IEA-Advanced Motor Fuels
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Annex/Task 61

Technology Collaboration Programme
by iea

Annex 61: Remote Emission Sensing

Project Duration	May 2020 – October 2023
Participants **Task sharing** **Cost sharing**	 China, Denmark, Finland, Sweden, Switzerland No cost sharing
Total Budget	€ 210,000 ($254,000 US)
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Purpose, Objectives and Key Question

The objective of this annex is to evaluate and propose how remote emission sensing (RES) can be used—for policy purposes as well as for direct enforcement—to detect high-emitting/ gross-polluting vehicles in real-world traffic.

The project will comprise all vehicle categories (i.e., passenger cars, light-duty commercial vehicles, heavy-duty trucks, buses and motorcycles) running on commonly used combustion fuels (i.e., petrol, diesel and CNG/LNG) designed to meet all adopted legislative emission limits (e.g., Euro 1/I – Euro 6/VI). However, special attention will be paid to high-emitting vehicles designed to meet the most recent emission standards, such as Euro 6. Target pollutants will be NO_X and PM.

The project aims to evaluate and compare the performance and applicability of the following main types of RES technologies to identify high-emitting vehicles:

- Conventional RES (Type 1 RES): This is in practice the technologies that are already offered to the market by commercial providers for emission measurement services.
- Point sampling RES (Type 2 RES): In terms of measurement strategy Type 2 RES is quite similar to Type 1/conventional RES, but it is still under development (i.e., not yet commercialized), and it demonstrates the best advantage for measuring PM emissions, both number and mass.
- Plume chasing RES (Type 3 RES): From a measurement strategy, this perspective is rather different than Type 1 and 2. Not as many vehicles can be measured per time unit, but the measurements on each vehicle have longer duration than those measured with Type 1 and 2. As a result, this RES is more useful to pinpoint high-emitters.

The project will make use of existing RES datasets in Europe, China and the US, as well as new datasets from upcoming RES measurement campaigns until early 2023.

The general outcome of the annex will be an independent comparison and evaluation of the performance of various RES technologies, with a focus on their ability and usefulness to detect excess-emitting vehicles for direct enforcement as well as emission legislation and air pollution policy purposes. The project will provide proposals on how RES can be practically applied for these purposes covering both existing and future in-use fleets. The project's final report will include:

- An "up-to-date" view of the real-world emission performance of European and Chinese in-use fleets, demonstrating the impact of current emission legislation on the real-world emissions of different vehicle categories grouped by emission standard, vehicle manufacturer, engine family, etc., to reveal eventual gaps between on-road emissions and legislative emission limits.
- A comparison and evaluation of the performance of different RES technologies to accurately measure on-road emissions, and particularly to accurately pinpoint high- or excess-emitting vehicles on an individual vehicle level and on vehicle model or engine family level.
- Proposals on how RES can be practically used to detect high-emitting vehicles for direct enforcement purposes as well as to monitor real-world emissions for emission legislation and air pollution policy purposes.

Activities

The project consists of five work packages:

WP 1: Collection and consolidation of existing data

The data to be collected and consolidated will comprise both RES data and relevant data from legislative and RDE tests (chassis dynamometer and PEMS). The collection and consolidation of data will occur in two steps:

- Collection and consolidation of existing data at project start.
- Collection and consolidation of additional data roughly six months before the end of the project.

WP 2: Comparison and evaluation of the performance of different RES technologies

- Comparison between different RES technologies.
- Comparison of RES technologies with PEMS and chassis dynamometer approaches to measure real drive emissions.
- Development and application of simulation tools for the flow and species dispersion of the exhaust plume in vehicle wakes to analyze the effects of different parameters (measurement, vehicle, climatic conditions).

WP 3: Evaluation of using RES to detect individual high-emitting vehicles for enforcement

This work package pinpoints vehicle owner/driver-imposed impacts on their vehicle's emission performance, such as tampering (use of AdBlue emulators, removal of DPFs, etc.), poor maintenance or very harsh driving. The analysis underpinning the evaluation and proposal will be carried out separately for three groups of vehicle categories:

- Light-duty vehicles (passenger cars and light commercial vehicles)
- Heavy-duty vehicles (trucks and buses)
- Two-wheelers

Links will be made to periodical technical inspections (PTI) and roadside inspections.

WP 4: Evaluation of using RES for emission legislation and air pollution policy purposes

This work package pinpoints the ability of different vehicle manufacturers to design vehicles (engines and exhaust after-treatment systems) that are compliant and durable in regards to real-world emission performance. As for WP 3, the analysis underpinning the evaluation and proposal will be carried out separately for three groups of vehicle categories:

- Light-duty vehicles (passenger cars and light commercial vehicles)
- Heavy-duty vehicles (trucks and buses)
- Two-wheelers

Links will be made to in-use compliance testing programs. In addition, the use of RES for improving performance and accuracy of road transport emission models and inventory systems, such as HBEFA and COPERT, will be evaluated.

WP 5: Project coordination & management, synthesis, reporting and dissemination

This work package includes administrative coordination, communication with the IEA AMF, synthesis of the data, compilation of the final report and dissemination of the results.

Key Findings

- **Application of RES Type 1 for identifying NO_X high- and low-emitting early Euro 6 (6a and 6b) light-duty diesel vehicles**

  Repeat RES Type 1 measurements and, to some extent, even single measurements appear to be useful for identifying NO_X high-emitting early Euro 6 light-duty diesel vehicles in real-world traffic. This is especially true of the worst polluting vehicles, namely those with RDE emissions exceeding 0.5 g/km up to 1.5 g/km (5-10 times the Euro 6 NEDC limit). Ten percent of the most high-emitting early Euro 6 diesel light-duty vehicles was estimated to account for 30% of the overall NO_X emissions from the early Euro 6 diesel LDV fleet in Sweden in 2018. A few engine families were clearly over-represented among the high-emitting early Euro 6 diesel LDVs.

- **Evaluation of RES Type 3 (plume chasing) against PEMS (onboard) emission measurements**
  The comparative tests of heavy-duty vehicles by using concurrent RES Type 3 and PEMS were conducted on a well-controlled track (four vehicles) and real-world highways (12 vehicles). These tested vehicles complied with China III to China VI standards (equivalent to Euro III to Euro VI). The results indicate good agreement of NO_x emission factors between plume chasing and PEMS. For example, the track tests derived an overall R^2 of 0.97 and an average discrepancy of -8% (chasing vs. PEMS; see Fig. 1). The real-world highway tests also had all chased emission factors ranging approximately within ±20% of the corresponding PEMS results. Of note, these comparative tests also validated the reliability of plume chasing for measuring NO_x emissions for older (e.g., China III without SCR) to modern (e.g., China VI) generations of HDVs.

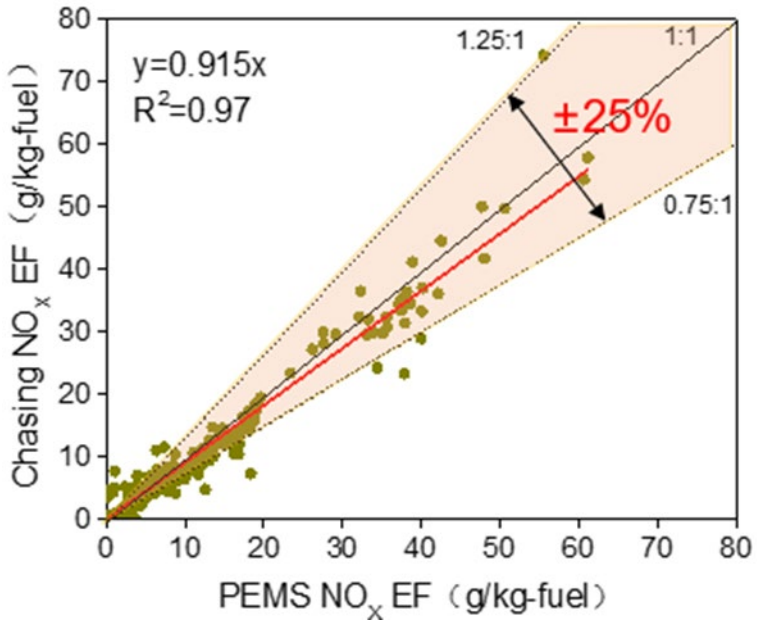

Fig. 1. The comparative tests of NO_x emissions between RES Type 3 and PEMS (four vehicles, 360 chasing events in total).

- **Development and application of simulation tools for the flow and species dispersion of the exhaust plume**
  It is sufficient if air and one pollutant component are simulated, since turbulent diffusion is dominant. A hybrid model of RANS (Reynolds Averaged Navier Stokes equations) for the flow around the vehicle and LES (Large Eddy Simulation) for the wake flow is under development in order to achieve a good trade-off between computational time and accuracy with regard to the simulation of species dispersion.

Main Conclusions

The project is still at a very early stage, since it was launched in fall 2020, but we can conclude:

- EU, Chinese and Swiss institutions have noted the importance of RES technologies in deriving real-world emissions and potentially identifying high-emitters. Governmental funding has been utilized to improve and apply these technologies.
- The preliminary results have shown some promising comparison results between RES technologies and regulatory instruments (e.g., PEMS).

Publications

- H. Wang, Y. Wu, S. Zhang, et al. (2020) Evaluating mobile monitoring of on-road emission factors by comparing concurrent PEMS measurements. *Sc. Tot. Env.*, 736, 139507. https://www.sciencedirect.com/science/article/abs/pii/S0048969720330242
- Further upcoming project reports will be available for download on the website: https://www.iea-amf.org/content/projects/map_projects/61.