1st Questionnaire Exemption Request No. 2016-1

Exemption Request for „Lead in bearings and bushes of professional-use non-road equipment engines that meet the following criteria:

I. **15 litre and larger total displacement professional use**

II. **Less than 15 litre engines for professional non-road equipment designed for use where the time between a signal to start and full load is required to be less than 10 seconds, for example in emergency, standby generators and peak shaving generators**

III. **Less than 15 litre engines for professional non-road equipment designed for operation in harsh and dirty environments such as construction sites, quarries, mines, etc. for example, in drills, air compressors, rock crushers, irrigation pumps and tub grinders“**

Abbreviations and Definitions

Pb	Lead
EUROMOT	The European Association of Internal Combustion Engine Manufacturers

Background

The Oeko-Institut and Fraunhofer IZM have been appointed by the European Commission, within a framework contract[1], for the evaluation of applications for exemption from Directive 2011/65/EU (RoHS 2), to be listed in Annexes III and IV of the Directive.[1]

EUROMOT has submitted a request for the renewal of the above mentioned exemption, which has been subject to a first evaluation. The information you have referred has been reviewed and as a result we have identified that there is some information missing and have formulated a few questions to clarify some aspects concerning your request.

Questions

1. In your application, the engines addressed, in which lead containing bearings and bushes are used, for which the exemption is requested, are categorised to be covered by RoHS Annex I category 11 (other EEE not covered by the other categories). In this regard it is explained that the “*Classification of engine driven machinery into a category is not straightforward. We have assumed that all types of equipment that require this exemption are in category 11.*” However this categorisation also implies that such engines (i.e. the

[1] The contract is implemented through Framework Contract No. FWC ENV.A.2/FRA/2015/0008 of 27/03/2015, led by Oeko-Institut e.V.

equipment in which they are applied) were not in scope of RoHS 1 (Directive 2002/95/EC) and did not need to comply with the RoHS substance restrictions before the coming into force of RoHS 2 (Directive 2011/65/EU).

a. Please explain why this implication is made and on what basis you assume that none of the other categories apply. For example, why is a leaf vacuum, as shown in figure 4 of the application, not considered a “tool” (Cat. 6) already in the scope of RoHS 1? Or why is it assumed that it was not in the scope of RoHS even were it to be categorized under for example Cat. 6?

We initially determined that the equipment for which we request an exemption would not fall under “electrical and electronic tools” in Category 6 based on guidance provided on the original WEEE 1 and RoHS 1 directives published May 2005 by the European Commission, available from http://ec.europa.eu/environment/waste/pdf/faq_weee.pdf.

That guidance provided that “electricity is the (e.g. not petrol or gas) primary energy” in order for equipment to fall in scope of RoHS 1, and proceeded to give examples of products outside the scope of RoHS, including combustion engines with ignition and petrol-driven lawnmowers (see FAQ 1.2). Based on that guidance, we determined that our diesel and gas-powered equipment would be out of the scope of RoHS 1. Accordingly, any such equipment that comes into scope of RoHS 2, would not need to comply with RoHS 2 until 22 July 2019, per the language in Article 2.2 which provides in part, “EEE that was outside the scope of Directive 2002/95/EC, but which would not comply with this Directive, may nevertheless continue to be made available on the market until 22 July 2019”.

It is unclear whether the equipment for which we request an exemption falls under Category 6 or Category 11, because Category 6 is still described as “electrical and electronic tools”, which based on the original guidance would not include petrol, diesel, and gas-powered equipment.

Thus, our members decided to include all such equipment under the catch-all EEE provision of Category 11. If Oeko-Institut and Fraunhofer IZM believe that Category 6 would also be an appropriate category to check under our exemption request section 4, we request that our request be amended accordingly.

b. Please provide a detailed list of possible equipment sub-groups that would benefit from the requested exemption (exhaustive, to the best of the knowledge of EUROMOT and its members);

Non-stationary heavy equipment designed for professional use in applications including but not limited to mining, petroleum, construction and power generation, and which does not require either mobility or continuous or semi-continuous movement between a succession of fixed working locations while working	Comment	Equipment designed for professional use in harsh and/or dirty environments	Comment
Mobile Power Generation Units	Because of the mobile or portable nature of the equipment, it does not qualify for the LSFI exclusion, nor does it fit the RoHS II definitioni of Non-Road Mobile Machinery because it does not require either mobility or continuous or semi-continuous movement between a succession of fixed locations while working.	Power Generation Equipment Powered by Diesel or Gaseous Fuel Internal Combustion Engine	All of the equipment in this category is designed for professional use. However, due to its size, power output or other limiting factor, it may not qualify for an exclusion as a large scale fixed installation. These applications by design, operate in dusty, dirty, or otherwise harsh conditions which require the use of lead containing bearings and bushes so that reliability may be assured.
Mobile HVAC Units		HVAC Units Powered by Diesel or Gaseous Fuel Internal Combustion Engine	
Mobile Dehumidifying Machines		Dehumidifying Units Powered by Diesel or Gaseous Fuel Internal Combustion Engine	
Mobile Air Compressors		Air Compressors Powered by Diesel or Gaseous Fuel Internal Combustion Engine	
Mobile Welding Equipment		Welding Equipment Powered by Diesel or Gaseous Fuel Internnal Combustion Engine	
Mobile Mixing, Grinding, Cutting and Crushing Equipment		Drilling or Trenching Equipment Powered by Diesel or Gaseous Fuel Internal Combustion Engine	
Mobile Fluid Pumping Equipment		Fluid Pumping Equipment Powered by Diesel or Gaseous Fuel Internal Combustion Engine	
Mobile Vacuum Equipment		Vaccum Equipment Powered by Diesel or Gaseous Fuel Internal Combustion Engine	
Mobile Cranes, Hoists, or Man Lifts		Crane, hoists, or Man Lifts Powered by Diesel or Gaseous Fuel Internal Combustion Engine	

Please note that this is a preliminary list and is not exhaustive. Other examples are described in the original submission.

c. Please specify sub-groups within this equipment in relation to why such equipment is not understood to fall under any other category and thus why such equipment is to be considered newly in scope;

As described in more detail in the response to question 1.a., all equipment for which we request an exemption is diesel, and/or gas-powered, and did not fall under the scope of RoHS 1 based on all available guidance reviewed at the time of promulgation as electricity was not the primary power source for such equipment. Accordingly, all the sub-groups listed above are being considered newly in scope of RoHS 2.

2. Among others it is specified that the exemption would be needed for irrigation pumps. Though for other specified applications, dust and dirt are understood to translate to airborne emissions, in the case of irrigation pumps it is assumed that emissions would be in the form of particles in aqueous media.
   a. Please confirm this understanding or explain in what sense the environment, in which irrigation pumps operate, result in more stringent reliability requirements for bearings and bushes.

Particles in aqueous media are not the concern for irrigation pumps, so this understanding is incorrect. This exemption request is intended for the engine that powers the irrigation pump, and not the other parts of the irrigation pump..

That said, the reference to irrigation pumps was intended merely as an illustration. All equipment referenced in question 1.b. was designed to operate in harsh environments. These environments are often remote, dusty / dirty and uncontrolled. Examples include construction, mining, agriculture, and petroleum extraction. By nature, these worksites require equipment which is mobile from one jobsite to the next while the work or project is in process.

Further circumstances contributing to the “harshness” of the environment include lack of proper service facilities. The equipment is expected to run continuously to support work or the workers with downtime only for maintenance or repair purposes. All of the equipment referenced in question 1.b.

is designed for use by professional operators and service is also to be performed by professional operators. This service is often carried out at the jobsite, as such the equipment must be designed with adequate robustness to facilitate field service.

As discussed in the exemption request, one of the principal benefits of leaded bearings is the unsurpassed ability to accept particulate matter which enters the bearing clearance area. Routine service such as fluid / filter changes and inspection opens direct paths for environmental contamination to bypass filtration systems and enter the engine's reciprocating assembly. As such the engine's internal systems must be designed with this condition.

The soft properties of lead are what enable the engine to accept the contamination with reduced risk of engine seizure and subsequent catastrophic failure (illustration page 18 of the exemption request).

b. Please clarify in this respect if such pumps convey water or other media (for example effluents or waste water) and if this would affect the reliability requirements relevant for bearings and bushes in such applications differently (please specify how).

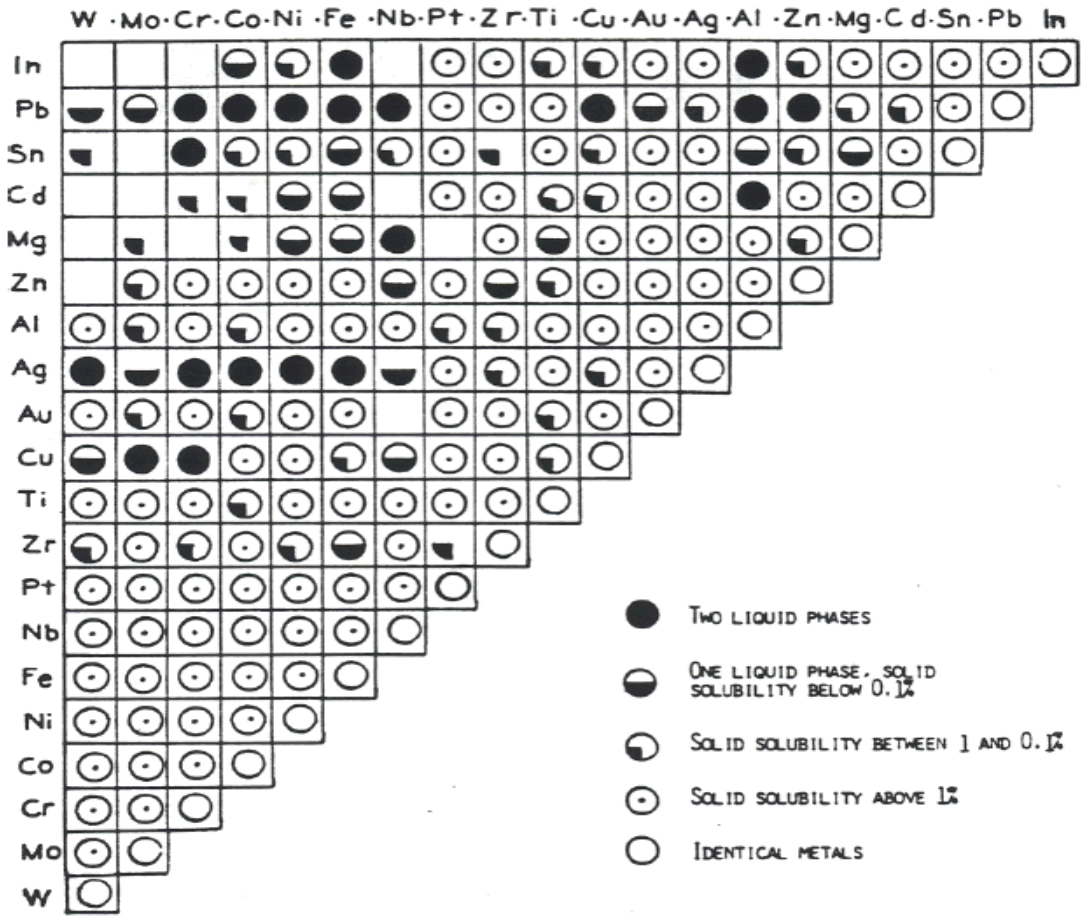
As mentioned in our response to 2.a., a water pump was used as an example for illustrative purposes. Engines used in applications referenced in 1.b. are designed to operate at or near rated torque peak for extended periods of time. Additionally, in the case of back-up power generation units, the equipment is expected to take on load even before tribological surfaces have received sufficient lubrication from the oil sump (Stribeck Curve, Page 17 of the exemption request).

This operating condition produces a great deal of heat and stress on the tribological surfaces.

Heat can cause metals to attract or fuse together, a condition which causes seizing or failure of the internal engine components when tribological surfaces weld to one another (See illustration, page 39 of the exemption request).

For durability, crankshafts, connecting rods, and engine blocks used in applications for professional use are constructed from cast or forged iron instead of lighter and less durable materials such as aluminium, magnesium and powdered metal commonly used in passenger carrying vehicle applications which, due to their application, do not need to be run at or near rated torque peak for extended periods of time.

Tribological materials must be selected which have low affinity to iron and therefore are the least likely to weld or bond to each other during high heat or heavy load conditions. Bearing materials must slide freely against each other in a variety of heat and load conditions, therefore good bearing materials have low solubility with the opposing shaft material. The Rabinowicz Metal Affinity Table below illustrates the point with a series of circles. Low solubility is represented by solid circles on the chart.



Only combinations with solid circles may be reliable, although as described in the submission, many other performance criteria are also important further limiting the choice of suitable materials.

3. You state "*There are many types of engines used in road vehicles (cars, vans, trucks, buses, etc.) and also vehicles that meet the definition of non-road mobile machinery of the RoHS directive 2011/65/EU (see examples below) and these are not included in this exemption request as they are better suited to use lead-free bearings although on road applications are out of scope of RoHS. Their use conditions and engine parameters are different to the engine designs that need this exemption and are described in this document*."
    a. Please explain in more detail the differences between engines for which the exemption is needed and engines for which it is not.

The difference between these engine types is essentially one of application and the technical response to the practicalities of those applications: Leaded bearings a) have a more robust tribological surface area and 2) they are better able to accommodate displacement.

Smaller engines used in on-highway applications, including passenger cars, are not required to accommodate dirt and debris to the same extent as engines in the scope of this exemption request. They are also more likely to be serviced in a controlled environment and so do not risk ingress of dirt / debris during normal servicing. On the other hand, engines designed for professional, off-highway use are typically used in "harsh/dirty" environments and the equipment is therefore serviced in field or point of use environments prone to environmental contamination.

As explained above, lead is very effective at accommodating dirt, debris, and misalignment in machined parts as described in section 7c of the exemption request.

Although displacement and bearing surface area will differ by engine manufacturer, it is a constant that larger engines simply have more tribological surface area which is at risk for contamination. Also, because larger engines generate greater torque and horsepower, they are more efficient and capable of greater amounts of work and are therefore used in professional use applications.

The relationship between displacement, bearing surface area and surface speed of different size engines is illustrated in figure 1 at the end of this document

As another example, industrial engines used in electric power generation can routinely remain in a stand-by condition for extended periods of time. This situation can erode, minimise or dismiss the oil film between the journal and bearing surfaces. These low-oil or oil-free surfaces, combined with the heavy weight of larger industrial engine crankshafts, can result in bearing to journal adhesion on start up. The properties of lead in bearings provide superior management of these events through the life of the engine.

Above, we describe the differences between engines used in on-highway applications and engines in scope of the exemption. Engines installed in equipment that meet the definition of Non-Road Mobile Machinery defined by RoHS 2 are similar to the engines which require this exemption and also use bearings containing lead. However, these are excluded from the scope of the RoHS Directive.

b. Please also refer in your explanations to the conditions of use, required reliability etc. that render the application of lead free bearings and bushes in certain applications at present as unfeasible.

Reliability and durability are established through a variety of tests beginning with the bench or laboratory testing of bearing material itself and concluding with on engine and in application tests for those materials showing the best laboratory results.

Pages 33-39 of the exemption request summarize the on-engine test results which led to the conclusion the reliability of lead free bearings cannot be assured.

4. In your application you mention "*Copper alloys containing up to 4% lead are used for some applications, but this application is currently covered by RoHS exemption 6C of Annex III and so is not discussed in this exemption request*". In the past, all bearings and bushes were covered under Ex. 9(b), which at a later point in time, under the regime of RoHS 1, was limited to use in compressors of certain applications. It could be understood that this restriction of the scope of Ex. 9(b) was based on the understanding that lead in copper alloys were no longer in use in bearings and bushes used in EEE applications, which fell under the regime of RoHS 1.
   a. In this sense please explain why you assume leaded-copper-alloys to fall under the scope of Ex. 6c of Annex III.

Exemption 6(c) of Annex III provides that "Copper alloy containing up to 4 % lead by weight" is exempted from the restriction in Article 4(1). Leaded-copper-alloy is a copper alloy that contains lead, and so it falls squarely under the scope of the exemption as conveyed in Annex III. The restriction of bearings and bushes covered under Exemption 9(b) to use in compressors of certain applications may have been based on the understanding that lead in copper alloys were no longer in

use in bearings and bushes used in EEE applications that fell under the regime of RoHS 1, but as explained above, the EEE applications at issue as part of this exemption request were not in scope of RoHS 1 and would not have been considered at that time.

Moreover, exemption 9(b) was originally adopted for bearings that were very different in design and applications to those in engine bearings. The loads, stresses and lubricants used in HVAC, for example are completely different to those in engine bearings. Although substitutes have been developed for 9(b) applications that were in scope of the original RoHS directive, these are unsuitable for use in engines because these were designed for HVAC systems.

b. Please clarify if such alloys are in use in some of the bearings and bushes for which the current exemption request has been made.

Copper alloys containing lead covered by Exemption 6(c) of Annex III of the RoHS directive are used in some applications in engines including as bearings. These need not be part of this exemption because they are already covered by exemption 6c.

c. Please explain the preferences for using such bearings and bushes in comparison with others.

As explained in the submission, for each specific type of engine and its intended applications, both lead-free and lead-based bearings have been tested to identify the materials and designs that meet the combinations of performance requirements for each bearing and bush in the engine. With some designs and applications, lead-free bearings are found to be suitable, meeting all performance requirements and so are used, whereas with others only lead-based provide all of the performance requirements. This is not always the case, but when a lead free bearing or bushing material meets the requirements and is a feasible option it will be selected.

5. In your application, a calculated estimation of the amount of Pb placed on the market through the relevant applications is detailed.
   a. Please clarify in relation to the calculation how the aspect of the amount of lead per bearing and bushes unit has been integrated (i.e., it is detailed that the % weight of Pb is different in the various unit components – was an average number used for all units or was this taken into consideration in the calculation through a weighted average etc.

The example given was an estimate based on averages. The exact content of lead in each engine will vary from one manufacturer to another as will market share and consumer product choice. These factors were considered in the derivation of Table 1 on page 7 of the exemption request.

b. The application states "*An audit of a representative electronic fuel injection diesel engine producing approximately 1800 kW of electricity revealed 176 grams of elemental lead to be present in the entirety of the 20 tonne assembly*." Please clarify if the amount of lead is relevant only for lead applied in bearings and bushes or for all components containing lead (for example, Pb in solders covered by valid RoHS Annex III exemptions). If the latter is the case, please estimate what share is relevant for bearing and bushing components.

The amount of lead specified in this example is exclusively for lead applied in bearings and bushings. Please note, however, that the above quoted sentence was providing the result from a

single audit of a single engine that falls within a large range based on the calculations provided in Table 1 on page 7 of the exemption request. For a more comprehensive understanding on the relevant percentages of lead in bearing and bushes, please refer to that table.

c. The application mentions "*Note that professional engines may be rebuilt several times in their lifetime and the bearings replaced. This means that old bearings are removed and recycled and new spare part bearings installed. However lead in spare parts is not included in the above calculations*". Please specify on average how often bearings and bushes are replaced in typical applications (i.e., during regular maintenance and during remanufacturing).

In 2014, purchasing data from one of the representative engine manufacturers reflects 22% of the bearings sold into the global market in a given year were sold for the purpose of rebuild and repair. It is common practice for half-shell bearings, for example those found in crankshaft main bearings and connecting rod bearings, to be replaced at an engine rebuild at overhaul. Other bearings and bushes, such as those found in connecting rod small end or gear bushes, will be evaluated at overhaul and either replaced or re-installed in the engine as is. The overhaul process is performed by disassembling the engine and replacing worn components, such as bearings and bushes, as needed, with the goal of reassembly to place the engine back into service. This process may be conducted not at all or up to 4 times for a large, heavy duty engine.

As described in the exemption request, there is a closed loop system for the recycling of mixed metal components, including the bearings and bushes subject to this exemption request, which are generated during the rebuild process and at end of life. Bearings and bushes have a positive metal value whereas disposal to landfill entails a cost. Accordingly, standard industry practice is to collect and recycle these bearings and bushes.

6. From the descriptions of testing of lead-free bearings, it appears that the RoHS Directive was not necessarily the motivation for performing these activities and that in some cases data is taken from general testing of bearings and bushes and not from testing performed specifically for the equipment relevant for this exemption request[2]. Please detail what efforts are further intended to be carried out to develop and test bearings and bushes for equipment to benefit from the requested exemption. In this respect, please specify:

The lead free development work was in fact a direct response to the requirements of our products falling into scope of Category 11 of 2011/65/EU.

a. How do manufactures influence bearings and bushes suppliers to further look into possible substitutes?

There are only a handful of bearing manufacturers with the capability and capacity to produce bearings for professional use diesel and natural gas engines. As a result, engine OEM's typically have a very strong relationship with these manufacturers. Engine bearing designs are typically owned by bearing manufacturer, meaning the bearing manufacturer derives the construction, materials, and manufacturing techniques with input from the customer (engine OEM) regarding end

[2] For example, the general figures relate various characteristics that have been tested, but it is often stated that data is from available information regarding general reliability testing of bearings and bushes and not testing specifically carried out for relevant equipment. In the section concerning testing of 9 litre engine, tests were performed in one case between 2004 and 2007, whereas the application implies that the RoHS 1 Directive did not apply to equipment and thus would not be expected to motivate such efforts

use requirements. The bearing manufacturer will do their own bench testing either in their own lab and/or in partnership with the engine OEM customer.

Market or regulatory forces will continue to push bearing manufacturers and OEMs to develop substitute materials. Bench testing and in application engine testing will be used to validate substitute materials against predetermined reliability and durability criteria reflective of the demands of the application.

b. What candidates have been identified for further testing?

As indicated in Table 2 on page 29 of the exemption request, a number of candidates were identified, tested, and determined to be unsuitable alternatives. Currently, we continue to work with the bearing industry to develop other potentially feasible lead-free candidates that perform as well as the leaded bearings and bushes to meet the regulatory and customer requirement.

One identified candidate is a copper/tin/bismuth alloy, and other derivations including those utilizing plastic or polymer coatings are undergoing continued testing. The exact formulation and construction methods of these bearings are considered a trade secret.

In all cases, the alternative materials have not met reliability requirements in the applications requested for exemption. Further time and testing will be required to ensure reliability in these applications. Question 7b of the exemption request describes the testing parameters and time scale required for completion of this protocol.

c. Could the amounts of lead be reduced? If not, please explain why.

The amount of lead in a given bearing and bush has been developed to provide a specific balance of performance characteristics (e.g. strength, seizure resistance, corrosion resistance, etc.) for a given bearing or bush system. That selection of material, and specifically lead content, has been developed to meet the reliability and durability needs for that specific system. There are different amounts or percentages of lead in different bearings and bushes in an engine as the requirements vary. However, given the specificity with which the amount of lead in a bearing or bush is calculated, simply reducing the lead content even a small amount potentially results in a decrease in reliability of the bearings or bushes.

d. Figure 7 of the application shows an engine where both lead free (coloured in green) and lead-based (coloured in magenta) bearings and bushes are applied. Please explain in what cases it has been found that lead-fee bearings and bushes can be used. What was the motivation for application of lead-free bearings and bushes in the past?

As explained in the submission, for each specific type of engine and its intended applications, both lead-free and lead-based bearings have been tested to identify the materials and designs that meet the combinations of performance requirements for each bearing and bush in the engine. With some designs and applications, lead-free bearings are found to be suitable, meeting all performance requirements and so are used, whereas with others only lead-based provide all of the performance requirements. This is not always the case, but when a lead free bearing or bushing material meets the requirements and is a feasible option it will be selected.

7. On the basis of the information in your application we propose a few changes in the exemption wording formulation given in your application.

a. Please confirm if the following formulation is sufficient to cover the use of bearings and bushes in engines, for which the request has been submitted. Alternatively please explain in detail why not and what further types of engines need to be covered under the scope of the exemption.
Lead in bearings and bushes of diesel or gaseous fuel powered internal combustion engines applied in:
   i. *Non-road professional use equipment and where engine total displacement is >15 litre;* **OK**
   ii. *Non-road professional use equipment and where engines have a <15 litres displacement,* **designed to operate in applications** *where the time between signal to start and full load is required to be less than 10 seconds.*
   iii. *Non-road professional use engines with <15 litres displacement, designed for operation in environments :*
      1. ~~*Designed to operate in an aqueous environment with suspended particles above XXX…*~~
      2. ~~*Exposed to air emissions conditions of more than XXX PM…*~~

Generally, it is not practical to base the exemption for the equipment on operating in certain air emission condition (e.g. dirt may enter an engine during servicing in the field, as described above). The environments that non-road professional use engines typically operate in are more likely to introduce contaminants, causing irreversible bearing damage. We suggest the following text for the third item instead:

- "Non-road professional use engines with < 15 litres displacement designed for operation in applications where regular maintenance is typically performed in an outdoor environment, such as mining, construction, and agriculture applications."

b. What is meant by the term "total displacement" used in the exemption wording formulation in relation to non-road professional use vehicles? Could a term used in the NRMM Directive, to differentiate between various types of vehicles in the scope of this Directive, be applied here to allow for harmonisation between the Directives in this respect, for example "engine power output"?

Total displacement refers to the total volume of all the engine's cylinders. The calculation for total volume = (3.14 * Cylinder Radius * Piston Stroke)* number of cylinders.

Because of the wide variety of engines, manufacturers, and power outputs utilized in a given application, it is suggested to keep the definition at a constants all manufacturers share. These constants are defined by the harsh and dirty engine operating environments, the lack of qualified and reliable substitutes for displacements 15L and greater, and the need for reliable performance of power generation equipment designed to provide power in signal to start conditions of less than 10 seconds.

c. In relation to the above formulation, please comment on the various descriptions of environmental conditions given in item III and where relevant provide performance thresholds.

It is true that manufacturers generally recommend equipment be cleaned (such as power washed) to remove loose dust and debris before any paths for contamination are opened to the engine (dipstick, oil cap, air filter, fuel filter, fuel/water separator, etc.). This is often not possible in the field or jobsite

where service of non-road professional use engine is commonly carried out. Therefore engines must be designed to be serviced on site by mobile mechanical service provider and the internals must be made durable enough to withstand the years of exposure to particles which may enter the tribological surface areas. In such cases current lead-containing materials offer the best capability to operate with debris contamination.

The above also assumes the manufacturer's maintenance schedules are observed. Service events also represent an opportunity for contaminates to bypass filtration systems and end up in the internal workings of the engine. This includes pouring oil from a dirty jerry can, dust falling into the engine intake during a filter change, opening the oil cap on a dirty engine, etc. If maintenance intervals are extended, more and larger particles will be circulated into the engine.

d. Is all equipment to benefit from the requested exemption in the scope of the Non-road mobile machinery Directive?

No. For example, stationary generators less than 375kW rated power will benefit from this exemption but are not in the scope of the Non-road Mobile Machinery Directive, as they are not considered "mobile".

e. Would the conditions set out in item ii and item iii suffice to exclude the use of bearings and bushes in small capacity engines where these are used in equipment not relevant to this request? For example in combustion engines of garden equipment?

Yes, most non-professional garden equipment in scope of RoHS is petrol powered, which is not included in the first paragraph of the proposed exemption wording.

f. Could the exemption be further limited to tri-metal bearings, understood to be more relevant to heavy duty applications? If not, please explain why.

No. There are several bi-metal bearings and bushes that require lead for heavy-duty applications. Examples of bi-metal bearings and bushes that require lead to meet reliability requirements include certain connecting rod small end bushes and valve-train rocker arm bushes.

Please note that answers to these questions are to be published as part of the available information relevant for the stakeholder consultation to be carried out as part of the evaluation of this request. If your answers contain confidential information, please provide a version that can be made public along with a confidential version, in which proprietary information is clearly marked.

Annex:
Figure 1:

Engine Displacement	Main Crank Bearing Journal Diameter	Surface Speed @ 1,500 RPM	Common Applications	
5.0 Litre	70mm	5,495 mm/second		2016 Nissan ½ ton passenger truck
6.7 Litre	83mm	6,516 mm/second		2015 Dodge Ram 3/4 ton Passenger truck
8.9 Litre	98mm	7,693 mm/second		Medium Duty Cargo Truck
15 Litre	127mm	9,970 mm/second		Class 8 Heavy Duty Truck
95 Litre	200mm	15,700 mm/second		Train Power Power Generation

Displacement Calculation (Litres)= (3.14 * Cylinder Radius * Piston Stroke)*Number of Cylinders
Surface Speed (mm/s) = (3.14 * Diameter)*RPM/60

Note a passenger truck application with a 70mm crank journal bearing diameter has an 81% lower bearing surface speed compared to that of a class 8 heavy duty truck. This same 15L engine and greater are utilized in equipment out of scope of the NRMM directive but in scope of 2011/65/EU. Heavy duty trucks are however excluded from, RoHS and as described above in answer to Q3, the 15l engines used in trucks experience very different use conditions to those in scope of RoHS.