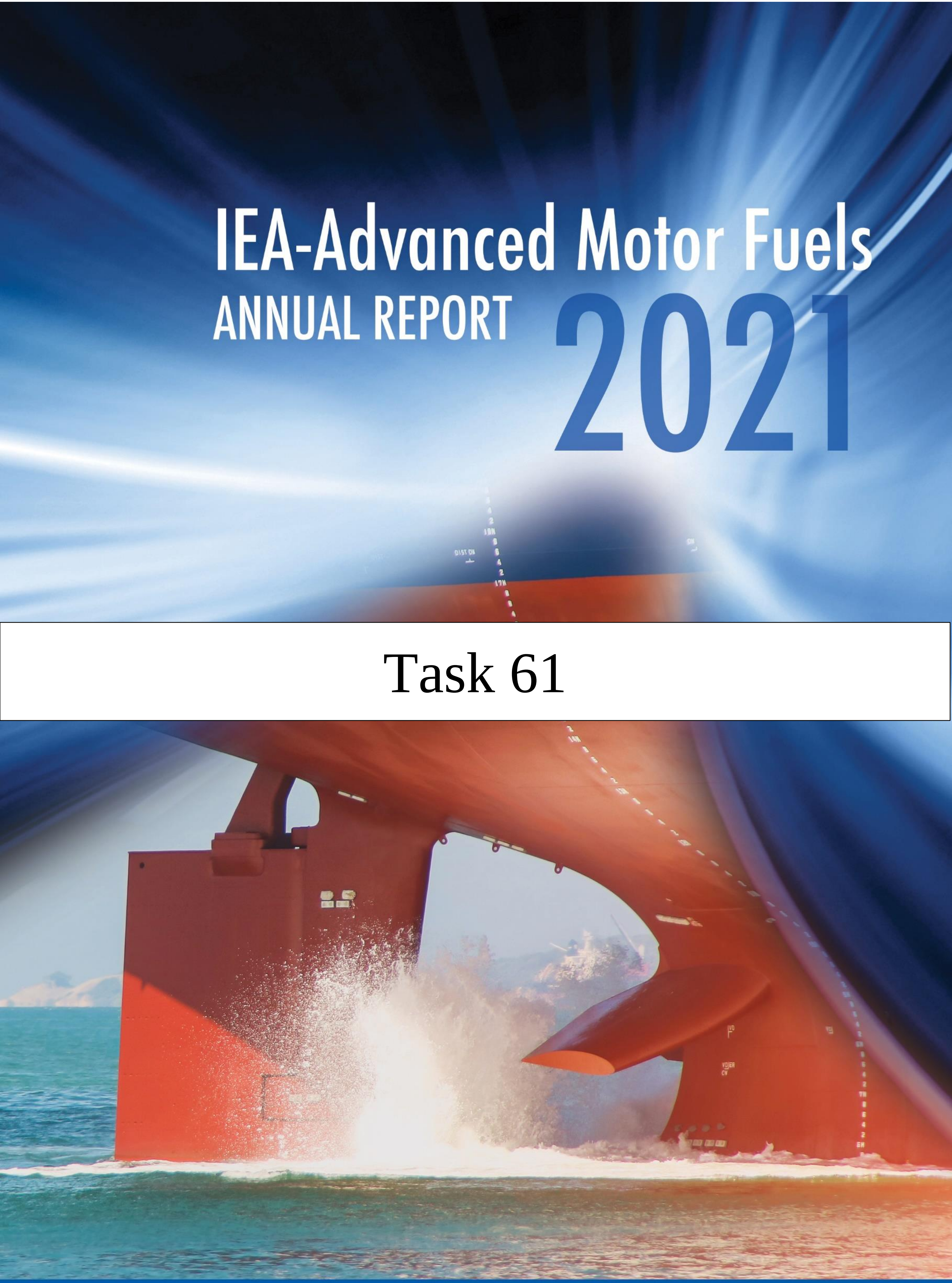
IEA-Advanced Motor Fuels
ANNUAL REPORT 2021



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 254,000)
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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 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 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, 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

WP 1: Collection and consolidation of existing data

In 2021, the RES datasets available for the work of Task 61 increased substantially. For example:

- The number of Type 1 RES records in the European CONOX database increased to more than 1,500,000 records, due to new data coming from Switzerland (Zürich), Germany (Berlin) and Belgium (Flanders). The Flanders data are the first in the CONOX database collected with the HEAT EDAR instrument (https://www.heatremotesensing.com/edar).
- In Europe, approximately 80,000 new Type 2 RES records were collected in the first two city demonstration measurement campaigns in Italy (Milan) and Poland (Krakow). The pollutants measured were PN (particle number) and BC (black carbon).
- In China, a cost-effective roadside sensor platform, including the use of electrochemical NO sensors and commercial instruments (CO_2, PN), was experimented on a road track. This pilot study indicates the cost-effective roadside sensor plat is capable of identifying high emitters.
- During the past five years, particularly 2019-2021, measurements with Type 3 RES on heavy-duty trucks have been carried out in several European countries (Austria, Denmark, Germany and Sweden). Data are available in already published or soon-to-be published reports. In some of the studies, trucks have been pulled over to the roadside for inspections of potential emission tampering (mainly SCR Adblue tampering).
- Through Tsinghua University, nearly 10,000 vehicles were measured using plume chasing. These tested vehicles contribute to the multiple-year measurements in several megacities for assessing emission control benefits (Chengdu, Shenzhen).
- VTT will release real driving emission (RDE) data from previous onboard PEMS tests when they are available.

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

The following are highlights of 2021:

- The CARES RES characterization measurements campaign at the RDW test track in the Netherlands during one week in June. RES Type 1-3 instruments were deployed to measure the emissions from PEMS-equipped gasoline and diesel light-duty vehicles, a heavy-duty truck and two motorcycles.
- The CARES city demonstration campaign in Milan. The RES Type 1 HEAT EDAR instrument and the CARES Type 2 PN, BC and NO_x sensors were deployed, and a few PEMS-equipped light-duty vehicles repeatedly passed the measurement sites.
- Tsinghua University: Plume chasing (RES3) measurements were validated to annual inspection (simplified dynamometer) and remote on-board monitoring data. The results reveal good correlations on manufacturer or fleet-average levels for China V and VI heavy-duty diesel vehicles.
- EMPA: A high-fidelity hybrid RANS-LES solver was developed for an accurate description of the plume dispersion by keeping the computational cost considerably low (testing/validation is in progress). Additionally, an extensive parameter study using the validated but less accurate RANS model was carried out, which led to a conference paper for 22nd Stuttgart International Symposium.

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 & management, synthesis, reporting and dissemination

In 2021, Task 61 made its first contribution to the IEA-AMF Annual Report. Activities and progress were reported in the Executive Committee meetings 61 and 62. Three Task 61 work meetings were arranged in 2021. A MS Sharepoint for Task 61 was prepared in 2021 to support the storage and exchange of internal work documents as well as reports and publications.

Key Findings

- In the first RES Type 1 campaign carried out in Flanders (in 2019), the HEAT EDAR instrument accurately detected deliberately SCR-tampered (high NO_x -emitting) heavy-duty trucks on the motorway in 6 out of 7 trucks pulled over for a roadside inspection. This is a detection rate of 86%. When trucks were pulled over by random, the SCR tampering rate was only about 10%.

- Preliminary results and experience indicate that the new RES Type 2 sensors – developed and demonstrated for the first time in the CARES project (in Milan and Krakow, respectively) in 2021 – could be important tools for learning more about real-world PN and BC emissions in general, and about high-emitters of these pollutants in particular.
- The 2021 results from the CARES RES characterization measurements at a test track, to be published in early spring 2022, will improved understanding of the three different RES types' ability to identify high-emitters and how they compare to PEMS measurements.
- The plume chasing data (RES3), in line with the trends represented by dynamometer and on-board monitoring results, indicated that China VI HDDVs have much lower NO_x and PM emissions than previous counterparts. For China V HDDVs, the results also showed that vehicles with newer (post-2018) model years could be more effective in reducing NO_x emissions than the earlier China V HDDVs. These benefits have been well captured by the reductions in fleet-average emissions and road concentrations (NO_x) both in Shenzhen and Chengdu. Furthermore, the updated version of the national emission inventory guidebook (to be released by the Ministry of Ecology and Environment of China) has been enriched by the plume chasing results.
- A clear relation between the momentary emissions caused by driver-to-driver differences was found from RDE-tests conducted in the Helsinki metropolitan area. The effect on CO, NO_x and PN formation was found to be especially strong in aggressive versus smooth driving styles, as rapid acceleration and high peaks in engine power typically cause a rapid rise in NO_x emissions. Furthermore, the PEMS tests demonstrated that the variation in emissions caused by different types of vehicles may be significant, especially over different Euro 6 emission standards.
- The EMPA parameter study found that the most crucial volume that RES must capture is the core exhaust plume, which lies within the first 1.5 m behind the vehicle. The location of the pollutant concentration peak (PCP) as well as the core exhaust plume shape are mainly influenced by the pipe position. The vehicle acceleration causes the PCP to shift towards the vehicle. Additionally, the simulations show that wind has no significant influence on the core exhaust plume. With regards to RES, an independence of the width of the street is found.

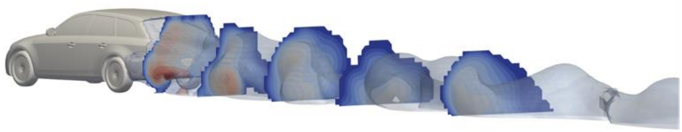

Fig. 1 The EMPA parameter study found that the most crucial volume RES must capture is the core exhaust plume, within 1.5 m behind the vehicle.

Main Conclusions

- The collection of new RES and RDE data resumed and was substantially enhanced in 2021 after more than a year of Covid-19 restrictions that hindered many planned field experiments in both Europe and China.
- A good agreement between RES and PEMS was observed in different field studies in both Europe and China.
- Recent RDE-tests demonstrated the big impact driver-to-driver differences have on emissions of NO_x and small particles. They also demonstrated the large variation in emissions that may occur between different types of vehicles.
- Further development of plume dispersion models and subsequent modelling exercises can be used for pinpointing advice on how RES capture of the plume can be optimized.

Publications

- Jerksjö, M., Sjödin, Å., Merelli, L., Varella, R., Sandström-Dahl, C. (2021) Remote emission sensing compared with other methods to measure in-service conformity of light-duty vehicles. IVL Report C620. https://www.ivl.se/english/ivl/publications/.

- Shen, Y., Zhang, Q., Wang, D., et al. (2021) Evaluation of a cost-effective roadside sensor platform for identifying high emitters. Science of the Total Environment, in press
- Xiang, S., Zhang, S., Wang, H., et al. (2021) Mobile Measurements of Carbonaceous Aerosol in Microenvironments to Discern Contributions from Traffic and Solid Fuel Burning. Environmental Science & Technology Letters, 8(10), 867-872
- Plogmann, J., Gubser, A., Dimopoulos Eggenschwiler, P. Remote Sensing Measurements and Simulations for Real Driving Emission Characterization of Vehicles, 22nd Stuttgart International Symposium (2022), accepted and available from April 2022.
- Further upcoming project reports will be available for download on the website: https://www.iea-amf.org/content/projects/map_projects/61.