Piling Rigs, but enforcing requirements on all other NRMM providing the best PM reduction to cost ratio. This option would also be a preferred approach within the supply industry therefore offering the least resistance to enforcement.
    b. Relaxing requirement for Piling Rigs and NRMM below 56 kW, but enforcing requirements on all other NRMM. This option provides the worse PM reduction to cost ratio, though this option of focusing on the middle ground would likely be the industry preferred option and therefore have the least resistance to enforcement.

The scenarios were also consulted with the Crossrail Project Managers and the Area Directors. Based on the consultation period data, the analysis of the potential options and from consultation with Crossrail management; it was decided to pursue option 4a and enforce the requirement on all NRMM with the exception of the Piling Rigs. Requests for dispensations or deviations from this requirement would be viewed on a case by case basis and understood within the context of the contract and the project as a whole. In addition it was decided to relax The NRMM Requirements on Cranes until July 2013 to allow the market time to adjust and upgrade, without suffering extensive project delays.

8 Performance Standard and Compliance Deadlines

The following performance standard and staged compliance deadlines for The NRMM Requirements were issued to Crossrail contractors in September 2012.

The performance standard of Volume 2B, Part 21 Environmental Management, Clause 21.10. for all NRMM 2 is defined as:

- *NRMM with type approval engines Euro III(b) or IV; or*
- *NRMM with type approval engines Euro II or III(A) combined with after treatment devices listed under or with certification from:*
- *The Energy Savings Trust Energy Savings Trust Non-Road Mobile Machinery Register; or*

- *The Swiss Federal Ordinance on Air Pollution Control (OAPC) FOEN Particulate Filter List; or*
- *Californian ARB Verification Classifications for Diesel Emission Control Strategies, Retrofit Device Verification Database Level 3; or*
- *Technology approved through the Transport for London (TfL) Low Emissions certification (LEC) process, Emission Stage Phase 4 achieving PM emissions limits Standard C, provided there is a proven record of off-road capabilities.*
- *An equivalent certification scheme provided that prior acceptance has been received from the Project Manager.*

By 8 November 2012, the contractor is requested to have implemented a programme of on-site checks on all NRMM which shall be recorded. The purpose of the checks is to demonstrate current compliance with the obligations set out in Part 21 Clause 21.10.2.

By 1 December 2012, the contractor is requested to ensure that all NRMM being used on site for a continuous period longer than 30 days shall be compliant with Volume 2B, Part 21 Environmental Management, clause 21.10.2. Piling Rigs, Diaphragm Wall base units and crawler cranes are exempt from this deadline.

By 20 July 2013, the contractor is requested to ensure that all crawler cranes being used on site for a continuous period longer than 30 days shall be compliant with Volume 2B, Part 21 Environmental Management, clause 21.10.2.

Dispensation for piling rigs and diaphragm wall base units until and unless notified otherwise, the project manager will not be enforcing Volume 2B, Part 21 Environmental Management, Clause 21.10.2 as it relates to piling rigs and diaphragm wall base units.

Table 4 Staged Compliance Deadlines

	General requirements	NRMM over 37kW	Dispensation Group 1 Crawler cranes	Dispensation Group 2 Piling Rigs and D-wall bases
Stage 1 31 July 2012	Implement a programme of on-site checks.	Equipment should either be compliant or the contractor must have a plan of action for compliance.	No action required at this stage	No action required at this stage
Stage 2 10 November 2012			Crawler cranes should either be compliant or the contractor must have a plan of action for compliance	
Stage 3 01 December 2012	Demonstrate on-going compliance through programme of on-site checks.	Demonstrate on-going compliance with requirement to the defined performance standard	End use of Stage 2 cranes, replaced by Stage IIIA or Stage IIIB cranes Crawler cranes should either be compliant or the contractor must have a plan of action for compliance	
Stage 4 31 March 2013			Crawler cranes should either be compliant or the contractor must have a plan of action for compliance. Demonstrate evidence of the plan of action	

			being implemented	
Stage 5 20 July 2013			Demonstrate on-going compliance with requirement to the defined performance standard	Crossrail will review the availability of Stage IIIB piling equipment and the progress made by the FPS with addressing technical issues.

9 Implementation

9.1 Roles and Responsibilities

The principal responsibility for implementation of The NRMM Requirements lies with the Tier 1 contractors. To provide assistance, Crossrail has issued the Guidance document CRL-XRL-T1-GUI-CR001-50001 and amended versions *"Guidance on Emissions from Non-Road Mobile Machinery (NRMM) and Retrofitting with Diesel Particulate Filters"*. Several briefings have also been provided at the regular forum for Tier 1 Contractor Environmental managers (the Environmental Managers Forum). In addition, an alert regarding the Ravex 'add on' exhaust filter kits was issued relating to their non-compliance with Crossrail's requirements.[17]

Acting in a client role, Crossrail has the following actions to check and report on compliance:

- Review contractor processes and data for compliance and provide input to Crossrail reporting
- Carry out inspections of on-site compliance
- Carry out audits of contractors processes
- Review and accept requests for dispensation from The NRMM Requirements
- Enforce The NRMM Requirements through contractual mechanisms.

Information on roles and responsibilities within Crossrail is provided in Document No: CR-XRL-T1-GUI-CRG03_Z-50001 '*Air Quality Interfaces*[18]*.* Further information on implementation of the responsibilities is provided below.

9.2 Compliance Data and Input to Crossrail Reporting

Crossrail is undertaking quarterly compliance reporting on contractors with the results reported as part of the Environmental Dashboard. This reporting is based on a review of the contractors' records for compliance.

Although not stated in the contractual requirements it is recommended contractors should keep a record of NRMM used onsite at any time in order to establish compliance with the Works Information.

There is no requirement for contractors to submit to the Crossrail Sustainability and Consents team a detailed quarterly record of NRMM used onsite. Individual Project Managers may decide to keep this requirement if it was considered to be required or helpful in completing compliance performance tracking.

[17] https://eb.crossrail.co.uk/eb/Search/QuickLink.aspx?n=CRL1-XRL-T1-XBU-CR001_Z-50001&t=3&d=Main%5ceBProd&sc=Global&r=1.0&i=view
[18] https://eb.crossrail.co.uk/eb/Search/QuickLink.aspx?n=CR-XRL-T1-GUI-CRG03_Z-50001&t=3&d=Main%5ceBProd&sc=Global&r=1.0&i=view

A review of records will allow quick reference for visual inspection as well as providing identification of any use of retrofit and reference to dispensations and the appropriate Crossrail CCM and corresponding PMC.

Table 6 Example Contractor Record Sheet

NRMM Type	Model	Supplier	Engine Size/Power Output (kW)	Period/Duration on Site (weeks)	Engine Emission EU Stage				DPF Make, Model and Certification	Dispensation Requested	Dispensation Received
					II	IIIA	IIIB	IV			
Excavator	CAT	Contractor	60	38			X		n/a	n/a	n/a
Excavator	Hitachi ZX135	Plant Hire Company A	60	122		X			Supplied with filter No:XXXXXX from Plant Hire Company A (see attached certificate)	n/a	n/a
Rotary Piling Rig	BG40	Contractor	75	50		X			n/a	Yes	Yes (see attached CCM/)

9.3 Site Inspections

Crossrail is undertaking site inspection checks on contractors to verify on site the information that has been provided by contractors.

The onsite inspections would typically follow a review of paperwork identifying a record of NRMM and their compliance status.

Inspections would be carried out to verify NRMM make and model and where appropriate identification of engine plate with EU Type approval code can be identified. Additional inspections may be required on Diesel Particulate Filters (DPF) where retrofit has been a compliance option. This will typically be through the identification of the make/model and cross-referencing that the make/model has been verified through an approved verification scheme. The warranty number of the DPF can also be cross-referenced against supporting documents provided by the supplier. Further, more detailed inspections to verify compliance may be requirement for selected pieces of equipment.

A field guide to assist with this identification process has been produced '*CR-XRL-T1-GUI-CR001-50006 Non-Road Mobile Machinery (NRMM) Diesel Engine Emissions Field Guide to Identification of Diesel Engine Emission Compliance'.*

Where a non-conformance is identified by the Crossrail team a Crossrail Non-Conformance Report (NCR) may be raised and dealt with in line with contractual arrangements.

9.4 Dispensations

Cases for deviations from The NRMM Requirements follow standard Crossrail procedures with requests set out to the relevant Crossrail Project Manager.

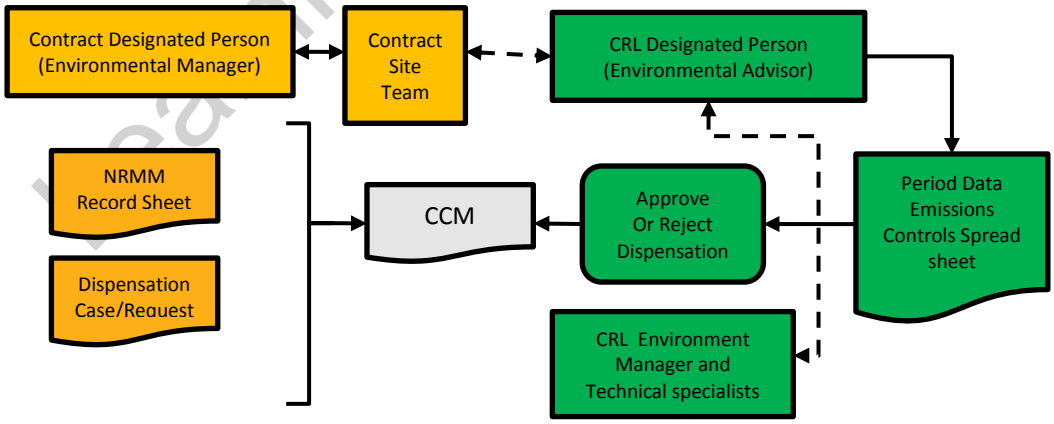
There is no standard method for concluding if a dispensation should be issues, instead the dispensation process should follow simple decision tree logic based questions to allow for the appropriate dispensation.

- Request for Dispensation received?
- Check type of NRMM with the Construction Team?
- Who is supplying the NRMM?
- Are they established suppliers and have they met requirements elsewhere?
- When is the NRMM due to come to site, what is the time frame to source alternatives?
- Will the NRMM be returning to site again?
- Can a timeframe for compliance be established?
- Can alternative NRMM be used or compliant NRMM sourced?
- Can the NRMM be retrofitted?
- What is the evidence base for/against choice of NRMM or ability to retrofit?
- Has someone in the Project done this before?
- Is the NRMM critical to project milestone?
- What is the cost of retrofit and who/when will bear the cost?
- Can the project succeed within the downtime required?

Dispensations should only be granted based on valid understanding of rational why the NRMM is not compliant. The dispensation should be communicated to the project team and suppliers to explain why a dispensation has been granted. Consultation with the Sustainability and Consents team should be undertaken to ensure that a consistent approach to dispensation is being adopted across the project. Figure 5 illustrates the dispensation reporting process.

Some NRMM may be brought onto site for a very limited time period and fitting of DPF may not be practicable. For example, any NRMM on-site for less than 30 days will not be expected to comply. Details of all NRMM on site (regardless of the duration of use) will still need to be supplied to Crossrail. Use of stock rotation to avoid the requirement should not be tolerated.

Figure 5 Crossrail NRMM Dispensation Request Process



10 Compliance Review

Following the implementation of the process controls, performance standard and compliance deadlines for The NRMM Requirements site visits and inspections were carried out by the Crossrail Sustainability & Consents team in February and March 2013.

This review was conducted across 24 active contractor sites. This was undertaken at the same time as the Crossrail 'Supplier Performance Appraisals'. This section details the findings and outcomes of this review. Table 8 presents a summary of Project NRMM position following the Review Period.

From the NRMM reviewed during the review period a total of 270 individual NRMM were recorded. The break down of this 270 NRMM was:

- EU Stage II 3 (1%) [Consultation period count 3 (21%)]
- EU Stage IIIA 193 (71%) [Consultation period count 82 (59%)]
- DPF Retrofit 84 (31%) [Consultation period no data]
- EU Stage IIIB 58 (21%) [Consultation period count 39 (28%)]
- Dispensation 89 (33%) [Consultation period no data]
- Outstanding 43 (16%) [Consultation period no data]

The composition of the fleet changed significantly between the consultation period and the review period. There was a 30 % increase in retrofit from a very low anecdotal count during the consultation period. Uptake of Stage IIIB had increased by 19 but represented a lower overall percentage than the consultation period.

Overall compliance with the requirement increases dramatically from a recorded 28% during the consultation period to at 86% (inclusive of dispensations) during the review. As dispensations do not necessarily indicate PM emission reductions the actual emission controls across all the project was 46%.

Figure 6 and figure 7 present the detailed breakdown of the NRMM into type category and related volumes across the Project. The full list of plant including Make and Model where available is provided in Appendix 5.

Figure 6 Supplier League Review Detailed Breakdown of NRMM (High Volumes)

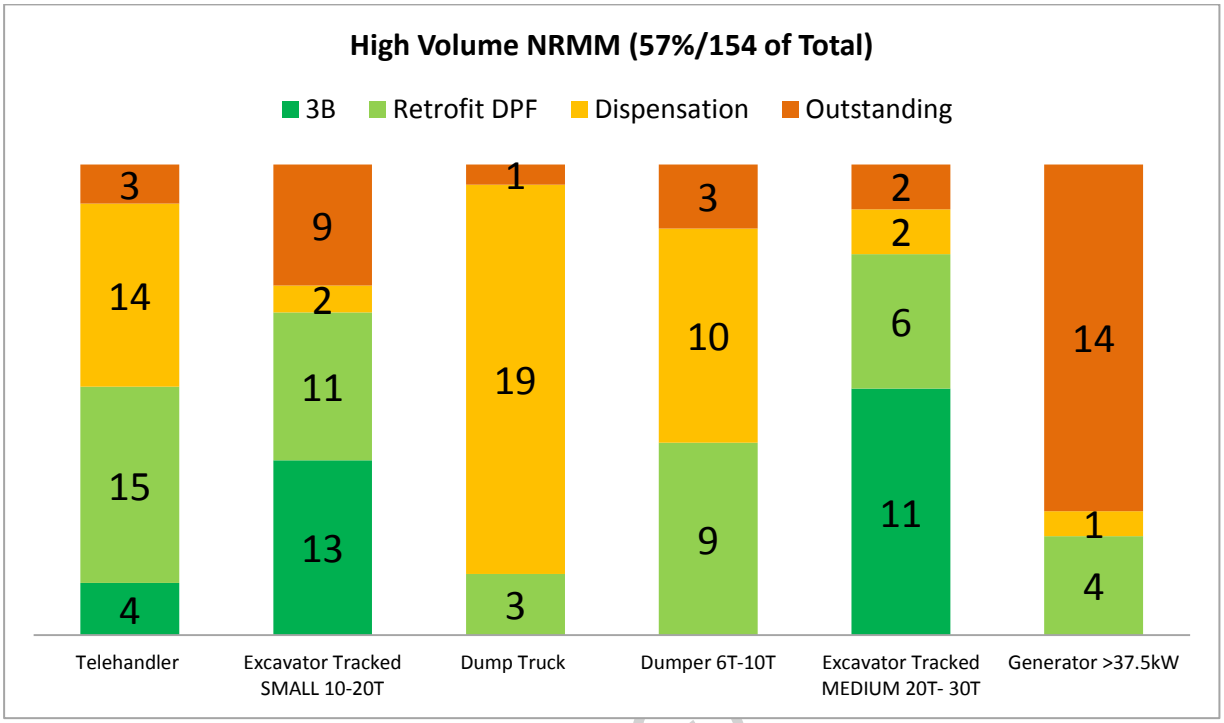
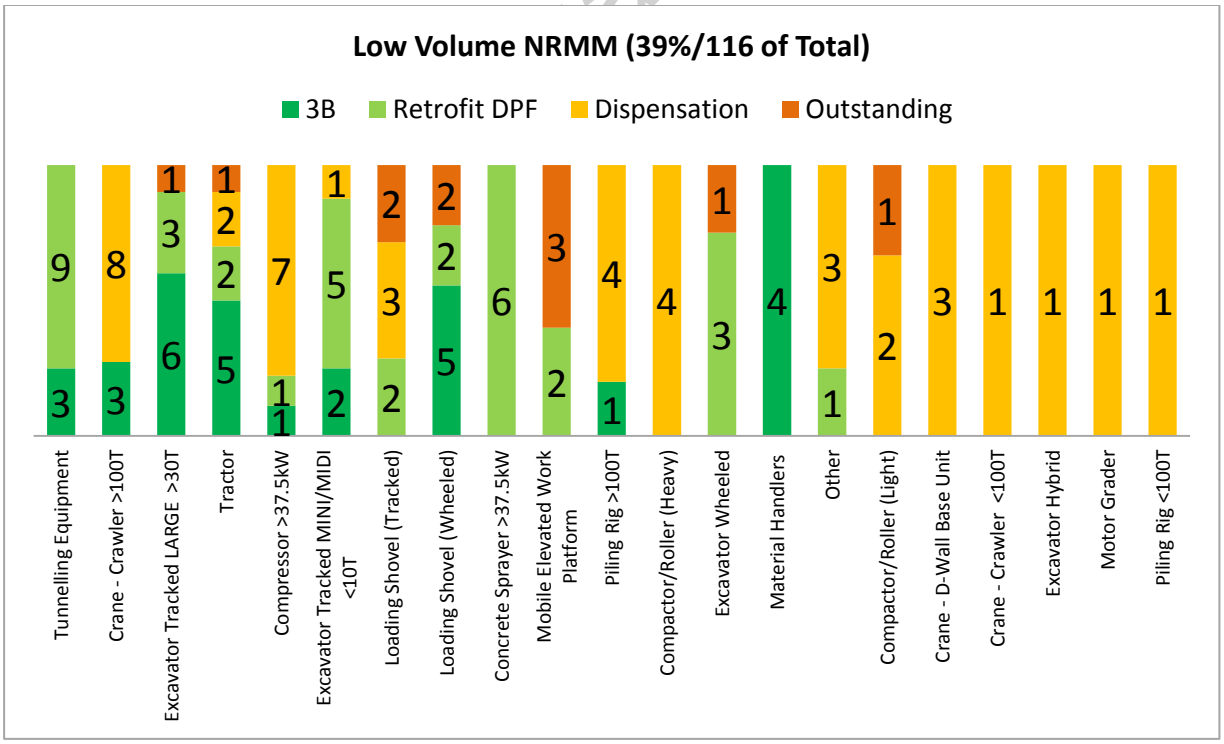


Figure 6 Supplier League Review Detailed Breakdown of NRMM (Low Volumes)



The review process also investigated several areas of involvement of the contractor in achieving a level of compliance, with those being; Procurement Process, Compliance Control and Onsite Inspections. Several areas of best practice were identified were compliance on site was high:

- The contractor team have undergone a thorough investigation into their fleets emission controls and DPF requirements.
- The Environment Manager is or has been directly involved in Procurement Process.
- The Plant manager has engaged with the Environmental Manager on which NRMM have undergone retrofit.
- DPF suppliers have been brought to site to discuss retrofit requirements with contractor teams.
- A NRMM record sheet is held, where responsibility of updating is through the Environmental Manager.
- NRMM inspected visually across the site including DPF and Engine plate numbers
- Weekly checks undertaken on site and details of any new NRMM recorded onto record sheet using photographic evidence as support documentation.
- Use of “stickers” attached to the NRMM on site to demonstrate visually that the NRMM are meeting the emission requirements. These can be related to a log of the NRMM showing the details of the emissions control.
- NRMM inspections are carried out by NRMM specialists on a 6 month basis to check that NRMM supplied have been provided with appropriate DPFs and are functioning correctly.

The review process also discovered several areas if concerns and issues from the contractor teams:

- Plant manager expressed concerns over retrofit, in particular the ‘cleaning though baking’ process of regeneration (which is done on site) and increase in gaseous emissions from retrofitted Liebheer SCL tunnelling plant which was retrofitted by Liebherr before coming to site.
- Concerns were also raised about the increase in fuel consumption from retrofit. High loading is required to have high temperatures for around 25% of the running time which does not happen on some equipment (Telehandlers) therefore some NRMM is required to be operated periodically at higher revolutions per min (RPM) than normal to allow function of DPF. There were concerns over with provision of improvement/education of operators to help overcome this issue.
- Some large 5 tonne capacity ‘Roto-type’ handlers were reported to have all experienced continual problems with engine performance, malfunctioning alarms and DPF degradation.
- Reservations were raised concerning investment made by some contractors with regarding to the wording in The NRMM Requirements of ‘current and immediate previous‘ if the wording is considered ‘rolling’ so when the dates for Stage IV come into affect any Stage IIIA engine with retrofit would not be compliant.

10.1 Review period Summary

Crossrail undertook a Site Visit and inspection and compiled data of 24 contract sites. The data showed a significant increase in compliance with The NRMM Requirements from a recorded 28% during the consultation period to at 86% (inclusive of dispensations) during the review. All contractors and sites had taken significant steps to implement emissions controls and the work was commendable.

Table 8 Summary of NRMM Position from Review Period

	Excavator /Dumper / Telehandler / Roller / Tractor / Loader /	**Crawler Crane**	**Generators**	**Piling Equipment**
Availability of 3B	– Evidence across the supplier chain, availability reasonably high and widespread. – Dumpers due to come to market between September 2013 – January 2014 – JCB to released telehandler series released with 'EcoMax' engines 3B/4i.expected to enter the market over summer/autumn 2013	– Low availability in the market	– No Stage IIIB in the market.	– Limited – Some Bauer BG40 in operation. – 3B generally not available in the market.
Evidence of Retrofit	– Wide selections of plant hire availability. – EST register updated with smaller number of DPF supplier stockists registered – Technical operation has been noted to cause issues with low powered and high idling equipment. –	– One contractor trailing DPF retrofit – Evidence of a single crane supply company offering 3A engine with DPF. – Crane supplier Kelbelco and NRC, state they will not retrofit any Crane.	– Limited – One Contractor successful with standby power diesel engines (non-safety critical) – Contractor investigating options for DPFs on generators and compressors. – Testing has been undertaken on compressors though no solutions have been found. – Technical problems regarding exhaust gas recirculation (EGR) engines have been uncovered	– Low – remains unchanged – No seen retrofit. – Supplier statements of retrofit in other countries, no UK experience. – No supplier case studies with details – No seen retrofit. – Supplier statements of retrofit in other countries, no UK experience.
Dispensations	– Wide variety of dispensations granted though no overall picture. – Dispensations in place for Articulated Dump, Dumper, Telehandler, Excavator, Loader, Tractor, Grader, Screen, Compactor – Most dispensations in place for limited period to allow for market changes.	– Concerns regarding July compliance have been raised. – Dispensations in place for time limited extensions to allow further investigation in retrofit of cranes.	– Dispensations have been requested for Safety Critical equipment, with a long term dispensation in place. – Dispensations for generators is still on-going	– All piling rigs on the project are under long term dispensations

Appendix 1: EU Directives and Emission Limits

EU Stage I/II

- Directive 97/68/EC was the first European legislation to regulate emissions from NRMM was promulgated on December 16, 1997.
- Stage I implemented in 1999.
- Stage II implemented from 2001 to 2004, depending on the engine power output.
- NRMM covered by the standard included industrial drilling rigs, compressors, construction wheel loaders, bulldozers, non-road trucks, highway excavators, forklift trucks, road maintenance equipment, aerial lifts and mobile cranes. Generating sets were not covered by the Stage I/II standards.
- Directive 2002/88/EC adopted on December 9, 2002, amending the Directive 97/68/EC by adding emission standards for small, gasoline fuelled utility engines below 19 kW. The Directive also extended the applicability of Stage II standards on constant speed engines. The utility engine emission standards are to a large degree aligned with the US emission standards for small utility engines.

EU Stage III/IV

- Directive 2004/26/EC adopted by the European Parliament on 21 April 2004 introduced Stage III/IV emission standards
- Directive 2010/26/EU provides further technical details on the testing and approvals of Stage IIIB and Stage IV engines.
- Stage III standards—which are further divided into Stages IIIA and IIIB—are phased-in from 2006 to 2013,
- Stage III B standards introduce PM limit of 0.025 g/kWh, representing about 90% emission reduction relative to Stage II. To meet this limit value, it is anticipated that engines will have to be equipped with particulate filters.
- Stage IV enters into force in 2014.
- Stage IV introduces a very stringent NOx limit of 0.4 g/kWh, which is expected to require NOx after-treatment.
- Stage III/IV standards also include a limit for ammonia emissions, which must not exceed a mean of 25 ppm over the test cycle.

EU Emission standards specify two sets of implementation dates:

- Type approval dates, after which all newly type approved models must meet the standard, and
- Market placement (or first registration) dates, after which all new engines placed on the market must meet the standard.

Table A1: EU Staged Emissions Market Placement Dates and Type Approval Codes

Cat.	Net Power	Date	CO	HC	NOx	PM
	kW		g/kWh			
Stage I						
A	130 ≤ P ≤ 560	1999.01	5.0	1.3	9.2	0.54
B	75 ≤ P < 130	1999.01	5.0	1.3	9.2	0.70
C	37 ≤ P < 75	1999.04	6.5	1.3	9.2	0.85
Stage II						
E	130 ≤ P ≤ 560	2002.01	3.5	1.0	6.0	0.2
F	75 ≤ P < 130	2003.01	5.0	1.0	6.0	0.3
G	37 ≤ P < 75	2004.01	5.0	1.3	7.0	0.4
D	18 ≤ P < 37	2001.01	5.5	1.5	8.0	0.8
* Stage II also applies to constant speed engines effective 2007.01						
Stage IIIA						
H	130 ≤ P ≤ 560	2006.01	3.5	4.0	X	0.2
I	75 ≤ P < 130	2007.01	5.0	4.0	X	0.3
J	37 ≤ P < 75	2008.01	5.0	4.7	X	0.4
K	19 ≤ P < 37	2007.01	5.5	7.5	X	0.6
† dates for constant speed engines are: 2011.01 for categories H, I and K; 2012.01 for category J.						
Stage IIIB						
L	130 ≤ P ≤ 560	2011.01	3.5	0.19	2.0	0.025
M	75 ≤ P < 130	2012.01	5.0	0.19	3.3	0.025
N	56 ≤ P < 75	2012.01	5.0	0.19	3.3	0.025
P	37 ≤ P < 56	2013.01	5.0	4.7†		0.025
† NOx+HC						
Stage IV						
Q	130 ≤ P ≤ 560	2014.01	3.5	0.19	0.4	0.025
R	56 ≤ P < 130	2014.10	5.0	0.19	0.4	0.025

Appendix 2: Crossrail Response to EIC Working Group Queries.

Crossrail have committed to The Mayors Air Quality Strategy by stating that they will reduce the impact on air quality by construction machinery. This commitment includes the retrofitting of approved diesel particulate filters on construction machinery. Will Crossrail enforce this commitment? And if so, how will Crossrail enforce it?

The Crossrail Environmental Minimum Requirements (EMR) require the nominated undertaker, Crossrail, to use low emission vehicles and plant fitted with catalyst, diesel particulate filters or similar devices as far as reasonably practicable. We have been working with our tier one contractors meet this requirement and will continue to do so. Normal contractual mechanisms will be used to enforce this requirement where necessary.

What are the planned timelines for Crossrail to enforce the retrofitting of DPF's?

Meeting the EMR can be achieved through using equipment that is Tier IIIB or better or by retrofitting older equipment with DPFs. It is not therefore simply a matter of enforcing the use of DPFs. Crossrail has set a deadline of 1 December 2012 for meeting our emissions control requirements and we are now working with our tier contractors to assess their performance. We have given longer timescales for certain types of construction equipment which are more technically challenging to retrofit and/or where there is little or no availability of Tier IIIB equipment. These include piling rigs and crawler cranes.

Crossrail to supply a list of the type of machines that are exempt from fitting DPF's, and the reasons for the exemptions.

Crossrail is not currently expecting crawler cranes or piling rigs to meet our emissions control requirements. We will be expecting crawler cranes to be compliant from July 2013 but have not set a deadline for piling rigs.

Crossrail is not expecting equipment that is on site for short timescales to meet our emissions control requirements (generally under 30 days).

We will also work with individual contractors to determine whether there are any other exceptions that apply to each site and will apply exemptions where it is reasonably practicable to do so.

Crossrail have suggested to at least one of EIC's members that the DPF Retrofit Guidance notes has changed, and this change allows for none "EST NRMM Register" products to be used provided they are covered by another recognised approval. However, only EST NRMM Registered COMPANIES are allowed to supply such alternate products. Could Crossrail provide written confirmation of these changes?

Crossrail has defined a performance standard as follows:

NRMM with type approval engines Euro II or III(A) combined with after treatment devices listed under or with certification from:

- The Energy Savings Trust Energy Savings Trust Non-Road Mobile Machinery Register; or
- The Swiss Federal Ordinance on Air Pollution Control (OAPC) FOEN Particulate Filter List (VERT VFT3); or

- Californian ARB Verification Classifications for Diesel Emission Control Strategies, Retrofit Device Verification Database Level 3; or
- Technology approved through the Transport for London (TfL) Low Emissions certification (LEC) process, Emission Stage Phase 4 achieving PM emissions limits Standard C, provided there is a proven record of off-road capabilities.
- An equivalent certification scheme provided that prior acceptance has been received from the Project Manager.

The EST NRMM Register has been dormant for several years. It has been suggested by EST recently that this register will be re-activated and that any company wishing to remain approved should pay a fee. EIC believe that none of its members would be willing to make further financial contribution to this register, and therefore it may become unpopulated. How will this effect Crossrail's DPF retrofit guidance?

All NRMM will have to meet Crossrail's performance standard as set out above. Crossrail has advised contractors to seek required retrofit from the companies listed under the EST Register in line with guidance set out in the Major of London's Best Practice Guidance.

How many machines have currently been fitted with DPF's as a result of Crossrail's requirements?

This information is not currently available. Your members will be able to supply information to the EIC relating to what they have retrofitted.

At a previous EIC meeting, Crossrail suggested that some "temporary" type DPF's had been fitted, and that Crossrail will insist they are replaced with "approved" filters. Has this action happened?

All NRMM have to comply with Crossrail's performance standard. Temporary filters do not meet this standard. This has been highlighted to our tier one contractors and Crossrail is working with them to, where necessary, replace machinery so that the standard is met.

The World Health Organisation have re-classified diesel exhaust emissions from Group 2A (probable carcinogen) to Group 1 (definite carcinogen), this change has an impact on corporate liability and "duty of care". Are Crossrail using this re-classification to force the need for retrofitting DPF's on such contracts were the requirement for DPF's was unclear or omitted in the original "request for tender"?

Crossrail continues to work with our tier one contractors to meet the Environmental Minimum Requirements as previously described.

Are there any funds that Crossrail can access to offset some of the contactors costs for retrofitting DPF's?

The NRMM Requirements relating to emissions controls were included within the contractual arrangements for tier one contracts. No additional funds are therefore necessary.

Some EIC member companies are active in the Construction market, and are speaking to many Crossrail contractors/suppliers. Without any doubt there is great confusion about the DPF retrofit requirements. Many Crossrail contractors/suppliers have reported that there is no clarity. Some machines without DPF's have access to

site, whilst other similar machines are required to be retrofit with DPF's on the same site. Can Crossrail provide feedback on this?

We have issued clarification and guidance to all of our tier one contractors so there should be no confusion. Our tier one contractors are then expected to flow down these requirements to their supply chain. We have also met with several plant hire companies used by Crossrail contractors to clarify our requirements. As stated previously, there may be situations where practicability on one site results in a different outcome to another site.

Crossrail imply that they only have influence over the first tier supplier, and it is the first tier supplier who should be enforcing the requirement through their contractors. EIC believe that Crossrail own each construction site, therefore why not enforce the retrofitting of DPF's on a site basis rather than on a supplier basis? This could allow Crossrail to focus initially on the more sensitive sites.

Crossrail does not "own" construction sites. They are handed to principal contractors for the purpose of carrying out the works. Tier one contractors are expected to cascade The NRMM Requirements to their supply chain and to enforce The NRMM Requirements on their sites. Crossrail does not have a contractual relationship with contractors below tier one. Crossrail will be undertaking checks to ensure that this is the case.

Appendix 3: Crossrail list of Contacts for Consultation Period.

Field	Company/Organisation	Main Contact	Contact Role	Contact Details	Contact Details
DPF Suppliers	Agrimach Ltd				
DPF Suppliers	Baumot UK				
DPF Suppliers	Cawdell Group				
DPF Suppliers	Dinex UK				
DPF Suppliers	Eminox				
DPF Suppliers	HJS				
DPF Suppliers	Huss				
DPF Suppliers	Johnson Matthey Plc				
DPF Suppliers	MANN+HUMMEL				
DPF Suppliers	Pirelli EcoTechnology				
DPF Suppliers	PURItech (UK)Ltd				
DPF Suppliers	Pyroban Envirosafe Ltd				
Organisation/Associations	Columbia University				
Organisation/Associations	Construction Equipment Association (CEA)				
Organisation/Associations	Construction Plant Hire Association (CPA)				
Organisation/Associations	Energy Saving Trust (EST)				
Organisation/Associations	Environment Industries Commission (EIC)				
Organisation/Associations	Federation of Piling Specialist (FSP)				
Organisation/Associations	Greater London Authority (GLA)				

Organisation/Associations	Transport for London (TfL)	[redacted]	[redacted]	[redacted]	[redacted]
Organisation/Associations	Transport for London (TfL)	[redacted]	[redacted]	[redacted]	[redacted]
Organisation/Associations	VERT	[redacted]	[redacted]	[redacted]	[redacted]
Original Equipment Manufactures	Bachy Soletanche	[redacted]	[redacted]	[redacted]	
Original Equipment Manufactures	Caterpillar	[redacted]	[redacted]	[redacted]	[redacted]
Original Equipment Manufactures	JCB	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	F Kelleher Plant Hire Ltd	[redacted]		[redacted]	[redacted]
Plant Hire Companies	Finning CAT	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	Flannery Plant Hire (Oval) Limited	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	GAP Group Ltd	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	Hawk Plant Hire				
Plant Hire Companies	Hewden Hire	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	Llynch Plant Hire	[redacted]		[redacted]	[redacted]
Plant Hire Companies	O'Keefe	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	One Call Group	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	Select Plant Hire	[redacted]	[redacted]	[redacted]	[redacted]
Plant Hire Companies	Speedy Asset Services	[redacted]	[redacted]	[redacted]	[redacted]

Appendix 4: Weldex/Cawdell Case Study

CASE STUDY

Cawdell ART™ fitted to Crawler Crane owned by WELDEX

31st August 2012

[redacted] *Engineering Manager, Cawdell Ltd*

Cawdell Ltd, PO Box 6121, BELPER, DE56 1WG.
Tel: 01332 755477 www.cawdellgroup.com info@cawdellgroup.com

MACHINE TYPE.

ZOOMLION CRAWLER CRANE

ENGINE SIZE....10.5 LTR.

POWER RATING....362 HP

CAWDELL DPF TYPE.

Cawdell ART™, ART23ss.

PURPOSE AND OBJECTIVE.

Weldex approached Cawdell Ltd requesting information relating to emission abatement solutions for two Zoomlion crawler cranes.

In order to comply with the initiatives set by CrossRail directly relating to emission regulations at their sites, Weldex required that Cawdell Ltd installed their ART™ technology to their cranes.

The ART™ is a self-regenerating diesel particulate filter which removes 95% of particulate matter. Internal components include a highly catalysed metallic pre-filter unit, followed by a silicon carbide "wall-flow" filter.

Given the potential low duty cycle of this particular application, and therefore the low exhaust temperatures likely to be encountered, it was agreed that a feasibility study would be undertaken in order to establish the suitability of the duty cycle prior to installation of the Cawdell ART™.

METHOD

A site visit was arranged by Cawdell Ltd in order to detail the machines for retrofit of the ART™. During this visit a digital data logger was installed to measure the exhaust temperature during "typical" operating conditions. Weldex ran the machine at a typical duty cycle with simulated load until sufficient data was accumulated.

The data was analysed at Cawdell Ltd and it was agreed that although the temperatures were on the low side for complete passive regeneration on many types of DPF's, it was considered that given the high performance of the ART™ even at low operating conditions, the installation should be undertaken.

Cawdell Ltd, PO Box 6121, BELPER, DE56 1WG.
Tel: 01332 755477 www.cawdellgroup.com info@cawdellgroup.com

Weldex made available the machines and the retrofits were completed over a three day period by Cawdell engineers. The installation program was completed on the 18th April 2012..

Exhaust back-pressure readings were taken at a repeatable engine condition. With the newly installed filters this indicated a back-pressure of 50mb to 60mb.

A further data logging session was agreed with the ART™ fitted to the machines.

CONCLUSIONS

A final inspection was arranged after several weeks of normal duty and a pressure delta test was undertaken, at the repeatable engine condition, on an operational machine to determine operating exhaust back-pressure.

A back-pressure of 60mb was recorded. This indicates no increasing restriction within the ART™ and therefore we can determine that the ART™ is "passively" self-regenerating correctly under normal operational conditions for the crawler-crane.

This test clearly indicates that although the machine operates with a low duty cycle, the ART™ is regenerating and maintaining a balance point.

BACKGROUND INFORMATION

The ART™ is manufactured in the UK by Cawdell Ltd, and is approved for London LEZ, and CrossRail dpf retrofit guidance. Cawdell are an approved supplier listed on the EST NRMM Register.

Cawdell have ISO 9001:2008 certification.

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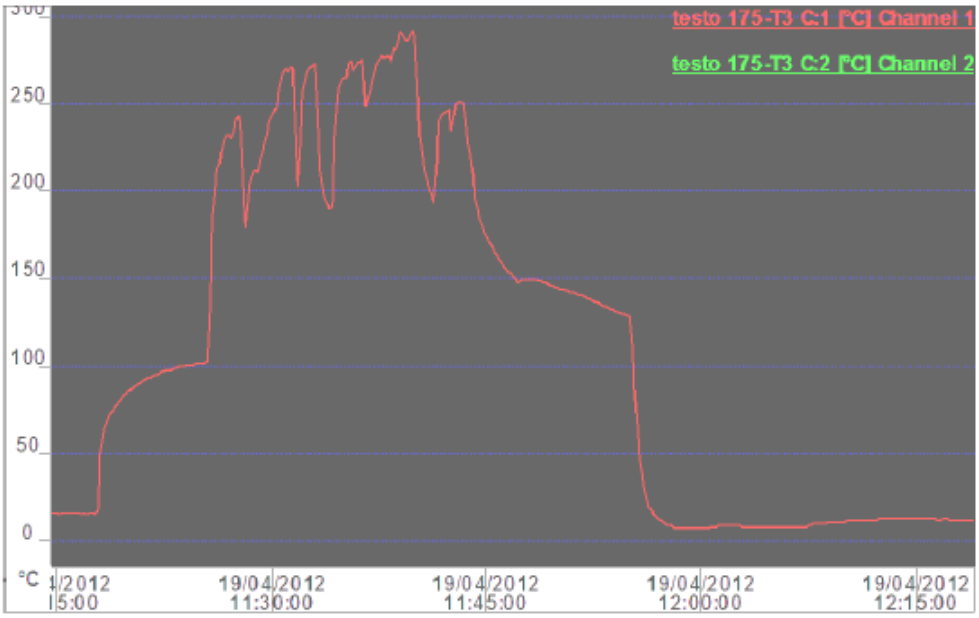
APPENDIX

WELDEX TEMP TRACE WITH ART 23
SS FITTED



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IMAGES SHOWING COMPLETED INSTALLATION.

Appendix 5: Review Period NRMM List March 2013

NRMM Type	Plant Make Model	II	IIIA	IIIB	DPF	Dispensation
Compactor/Roller (Heavy)			x		N	Y
Compactor/Roller (Heavy)	BOMAG 213		x		N	Y
Compactor/Roller (Heavy)	HAMM		x		N	Y
Compactor/Roller (Heavy)	BOMAG 213		x		N	Y
Compactor/Roller (Light)	BOMAG 161				N	N
Compactor/Roller (Light)	JCB VM116D		x		N	Y
Compactor/Roller (Light)	JCB VM116D		x		N	Y
Compressor >37.5kW	SULLAIR		x		N	Y
Compressor >37.5kW	SULLAIR		x		N	Y
Compressor >37.5kW			x		N	Y
Compressor >37.5kW			x		N	Y
Compressor >37.5kW			x		N	Y
Compressor >37.5kW			x		N	Y
Compressor >37.5kW			x		N	Y
Compressor >37.5kW			x		Y	N/A
Compressor >37.5kW	PUTZMIESTER Concrete Pump			x	N/A	N/A
Concrete Sprayer >37.5kW	MEYCO Potenza		x		Y	N/A
Concrete Sprayer >37.5kW	MEYCO Potenza		x		Y	N/A
Concrete Sprayer >37.5kW	MEYCO Poca				Y	N/A
Concrete Sprayer >37.5kW	MEYCO Poca		x		Y	N/A
Concrete Sprayer >37.5kW	MEYCO Potenza		x		Y	N/A
Concrete Sprayer >37.5kW	MEYCO Potenza		x		Y	N/A
Crane - Crawler <100T	SENNEBOGEN 650 HD		x		N	Y
Crane - Crawler >100T	SUMITOMO SCX800HD		x		N	Y
Crane - Crawler >100T	LIEBHERR		X		N	Y
Crane - Crawler >100T	IHI CCH500		x		N	Y
Crane - Crawler >100T	SENNEBOGEN 6100 HD		x		N	Y
Crane - Crawler >100T	CKE1100G			x	N/A	N/A
Crane - Crawler >100T	CKE1100G			x	N/A	N/A
Crane - Crawler >100T			x		N	Y
Crane - Crawler >100T	KOLBELCO CKE1350		x		N	Y
Crane - Crawler >100T			x		N	Y
Crane - Crawler >100T			x		N	Y
Crane - Crawler >100T	LIEBHERR			x	N/A	N/A
Crane - D-Wall Base Unit	LIEBHERR HS 855 HD		x		N	Y
Crane - D-Wall Base Unit	LIEBHERR HS 855 HD		x		N	Y
Crane - D-Wall Base Unit	BAUER BG30		x		N	Y

Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	N
Dump Truck	CAT 725		x		N	Y
Dump Truck	JCB 722		x		Y	N/A
Dump Truck	HYDREMA		x		Y	N/A
Dump Truck	JCB 714		x		N	Y
Dump Truck	HYDREMA		x		N	Y
Dump Truck			x		Y	N/A
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	CAT 725		x		N	Y
Dump Truck	VOLVO A30D		x		N	Y
Dumper 6T-10T	DIECI F7000		x		Y	N/A
Dumper 6T-10T	THWAITES		x		N	N
Dumper 6T-10T	DIECI F7000		x		Y	N/A
Dumper 6T-10T	DIECI F7000		x		Y	N/A
Dumper 6T-10T			x		N	Y
Dumper 6T-10T			x		N	Y
Dumper 6T-10T	NEUSON		X		Y	N/A
Dumper 6T-10T	NEUSON		X		N	N
Dumper 6T-10T	NEUSON		X		Y	N/A
Dumper 6T-10T	HITACHI				Y	N/A
Dumper 6T-10T	BARFORD SKR9 dumper				Y	N/A
Dumper 6T-10T	THWAITES		x		N	Y
Dumper 6T-10T	TEREX		x		N	Y
Dumper 6T-10T	TEREX		x		Y	N/A
Dumper 6T-10T	TEREX		x		N	Y
Dumper 6T-10T	TEREX		x		N	N
Dumper 6T-10T	TEREX		x		Y	N/A

Dumper 6T-10T	TEREX		x		N	Y
Dumper 6T-10T	DUMEC		x		N	Y
Dumper 6T-10T	PICCINI		x		N	Y
Dumper 6T-10T	THWAITES		x		N	Y
Dumper 6T-10T	THWAITES		x		N	Y
Excavator Hybrid	KOMATSU HB210		x		N	Y
Excavator Tracked LARGE >30T	HITACHI ZX350				N	N
Excavator Tracked LARGE >30T	KOMATSU PC490			x	N/A	N/A
Excavator Tracked LARGE >30T	CAT 336E			X	N/A	N/A
Excavator Tracked LARGE >30T	CAT 320E		X		Y	N/A
Excavator Tracked LARGE >30T	CAT 320E		X		Y	N/A
Excavator Tracked LARGE >30T	HITACHI ZX350			x	N/A	N/A
Excavator Tracked LARGE >30T	CHAMELEON			x	N/A	N/A
Excavator Tracked LARGE >30T			x		Y	N/A
Excavator Tracked LARGE >30T	HITACHI ZX350			x	N/A	N/A
Excavator Tracked LARGE >30T	KOMATSU PC490			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	CAT 320E			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	HITACHI ZX210		x		N	N
Excavator Tracked MEDIUM 20T- 30T	CAT			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	HITACHI ZX220		x		Y	N/A
Excavator Tracked MEDIUM 20T- 30T	KOMATSU PC360			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	KOMATSU PC210		x		N	N
Excavator Tracked MEDIUM 20T- 30T	CAT 320E			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	CAT 320E			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	CAT 320E			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	CAT 320E			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	CASE		x		Y	N/A
Excavator Tracked MEDIUM 20T- 30T	CAT 20E			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	HITACHI ZX135		x		Y	N/A
Excavator Tracked MEDIUM 20T- 30T	HITACHI ZX135		x		Y	N/A
Excavator Tracked MEDIUM 20T- 30T	HITACHI ZX225		x		Y	N/A
Excavator Tracked MEDIUM 20T- 30T	HYUNDAI 145		x		Y	N/A
Excavator Tracked MEDIUM 20T- 30T	KOLBELCO 215			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	KOLBELCO 215			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	KOMATSU PC360			x	N/A	N/A
Excavator Tracked MEDIUM 20T- 30T	KOMATSU PC450		x		N	Y
Excavator Tracked MEDIUM 20T- 30T	KOMATSU PC450		x		N	Y
Excavator Tracked MINI/MIDI <10T	CAT			X	N/A	N/A
Excavator Tracked MINI/MIDI <10T	CAT 312E			x	N/A	N/A
Excavator Tracked MINI/MIDI <10T	CAT		x		Y	N/A

Excavator Tracked MINI/MIDI <10T	VOLVO ECR88		x		Y	N/A
Excavator Tracked MINI/MIDI <10T	VOLVO ECR88		x		Y	N/A
Excavator Tracked MINI/MIDI <10T	HITACHI ZX135		x		Y	N/A
Excavator Tracked MINI/MIDI <10T			x		Y	N/A
Excavator Tracked MINI/MIDI <10T	KOMATSU PC130		x		N	Y
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	HITACHI ZX135		x		N	N
Excavator Tracked SMALL 10-20T	KOMATSU PC290		x		Y	N
Excavator Tracked SMALL 10-20T	KOMATSU D61		x		N	N
Excavator Tracked SMALL 10-20T	KOMATSU D65		x		N	N
Excavator Tracked SMALL 10-20T	KOMATSU WA480		x		N	N
Excavator Tracked SMALL 10-20T	TAKEUCHI TB175		x		N	N
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	HYUNDAI 145		x		Y	N/A
Excavator Tracked SMALL 10-20T	CASE		x		Y	N/A
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T				x	N/A	N/A
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	HITACHI ZX225				Y	N/A
Excavator Tracked SMALL 10-20T	JCB JS160				N	N
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	KOMATSU PC228		x		N	N
Excavator Tracked SMALL 10-20T	CAT 320E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	CAT 320E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	TAKEUCHI TB175		x		Y	N/A
Excavator Tracked SMALL 10-20T	DOOSAN DX 140		x		Y	N/A
Excavator Tracked SMALL 10-20T	TAKEUCHI TB175		x		Y	N/A
Excavator Tracked SMALL 10-20T	HITACHI ZX160		x		Y	N/A
Excavator Tracked SMALL 10-20T	HITACHI ZX160		x		Y	N/A
Excavator Tracked SMALL 10-20T	HITACHI ZX225		x		Y	N/A
Excavator Tracked SMALL 10-20T	HYUNDAI 145		x		Y	N/A
Excavator Tracked SMALL 10-20T	CAT 320E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	CAT 312E			x	N/A	N/A
Excavator Tracked SMALL 10-20T	KOMATSU PC210		x		N	Y
Excavator Tracked SMALL 10-20T	DOOSAN DX 340		x		N	Y
Excavator Tracked SMALL 10-20T	HITACHI ZX330		x		N	N
Excavator Wheeled	HITACHI ZX170		x		N	N

Excavator Wheeled	HITACHI ZX150		x		Y	N/A
Excavator Wheeled	HITACHI ZX170		x		Y	N/A
Excavator Wheeled	JCB JS200W		x		Y	N/A
Generator >37.5kW					N	N
Generator >37.5kW					N	N
Generator >37.5kW					N	N
Generator >37.5kW					N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW			x		Y	N/A
Generator >37.5kW			x		Y	N/A
Generator >37.5kW			x		Y	N/A
Generator >37.5kW			x		Y	N/A
Generator >37.5kW			x		N	N
Generator >37.5kW			x		N	N
Generator >37.5kW	ATLAS COPCO QAS325	x			N	Y
Loading Shovel (Tracked)	KOMATSU WA100M		x		Y	N/A
Loading Shovel (Tracked)	CAT 966H				N	N
Loading Shovel (Tracked)	VOLVO L150				N	N
Loading Shovel (Tracked)	CAT D6		x		N	Y
Loading Shovel (Tracked)	CAT 953		x		Y	N/A
Loading Shovel (Tracked)	CAT D6		x		N	Y
Loading Shovel (Tracked)	CAT D6		x		N	Y
Loading Shovel (Wheeled)	CAT 966H			x	N/A	N/A
Loading Shovel (Wheeled)	JCB 524-50		x		N	N
Loading Shovel (Wheeled)	LIEBHERR L528			x	N/A	N/A
Loading Shovel (Wheeled)			X		N	N
Loading Shovel (Wheeled)	VOLVO			x	N/A	N/A
Loading Shovel (Wheeled)	HYUNDAI 770			x	Y	N/A
Loading Shovel (Wheeled)	HYUNDAI 770			x	Y	N/A
Material Handlers	FUCHS MHL360			x	N/A	N/A
Material Handlers	FUCHS MHL360			x	N/A	N/A
Material Handlers	FUCHS MHL360			x	N/A	N/A
Material Handlers	FUCHS MHL360			x	N/A	N/A

Mobile Elevated Work Platform					N	N
Mobile Elevated Work Platform					N	N
Mobile Elevated Work Platform					N	N
Mobile Elevated Work Platform	GENIE Z45		x		Y	N/A
Mobile Elevated Work Platform	GENIE Z45		x		Y	N/A
Motor Grader	VOLVO G930		x		N	Y
Other			x		Y	N/A
Other	SANDVIK Screen QE140		x		N	Y
Other	SANDVIK Screen QE140		x		N	Y
Other	SANDVIK Crusher QJ241		x		N	Y
Piling Rig <100T	LIEBHERR LRB125		x		N	Y
Piling Rig >100T			x		N	Y
Piling Rig >100T			x		N	Y
Piling Rig >100T	LIEBHERR LB36		x		N	Y
Piling Rig >100T	LIEBHERR LRB255		x		N	Y
Piling Rig >100T	BAUER BG30			x	N/A	N/A
Telehandler	MERLO P25.6		x		Y	N/A
Telehandler	MERLO ROTO 33.16		x		Y	N/A
Telehandler	JCB 535-125		x		N	N
Telehandler			x		Y	N/A
Telehandler				x	N/A	N/A
Telehandler	JCB 535-95		x		N	Y
Telehandler	JCB 540-170		X		Y	N/A
Telehandler	JCB 540-170		X		Y	N/A
Telehandler	TERBERG		X		N	N
Telehandler	JCB 540-170		X		N	Y
Telehandler	JCB 540-170		X		N	N
Telehandler	JCB 540-170		X		N	Y
Telehandler	JCB 540-170		X		N	Y
Telehandler	JCB 535-95		x		Y	N/A
Telehandler	JCB 535-95		x		Y	N/A
Telehandler	JCB 535-95		x		Y	N/A
Telehandler				x	N/A	N/A
Telehandler	JCB 535-95		x		Y	N/A
Telehandler			x		Y	N/A
Telehandler			x		N	Y
Telehandler	JCB 535-95	x			Y	N/A
Telehandler	JCB 535-95			x	N/A	N/A
Telehandler	JCB 533-105		x		N	Y
Telehandler	JCB 533-105		x		N	Y

Telehandler	JCB 535-95			x	N/A	N/A
Telehandler	JCB 535-95		x		N	Y
Telehandler	JCB 535-95		x		N	Y
Telehandler			x		N	N/A
Telehandler	JCB 535-95		x		N	Y
Telehandler	JCB 524-50		x		N	Y
Telehandler	MERLO ROTO 40.26		x		Y	N/A
Telehandler	JCB 535-125		x		Y	N/A
Telehandler	MERLO ROTO 50.10		x		Y	Y
Telehandler	MERLO ROTO 50.10		x		Y	Y
Telehandler	JCB 524-50	x			N	Y
Tractor	JOHN DEERE			x	N/A	N/A
Tractor	JOHN DEERE			x	N/A	N/A
Tractor	JOHN DEERE			x	N/A	N/A
Tractor	New Holland T6			x	N/A	N/A
Tractor	New Holland T6			x	N/A	N/A
Tractor	JOHN DEERE		x		N	N
Tractor	FORD		X		N	Y
Tractor	KALMAR		X		Y	N/A
Tractor	KALMAR		X		Y	N/A
Tractor	JOHN DEERE		x		N	Y
Tunnelling Equipment	TEREX TE210		x		Y	N/A
Tunnelling Equipment	TEREX ITC 120			x	N/A	N/A
Tunnelling Equipment	Robodrill Pantofore		x		Y	N/A
Tunnelling Equipment	TEREX ITC 120			x	N/A	N/A
Tunnelling Equipment	TEREX ITC 120			x	N/A	N/A
Tunnelling Equipment	LIEBHERR 944		x		Y	N/A
Tunnelling Equipment	LIEBHERR 944		x		Y	N/A
Tunnelling Equipment	LIEBHERR 944		x		Y	N/A
Tunnelling Equipment	Schoma Locomotive		X		Y	N/A
Tunnelling Equipment	Schoma Locomotive		X		Y	N/A
Tunnelling Equipment	Schoma Locomotive		X		Y	N/A
Tunnelling Equipment	Schoma Locomotive		X		Y	N/A