Emission Monitoring and Periodic Inspection (EMPI) of Non Road Mobile Machines

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for initial discussion with interested parties

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1. Introduction

Reducing emissions from non-road mobile machinery is important for public health, nature and the climate. The Netherlands Ministry of Infrastructure and Water Management will therefore be working in 2021, in consultation with local authorities and market parties, on a roadmap for "Sustainable mobile equipment and construction logistics". This concerns integrated policy development for the Dutch Clean Air Agreement, the Dutch Climate Agreement, the Nitrogen Policy and also for the Strategy for Climate-neutral and circular infrastructure projects and the process of updating the Criteria for Sustainable Public Procurement (SPP-criteria)[1].

Reducing the emissions of mobile machinery can be achieved by a combination of on the one hand accelerating the transition to zero-emission mobile machinery and on the other hand realizing health gains in the shorter term through the accelerated replacement with cleaner alternatives of the current fleet of equipment with combustion engine. This can be realized, among other things, by setting SSP criteria for public tenders and / or setting criteria by the competent authority in environmental permits.

In the Dutch Clean Air Agreement, it has been agreed that the parties will make agreements about concrete requirements and award criteria (SSP criteria) in public tenders for (construction) projects with mobile machines. In addition, the parties are investigating the possibilities and effects of including emission requirements in environmental permits and environmental zones for mobile machines that are used, for example for logistics, events, green management, infrastructure and construction works. Appendix I contains the text on Mobile Equipment from the Dutch Clean Air Agreement.

This memorandum describes a possible approach for controlling the real-world emissions from mobile machines. This control can be used to check whether SSP criteria and / or requirements from environmental permits are met. The control consists of continuous monitoring of the NOx emissions and periodic checks of the operation of the particulate filter and the NOx sensor. In addition, this memorandum describes a possible classification of mobile machines according to polluting emissions. Finally, a possible demonstration project is described to gain experience with the proposed emission monitoring and periodic inspection (EMPI) of mobile equipment.

The aim of the demonstration project is to monitor the emissions from 50 to 100 mobile machines. TNO will be the main contractor. The mobile equipment sector is making an inventory of whether the project could possibly become part of "the Green Course (TGC)". This is the Construction & Infrastructure sector platform (including green maintenance) aimed at reducing emissions from mobile machinery and (construction) equipment. In addition, the Swiss organization VERT has indicated that it wishes to devote attention to this possible demonstration project.

The project concerns all machines belonging to the European definition of Non Road Mobile Machinery, i.e. all vehicles and machines, with a combustion engine, that are not necessarily intended for road transport. The focus is not on agricultural vehicles and track towers unless they are used in urban areas and / or for tenders for construction, civil engineering or green projects. Inland ships are excluded from the project. Optionally, it is also possible to include construction logistics trucks or kippers, in the project.

By monitoring and controlling the emissions of mobile machinery, it can be assessed whether the SSP criteria set for tendering for public works are met and / or criteria that the competent authority can set for private projects. This topic is addressed within the Dutch Clean Air Agreement within "Work Package 2 Contracting and Enforcement" of the theme Mobile Tools.

2. Possible approach for controlling the emissions

Over the past decades, the EU has implemented a step-by-step reduction of nitrogen oxides and particulate matter emissions for air pollutant emissions from mobile machinery. Based on Regulation (EU) 2016/1628, the Stage V standards are currently in force for mobile machines. In addition, Regulation (EU) 2017/655 sets requirements for families of engine types for monitoring

[1] https://www.pianoo.nl/en/public-procurement-in-the-netherlands/sustainable-public-procurement-spp

emissions in practice. This must be used to demonstrate that in good condition, in-service engines with a power between 56 and 560 kW comply with the emission requirements under normal operating conditions.

The Stage V requirements for mobile machines between 56 and 560 KW have led manufacturers to equip diesel engines with complex systems for cleaning the exhaust gases. This concerns SCR catalytic converters (AdBlue systems) for the reduction of nitrogen oxides and particulate filters for the reduction of particulate matter emissions. Stage V engines between 19 and 56 kW are only equipped with a particulate filter, to meet the particle number emission requirement.

When exhaust gas cleaning systems such as SCR catalytic converters and diesel particulate filter function properly, the emissions from the exhaust are reduced to (very) low levels. However, there are circumstances under which (significantly) higher emissions can occur. This may concern operating conditions in which SCR catalytic converters do not function properly, such as prolonged idling or manipulation of exhaust gas cleaning systems (Adblue manipulation, particle filter removal). In addition, there may be aging of emission control systems making them less effective or malfunctions that are not detected by the on-board diagnostic system (OBD).

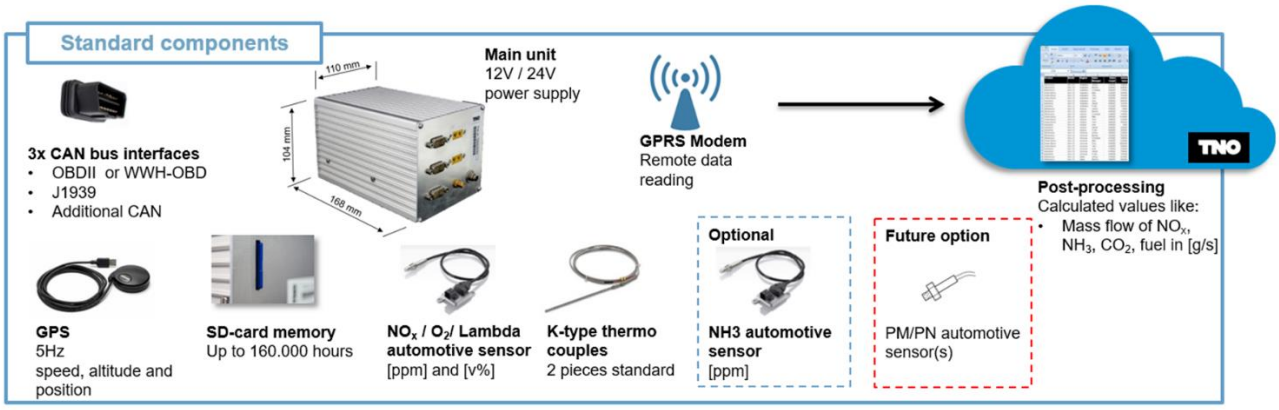
Modern diesel engines have sensors for measuring NOx emissions. The engine management system uses this data to control the SCR catalytic converter. Continuous monitoring of the signal from the NOx sensor offers the possibility of providing insight into the NOx emissions of a diesel engine. The intention is to have the control of the emissions of mobile machinery consist of a continuous monitoring of the NOx emissions combined with a periodic check of the particulate filter and a periodic check the NOx sensor. The diesel particulate filter is checked by measuring the number of soot particles in the exhaust gas. The NOx sensor is checked by measuring the NOx concentration in the exhaust.

2.1 Continuous monitoring of the NOx emissions

NOx monitoring means the continuous measurement of the NOx concentration of the exhaust gases of a diesel engine with a NOx sensor. For this, use can be made of a NOx sensor specially installed in the exhaust for NOx monitoring, such as with the TNO SEMS system, or of the NOx sensor of the machine itself and that is used for controlling the SCR catalytic converter. In advanced mobile machines, the NOx sensor has a CAN interface and can therefore be read by translating the digital CAN messages into concentration values over time.

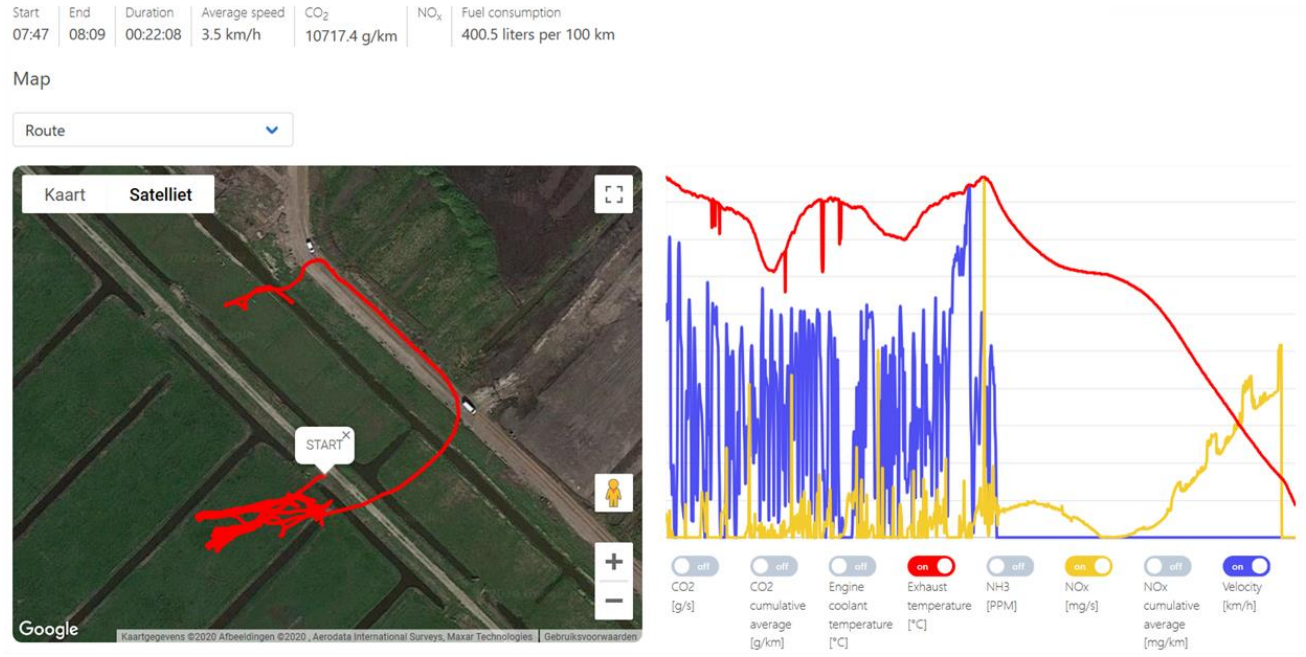
Using further information about the exhaust gas flow and fuel consumption, the signal from the NOx sensor is converted, if possible, into the NOx emissions in grams per hours, and in grams per kWh of work delivered by the engine. The NOx monitoring data is periodically / daily transferred online to a central back office database. Via monitoring, the owner of a low emission mobile machine must demonstrate that during practical operating conditions the NOx emissions do not exceed, for example, 0.6 g / kWh. The value of 0.6 g / kWh is based on the Stage V standard of 0.4 g / kWh and a conformity factor of 1.5.

The image below shows TNO's SEMS emission measurement system.



For a further description of the SEMS system see: https://www.tno.nl/en/focus-areas/traffic-transport/roadmaps/sustainable-traffic-and-transport/sustainable-mobility-and-logistics/improving-air-quality-by-monitoring-real-world-emissions/measuring-real-world-emissions-with-tno-s-smart-emissions-measurement-system-sems/

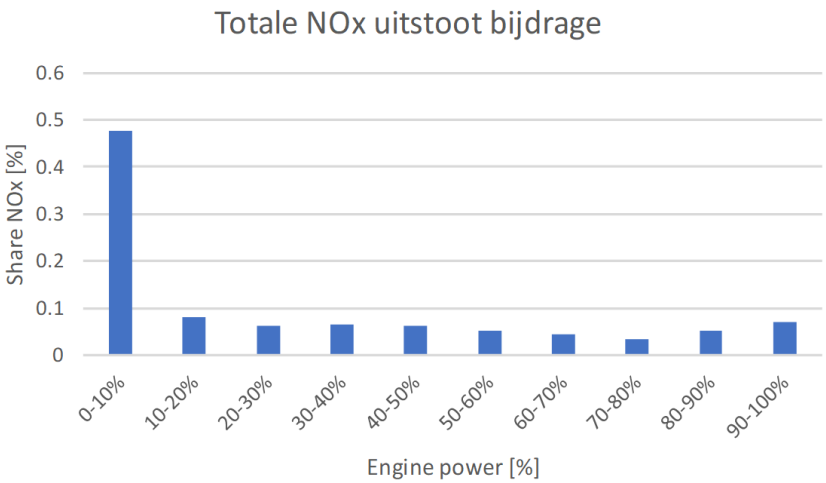
The above images show the SEMS system built into a mobile machine. The middle image shows the SEMS registration box under the seat in the cab. The right image shows the NOx sensor, the ammonia sensor and the temperature sensor (thermocouple) mounted in the exhaust of the mobile implement.



The image above shows the result of 22 minutes measuring with the SEMS system. The first image shows the route traveled by the machine on a google maps map and the second image the measured concentration of NOx in the exhaust (yellow line), the vehicle speed (blue line) and the temperature of the exhaust (red line). The engine has been running at low idle speed for the last ten minutes. During this time, the exhaust temperature gradually decreased so that the NOx concentration gradually increased because the SCR catalyst became too cold.

The image below shows the result of 350 hours of measurement. The final result is that 9.0 kg NOx has been emitted and that the specific NOx emission is 0.4 g / kWh. This exactly corresponds to the Stage V NOx standard for engines > 56 kW. The figure on the right shows that half of the NOx is emitted at an engine load of up to 10%. This concerns periods of low idling for a longer period of time. The temperature of the catalytic converter then decreases, which increases NOx emissions. If the engine had been switched off under these conditions, the NOx emissions would have been approximately half, i.e., approximately 0.2 g / kWh. A diesel engine without facilities to reduce NOx emissions emits approximately 8 g / kWh. This measurement shows that with an effective SCR catalytic converter in combination with switching off the engine during prolonged idling, NOx emissions can be reduced by about a factor of 40.

- Stage V
- SCR, DPF
- 350 h
- 9,0 kg NO_x
- 16,0t CO_2
- 0,4 g NO_x/kWh



2.2 Periodic check of the particulate filter

The diesel particulate filter is checked by measuring the number of soot particles in the exhaust of the diesel engine with a particle counter. The method of checking particulate filters has been used for some time in Swiss tunnel construction. See: https://tsi.com/getmedia/3cf412de-3146-4a95-a927-0a7a05544233/NPET-001_Application_Examples_App_Note_A4-web?ext=.pdf

The measurement is carried out at low engine idle speed. The limit value is considered to be 250,000 soot particles per cubic centimeter. This roughly corresponds to a filter efficiency of 95%. In 2021, new types of particle counters will come onto the market that have been developed for checking particulate filters in the PTI of cars. From 1 July 2022, the new PTI test with particle counter will be introduced in the Netherlands for checking the particulate filter of diesel cars.

2.3 Periodic check of the NOx sensor

The NOx sensor of the monitoring system is checked by measuring the NOx concentration in the exhaust with a portable NOx meter. The validation of the NOx sensor must be done by comparing the results of the NOx measurement in the exhaust with the signal from the NOx sensor. The left image below shows a NOx sensor. The right image shows a portable NOx meter for flue gases

A NOx sensor measures the volume fraction NOx, expressed in ppmV or in%. The measurement accuracy of a NOx sensor specified by the manufacturer is usually <10%. Typically, the accuracy is around 5%. To check the NOx sensor, there must be a "real time function" on the NOx monitoring. With this function, the instantaneous signal from the NOx sensor must become available. The inspector in the field can then immediately see whether the NOx concentration measured in the exhaust corresponds within a certain margin with the value measured by the NOx sensor of the monitoring system. It should be further investigated whether an exhaust gas flow validation measurement should also be performed during the field check.

3 Possible classification of mobile machines according to polluting emissions

For categorization of mobile machinery according to polluting emissions, it is possible to use a classification that is consistent with the classification of road vehicles by emission classes as currently applied in the Netherlands for the admission to environmental zones.

First ideas[2] for categorizing polluting emissions from mobile machines:

- Zero emission
- Low emission
- Diesel with filter and NOx-reduction
- Diesel with NOx-reduction
- Diesel except the most dirty
- Most dirty diesel

For an environmental zone for road vehicles, access is permitted on the basis of Emission Classes, as laid down in the Administrative Provisions on Road Traffic Decree and the Vehicle Registration Regulations in connection with the harmonization of environmental zones.

Categorization of car emissions for admission to environmental zones:

There is a great deal of similarity between the above possible categorization of mobile machinery according to polluting emissions and the classification of road vehicles according to emission classes. Trucks of emission class 4 (green) have a relatively low NOx emission. Diesel passenger cars and delivery vans of emission class 5 (blue) are equipped with a particulate filter[3]. Emission class 6 (purple) trucks are equipped with both an SCR catalytic converter and a particulate filter

[2] This is not a proposal from the Ministry of Infrastructure and Water Management
[3] Heavier diesel delivery vans of emission class 5 with an approval according to the truck regime usually do not have a particulate filter.

for low NOx and low particle emissions respectively. Appendix II provides a further elaboration according to Stage standards for the classification of mobile machines.

The category classification for mobile machines can also be met by the use of retrofit wall-flow particulate filters and retrofit SCR systems. It is not necessary that these are certified retrofit systems or that the engine with a retrofit system has a new European type approval. Monitoring of NOx emissions of retrofit SCR systems and / or periodic checking of retrofit particulate filters with a particle counter provide a sufficient guarantee that low emission levels occur in practice during daily use and over the entire service life. The installation of a certified retrofit particulate filter or SCR system, on the other hand, only offers a guarantee that the system will function properly after installation. It does not mean that the retrofit facility will continue to perform well over a number of years. The image below shows a retrofit SCR installation on a Stage V mobile machine with a power of 54.5 kW. The Stage V NOx standard for medium-sized machines is still quite moderate, i.e., 4.7 g/kWh, versus 0.4 g/kWh for larger machines. This installation has been built into a new machine by the importer and is already equipped with an online emission monitoring system.

The level of NOx emissions from mobile machines is strongly dependent on the use, in particular the extent to which the engine is running at idle and at low load. In these circumstances the exhaust gas does not get hot enough, so that the SCR catalytic converter does not function (properly). This effect is taken into account by the described categorization according to emissions, whereby it is demonstrated by means of monitoring that the required emissions are being met. With this approach, the deployment behavior of a mobile machine therefore plays a role in that it can be demonstrated that the required emission level is being achieved.

As shown in the table below, the described categorization of mobile equipment by emission can also be used to set minimum SPP criteria. The use of renewable energy is not part of this classification according to polluting emissions. In modern mobile machines with particulate filter and SCR-catalyst, the use of biofuels (such as HVO) does not lead to lower emissions from the exhaust. With old mobile machines, there may be lower particulate matter emissions. The application of renewable energy is aimed at reducing CO2 emissions along the chain. Based on the above categorization according to polluting emissions, the use of renewable energy can be included as a separate criterion, in the case of as well electricity, as LPG, CNG, LNG and diesel.

	Criterion	Elec-tric	LPG CNG LNG	Diesel wit			NOx-moni-toring	Pn-con-trol
				filter + NOx-red.	NOx-reduc-tion	-		
○	Zero emission	OK					n / a	n / a
●	Low emission	OK	OK	OK			✓	✓
●	Diesel with filter and NOx-reduction	OK	OK	OK			✓	✓
●	Diesel with NOx-reduction	OK	OK	OK	OK		✓	-
●	Diesel except the most dirty	OK	OK	OK	OK	OK	✓	-

4 Demonstration project

The purpose of the demonstration project is to monitor the emissions of individual mobile machines. The option for the project is to also assess the total amount of NOx emitted in public tenders and / or private projects. This can then be used to check whether the requirements set for this have been met. The demonstration project is a follow-up to the emission measurement and monitoring study with mobile equipment, which was carried out by TNO in 2019 and 2020 on behalf of the Ministry of Infrastructure and Water Management. For this project, a number of smaller mobile machines, such as a refrigerated trailer, as well as a number of large Stage V mobile machines, such as the wheel loader on the title page of this memorandum, were measured. For the study, the emission data of the mobile machines measured with the SEMS system were always automatically sent to the TNO back office database. The report of this study will be available in early 2021.

4.1 Control of emissions from individual machines

For the demonstration project, it is envisaged that the emissions of 50 to 100 machines will be monitored. This involves monitoring and checking the emissions of individual machines during daily use. Factors such as the proper functioning of the SCR catalytic converter / EGR system and the particulate filter, actual use in practice and any manipulation of engine tuning or after-treatment systems play a role in the emissions that occur. This is in contrast to the emission monitoring in the context of Regulation (EU) 2017/655, which requires manufacturers to demonstrate for families of engine types that in good working order engines meet the emission requirements under normal operating conditions.

In principle, diesel machines from the following emission categories can participate in the project:

- Low emission mobile machines
- Mobile machines with particulate filter and NOx reduction
- Mobile machines with NOx reduction

For the demonstration project, it is considered that the registration of and access to the emission data of the participating mobile machines also take place via a back office database at TNO. To participate in the demonstration project, a mobile machine must be equipped with an online data connection to the back office database at TNO. This may involve an on-line connection through:

- the complete SEMS system,

- the mini SEMS box (second generation SEMS system),

- a monitoring via the importer / manufacturer.

The entire SEMS system uses a NOx sensor that is specially fitted in the exhaust. The mini or second generation SEMS system uses the NOx sensor with which a mobile machine is already equipped by the manufacturer. The mini-SEMS system is connected to the CAN bus of the machine for this purpose, so that monitoring data can be forwarded to TNO. The online monitoring system is used to identify the mobile machine, determine position using GPS, record the running hours, the NOx signal, engine speed, exhaust temperature, etc. The image below shows the mini SEMS system.

4.2 Optional assessment of the total NOx emissions per tender / project

In addition to control of emissions from individual machines, online monitoring of the emissions can also be used to determine the total amount of NOx that is emitted by all the mobile machines used in a tender or project. In this way, it can be checked whether the requirements set for the total emissions during the tendering or implementation are met. It is also possible to determine the total amount of CO2 emitted, although this can also be easily derived from the number of liters of fuel used. Determination of the total amount of particulate matter emitted is less possible as measuring particulate matter emissions in diesel engines without a particulate filter is complex. However, if all the mobile machines used are fitted with a properly functioning particulate filter, the total amount of particulate matter emitted is very limited.

In order to determine the total NOx emissions, in principle all diesel machinery used must be equipped with an emission monitoring system. This monitoring system then serves for identification of the machine, position determination using GPS, for registering the running hours, the NOx signal, speed, exhaust temperature, etc. For smaller 'tools' such as small mobile diesel pumps, diesel generators for light towers, etc., the monitoring is only for identification and position determination and the emissions can be estimated on the basis of fuel consumption and standard NOx emissions. Fully electric tools could also be fitted with a monitoring system, which then serves to estimate the avoided amount of NOx and CO2 emissions.

4.3 Execution of the demonstration project

TNO will be the main contractor of the demonstration project. Other participating parties may be companies that use mobile machines, municipalities that set SSP criteria for mobile machines, the 'competent authority' that sets emission requirements for permits, (BMWT) companies that maintain mobile machines and carry out checks on mobile machines. Parties such as Rijkswaterstaat, ProRail, provinces or other parties from the Dutch Clean Air Agreement can also participate. Participating parties can register one or more mobile machines for emission control. In addition, it can be considered that manufacturers of retrofit SCR systems and retrofit particulate filters will provide mobile machines to participate in the project. If the project will also determine the total amount of NOx emitted from tenders or projects, it must be further detailed how exactly to do this.

In the demonstration project, the SEMS systems will be installed under the responsibility of TNO. It must be further elaborated on what role other parties (participating BMWT companies) can play in the installation of SEMS systems and the performance of periodic emissions inspections for participating machines. In the case of an online monitoring connection via the importer / manufacturer, this must be linked to the back office database at TNO. A new element is that it must be possible to enter manually in the monitoring database at TNO when a particulate filter check with a particle counter and / or a validation check of the NOx sensor has been carried out on a mobile machine. In order to perform these periodic checks in the field, it must be possible to log in to the database to manually enter the results of the checks.

The intention is that the contractor (e.g., a construction company), the client (e.g., a municipality) and the company that carries out the emission control (e.g. a BMWT company) have access to the emission data of a participating mobile machine. This concerns a google maps map showing the route traveled by the mobile machine with next to it a graph with the measured NOx emission, vehicle speed, etc. In the same way, the emission data from the last trip with the VW Caddy company car from TNO can be viewed. See: https://demo.emissionmonitor.eu/demo. For the project, access to the emission data must of course be limited to the above three parties. A client (e.g., a municipality) will only have access to the emission data of machines that are used for the project during the execution of a project. September 2021 to December 2022 is envisaged for the duration of a project.

5 Eventually introduction of emission control for mobile machinery

The widespread introduction of monitoring and periodic inspection of the emissions of mobile machinery offers the opportunity to check whether the measures taken to use cleaner diesel-fueled machinery on construction sites are having the intended effect in practice. In the final intended set-up, the emission monitoring and periodic inspections are carried out by, for example, BMWT companies on behalf of construction companies. The BMWT may be able to play a role as a certification organization for inspection companies.

If monitoring and periodic inspection of the emissions of mobile machinery is to be used on a large scale to check the set emission requirements and / or award criteria, then the database with monitoring data could be hosted by the Netherlands Vehicle Authority RDW. The background to this is that monitoring of the NOx emissions is an option for all vehicles, vessels and machines with a diesel engine. It is also possible that the RDW will eventually set up a recognition scheme for companies that, on behalf of the owner, are going to install the monitoring systems in mobile machines and carry out periodic emission inspections in the field.

It is also possible that in addition to periodic emission inspections, random emission inspections will also be carried out and / or that a system of re-inspections will be introduced, just as for the Dutch PTI of road vehicles. However, the approach is not that the emission monitoring and periodic inspection (EMPI) for mobile machines will become a legal obligation, as now the PTI is a legal obligation for all road vehicles. With the possible introduction of EMPI for mobile machine, there is therefore no question of mandatory enforcement being introduced on the basis of statutory permanent requirements.

At the request of the Ministry of Infrastructure and Water Management, TNO will estimate the environmental impact of the possible widespread introduction of monitoring emissions and periodic inspection of mobile machinery. This concerns monitoring and inspection linked to the setting of SSP criteria in public tenders and to the setting of emission requirements in environmental permits. The total environmental impact of this arises from (1) the use of cleaner machines, (2) adaptation of the operating behavior (less idling) and (3) the guarantee of correctly tuned engines and properly functioning after-treatment systems (no defects, manipulation, etc.).

The effect of adjusting the operation behavior and of a properly functioning after-treatment system can (largely) be attributed directly to the emission monitoring and periodic inspection of mobile equipment. Operators will not quickly adapt their operating behavior without NOx emission monitoring, i.e. switching off the engine during prolonged idling. The emission measurements carried out by TNO have shown that with low-emission machines, approximately half of the emissions are formed when idling. Malfunctioning SCR systems or manipulated engine tuning resulting in higher NOx emissions than the standard value applicable to the machine in question, will also be revealed by the emission control.

Appendix I. Text Mobile Equipment from the Dutch Clean Air Agreement

Mobile machines such as construction equipment, sweepers, aggregates and agricultural implements, despite their limited numbers, contribute 10% to the negative health effects of domestic sources. As with road traffic, the European emission requirements are of great importance for the reduction of emissions. At present, a significant number of machines are still **not equipped with an effective particulate filter**. In addition**, high NOx emissions are released when the machines are idling**. Agreements have been made in the Dutch Climate Agreement to accelerate the transition to zero-emission mobile machinery. The national government, provinces and municipalities have an important influence on the market for mobile equipment **with the tendering of roads, engineering works and via the (environmental) permit**. The agreements focus on construction equipment, equipment for landscaping, aggregates for, for example, well drainage and festivals, cooling facilities in road transport and special vehicles that fall under the mobile equipment category. Various municipalities have already started exploring and applying options to reduce these emissions. In the past, ample attention has been paid to these sources, for example via the Green Deal "the new turning". The agreements from the Climate Agreement and sustainable Infrastructure and Water Management with regard to zero-emission construction equipment will contribute to health gains for mobile equipment in the longer term.

Target

The aim is to achieve a reduction of the negative health effects of mobile equipment by 75% 10 by 2030 compared to 2016.

Measures:

1. The parties strive to end the use of (older) diesel mobile equipment as soon as possible and to stimulate clean alternatives. The ambition is to end the use of **mobile equipment without a particulate filter and high nitrogen oxides emissions** as soon as possible and to accelerate the growth path towards zero-emission mobile equipment by 2030. Because the parties apply the same standards and by offering a longer-term perspective, a level playing field is created and market parties are given certainty to invest in cleaner and zero-emission mobile equipment.

2. The National Government, in collaboration with the Parties, is investigating what a development path ('roadmap') for clean and zero-emission construction equipment could look like and will publish the results in 2020. This study looks at the possibilities, bottlenecks and preconditions for cleaner or zero-emission and the ways in which governments (central and local authorities) can contribute to this, such as procurement policy, regulations or facilitating. Where possible, a link is sought with the acceleration that is taking place within the framework of the nitrogen approach. It is being investigated whether the application of **diesel powered equipment without a particulate filter** in built-up areas can be discontinued from 2022 and how far-reaching emission reductions can be stimulated in tenders.

3. By 2020, the parties will make agreements about **concrete requirements and award criteria in the tenders** and make further agreements about the periodic tightening of the requirements and award criteria in the period up to 2030. The national government will include the requirements and award criteria in the SSP criteria as published. on the PIANOo website and communicates the agreements so that (market) parties can prepare for future tightening of the criteria.

4. The parties will include the formulated requirements and stimulating provisions in tenders for (construction) projects for mobile equipment. If desired, for example for highly exposed areas, parties can opt for a more far-reaching ambition.

5. The parties, in consultation with the (market) parties involved, are examining the possibilities and effects of i**ncluding emission requirements in environmental permits and environmental zones** for urban and in particular highly exposed areas for mobile equipment that are used, among other things for logistics, events, landscaping, infrastructure and construction.

6. The central government, in collaboration with the Parties, is investigating **the possibilities of enforcing the emission requirements in practice** and, if necessary, **developing an inspection system for supervision and control of compliance with tender requirements for cleaner mobile equipment**. This involves looking at the possibilities of a voluntary particulate filter test and NOx monitoring, for example in the form of (voluntary) PTI emission inspection for mobile machinery and the options for including air emissions in the system and certification of the CO2 performance ladder.

7. The national government is actively committed to further tightening the European standards with regard to air polluting emissions for mobile equipment. Facilities for continuing to comply with the standards are an important point of attention in this respect.

Appendix II. Further elaboration according to Stage standards

The table below shows a further elaboration of the possible categorization of mobile equipment according to polluting emissions and the associated levels of NOx and particulate matter emissions. In each case, it is indicated which Stage standards for different power classes meet the relevant emission levels.

	Category NRMM	Emission		Power			
		NOx	Pm/Pn	< 19kW	19-37kW	37-56kW	56-560kW
○	Zero emission	0	0	Elek.	Elek.	Elek.	Elek
●	Low emission	0,4 g/kWh	0,015 g/kWh 1 x 10^{12} /kWh	-	-	-	Stage V Stage IV met filter
●	Diesel with filter (and EGR/SCR)	4,5 g/kWh	0,025 g/kWh (1 x 10^{12} /kWh)	-	Stage V	Stage V Stage IIIB met filter	Stage IIIB met filter
●	Diesel (and EGR/SCR)	4,5 g/kWh	0,025 g/kWh	-	-	Stage IIIB zonder filter	Stage IIIB/IV zonder filter
●	Diesel except the most dirty	7 g/kWh	0,6 g/kWh	Stage V	Stage IIIA	Stage II/IIIA	Stage II/IIIA
●	Most dirty diesel	9,2 g/kWh	0,85 g/kWh	Stage IIIA/B	Stage II	Stage I	Stage I

The Stage V emission standards for NOx are less stringent for mobile machines with smaller powers (<56 kW) than for machines with high powers. The emissions under working conditions of machines with low power is therefore considerably higher, because the use of an SCR catalytic converter is not necessary.

Stage IV mobile machines > 56 kW can be fitted with a particulate filter. In that case, these tools for NOx and particulate matter are just as clean as Stage V mobile machines > 56 kW and can be regarded as a low-emission mobile machine.

This classification has a stimulating effect on retrofit. A Stage V machine 19-56 kW can go from blue to purple by mounting a retrofit SCR. A Stage IV machine 56-560 kW can go from green to purple by installing a retrofit soot filter.

Stage IIIB mobile machines > 56 kW are often equipped with a soot filter and also a (somewhat less effective) SCR. If the operation of the SCR is improved by means of a retrofit update (more AdBlue injection, possibly a larger catalytic converter), then an updated Stage IIIB machine > 56 kW may turn purple.

This classification can also have a strong stimulating effect on the electrification of mobile machines <19 kW. If yellow is no longer permitted, Stage V mobile machines < 19 kW no longer meet the emission requirements. Electrification offers a solution for this.