IEA-Advanced Motor Fuels

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Task 61

Technology Collaboration Programme
by iea

Task 61: Remote Emission Sensing

Project Duration	May 2020 – October 2023
Participants **Task sharing** **Cost sharing**	 China, Denmark, Finland, Sweden, Switzerland None
Total Budget	EUR 210,000 (USD 229,165)
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Purpose, Objectives, and Key Question

The objective of this task 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, in practice, refers to the technologies 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 from 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 and China as well as new datasets from upcoming RES measurement campaigns until early 2023.

The general outcome of Task 61 will be an independent comparison and evaluation of the performance of various RES technologies, focusing 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 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 various 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 a 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

WP 1: Collection and consolidation of existing data
In 2022, the RES datasets available for the work of Task 61 continued to increase.

- The number of Type 1 RES records in the European CONOX database increased by more than 300,000 to about 1,800,000 records, due to new data from measurement campaigns carried out in Switzerland (Zürich), Germany (Frankfurt), and Italy (Milan).
- Additional measurements with Type 3 RES on heavy-duty trucks, and for the first time also on light-duty vehicles, have been carried out in several European countries (the Czech Republic, Germany, and Sweden).
- VTT collected and released real driving emission (RDE) data from previous onboard PEMS tests conducted in Finland. The data package included results from PEMS tests performed on a city route with four Euro 6 diesel passenger cars.

WP 2: Comparison and evaluation of the performance of different RES technologies
Following are highlights of 2022.

- Two reports have been published from the CARES RES characterization measurements campaign carried out at a test track in the Netherlands in June 2021, in which RES Type 1, Type 2, and Type 3 measurements were compared with PEMS (onboard) measurements and their ability to identify high-emitting vehicles was explored.
- The CARES city demonstration campaign in Prague and Brno, Czech Republic, was carried out in September 2022, where instruments representing RES Type 1 (the Opus RSD 5500), RES Type 2 (the CARES PN, BC, and NO_x sensors), and RES Type 3 RES (the CARES plume chasing instruments measuring NO_x and PN) were deployed, resulting in more than 100,000 vehicles measured. The campaign also involved pulling suspected high-emitting vehicles over for roadside inspections and a PEMS-equipped light-duty vehicle repeatedly passing the RES measurement sites.
- A total of 172 PEMS-chasing conjoint tests were conducted in Jiangsu Province to evaluate the accuracy of the plume chasing for HDDV emissions and to analyze the impact from meteorological variables and vehicle speed. In the experiments, various operating scenarios and vehicle types were considered.
- The high-fidelity hybrid LES/RANS solver for an accurate description of the plume dispersion by keeping the computational cost considerably low is still under development (testing and validation in progress). In fact, a study of multiple coupling methods of LES and RANS led to better performance. Additionally, parameter studies regarding RES using the validated but less accurate URANS model were concluded in a journal paper, which is currently under review. Comparisons to experimental data from various RES devices were initiated.

WP 3: Evaluation of using RES to detect individual high-emitting vehicles for enforcement
See some of the activities listed under WP1 and WP2 (relevant for high-emitter detection).

WP 4: Evaluation of using RES for emission legislation and air pollution policy purposes
See some of the activities listed under WP1 and WP2 (relevant for RES policy applications).

WP 5: Project coordination and management, synthesis, reporting, and dissemination
In 2022, activities and progress were reported in Executive Committee meetings 63 and 64. Two Task 61 work meetings were arranged in 2022.

Key Findings

- The RES Type 1 and 2 measurements carried out in Milan within the CARES project have revealed that, contrary to conventional belief, vehicles fueled by LPG and CNG show high real-world emissions of NO_x, CO, HC, and black carbon.
- RES Type 1 instruments may have problems measuring particularly PM and HC emissions accurately at low ambient temperatures (below +5 degrees C), due to the condensation of water vapor to water droplets in the diluting exhaust plume.

- Measurements carried out in 2022 in the Czech Republic by means of RES Type 3 in combination with roadside inspections reveal that tampering, defects, and software issues of the emission control systems of Euro V and Euro VI heavy-duty trucks occur quite frequently in Europe.
- A large sample of RES Type 3 measurements (~10,000 HDDVs in Shenzhen) indicated that the implementation of more stringent emission standards has significantly reduced the average NO_x and BC emission factors of local HDDVs.
- Effective ratio (ER) – a practical parameter – was proposed, which contains the displacement of the vehicle wake length and the wind speed fluctuations. The measurement results of chasing are in good agreement with that of PEMS when the ER is less than 1 – that is, high vehicle speed and low crosswind (normal to the driving direction) speed. Thus, the ER can be further used to identify the effective chasing data and improve the accuracy of chasing.
- The EMPA parameter study found that the most crucial volume that RES must capture is the core exhaust plume (CEP), which lies within the first 1.5-2 m behind the vehicle. Therefore, low measurement frequencies lead to few measurement points in the CEP and thus to a less robust estimation of the concentrations. A plane-measurement instrument always detects a higher fraction of the original exhaust gas (in terms of absorption) compared to a line-measurement instrument: approximately 70% more in the CEP and 95% more in the far downstream region. Increasing vehicle velocities result in a decreased size of the core exhaust plume (CEP) in all directions. Crosswind has little influence on the CEP. As both the wind and the distance from the tailpipe increase, the amount of pollutant that can be detected by RES devices decreases. Moreover, the interference of pollutant concentrations from multiple plumes in the longitudinal direction has a smaller effect on measurement accuracy than the increased turbulent intensity by the vehicle ahead.

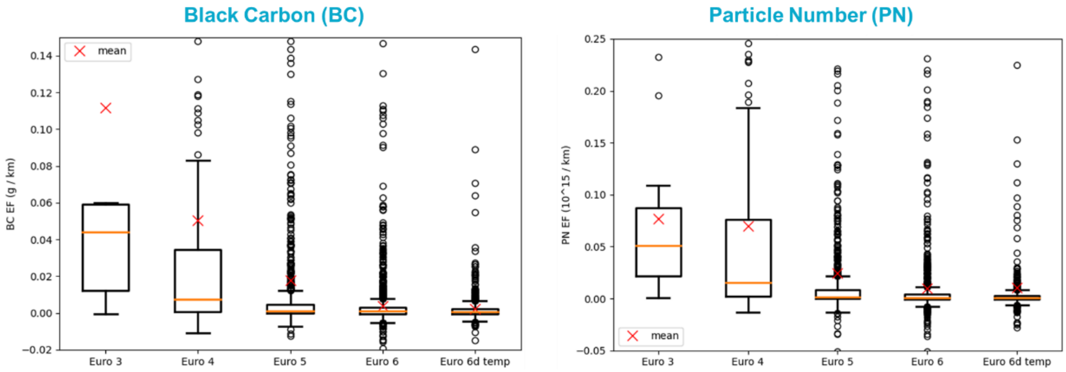

Fig. 1. Results from the First-ever RES Measurements of Black Carbon (BC) and Particle Number Emissions from Diesel Passenger Cars (Averages by Euro Standards in City of Milan)

Main Conclusions

- The earlier observed good agreement between RES Type 3 and PEMS measurements, in particular, has been confirmed in both Europe and China from new measurements conducted in 2022.
- Applications of the newly developed RES Type 2 sensors for BC and PN in several European cities have proved that these are crucial for complementing (commercial) RES Type 1 instruments to better understand real-world emissions of particulate matter.
- Further development of plume dispersion models and subsequent modeling exercises can be used for pinpointing advice on optimizing RES capture of the plume.

Publications

- Shen, Y., Zhang, Q., Wang, D., et al. Evaluation of a cost-effective roadside sensor platform for identifying high emitters[J]. Science of The Total Environment, 2022, 816:151609. https://www.sciencedirect.com/science/article/pii/S0048969721066857.
- Xiang, S., Zhang, S., Yu, Y.T., et al. Evaluation of the Relationship between Meteorological Variables and NO_x Emission Factors Based on Plume-Chasing Measurements[J]. ACS ES&T Engineering, 2023. https://pubs.acs.org/doi/full/10.1021/acsestengg.2c00317.

- Farren, N,, Carslaw, D., Knoll, M., Schmidt, C., Denis, P., Hallquist, Å. (2022) Measurement technology intercomparison and evaluation. CARES deliverable D1.1. https://cares-project.eu/wp-content/uploads/2022/10/CARES_D1_1_July22.pdf.
- Farren, N., Carslaw, D., Knoll, M., Schmidt, C., Denis, P., Hallquist, Å. (2022) Monitoring of vehicle tampering. CARES deliverable D1.2. https://cares-project.eu/wp-content/uploads/2022/10/CARES_D1_2-_July22.pdf.
- Qiu, M., and Borken-Kleefeld, J. (2022) Using snapshot measurements to identify high-emitting vehicles. *Environ. Res. Lett.* **17**, 044045. https://doi.org/10.1088/1748-9326/ac5c9e.
- Yang, Z., Tate, J. E., Rushton, C. E., Morganti, E., Shepherd, S. P. (2022) Detecting candidate high NOx emitting light commercial vehicles using vehicle emission remote sensing. *Sc. Tot. Env*., **823**, 153699. https://doi.org/10.1016/j.scitotenv.2022.153699.

Further upcoming project reports will be available for download on the website https://www.iea-amf.org/content/projects/map_projects/61.