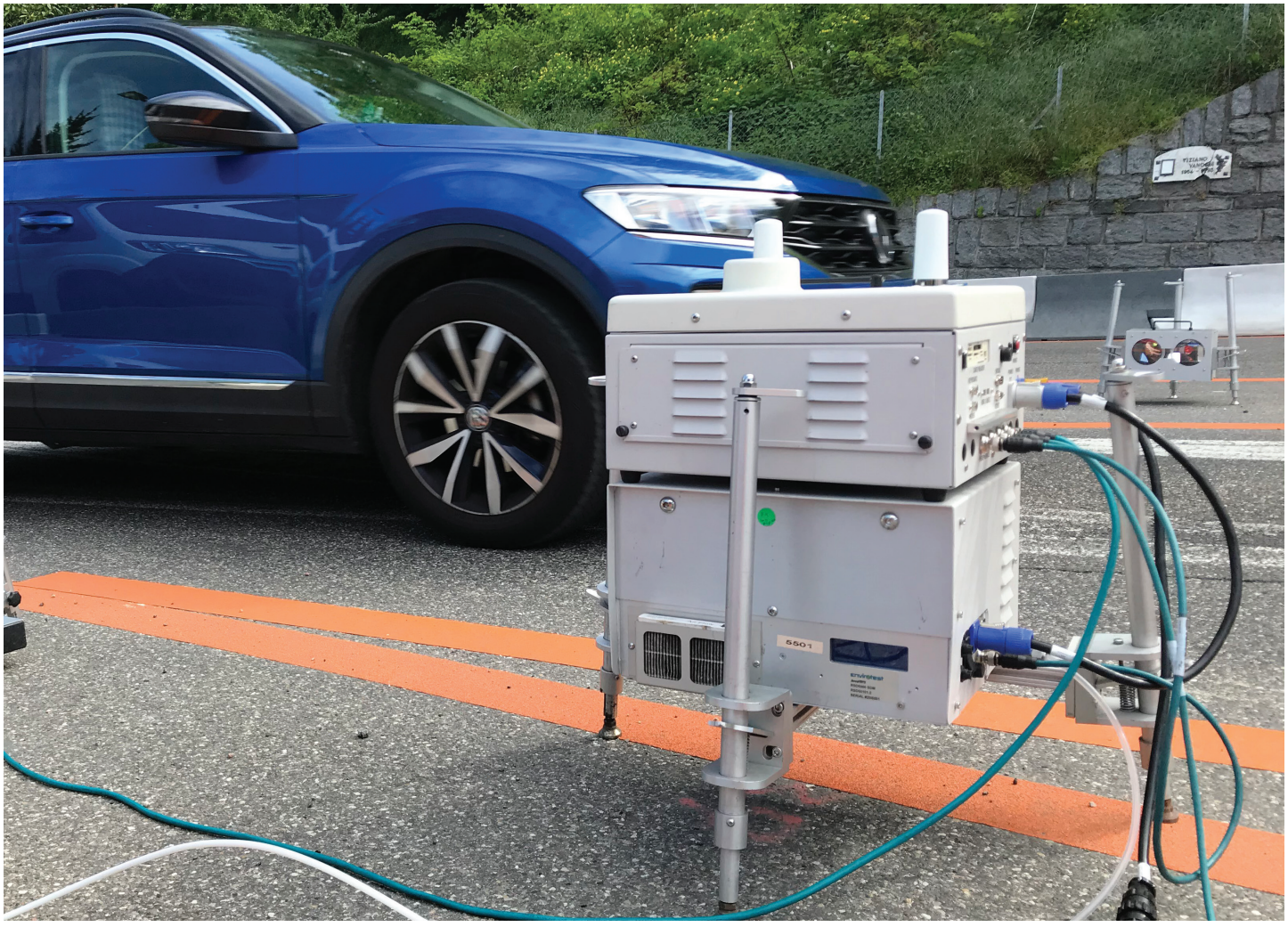
THE EMISSIONS OF REAL TRAFFIC

Laser-based measuring devices along roads have the potential to reliably determine the exhaust emissions of each individual vehicle in moving traffic. This makes it possible to identify high polluting vehicles and create emission profiles for vehicle classes and models. This is the conclusion of an internationally networked research project of the Swiss Federal Laboratories for Materials Science and Technology, or Empa, in Dübendorf.



The OPUS measurement system during the project test phase in Switzerland. Illustration: Empa/InNET Monitoring AG, 6460 Altdorf

A technical report about the results of a research project in the field of combustion, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Umwelttechnik (issue April 2024).

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Exhaust emissions from road traffic are a global challenge. Consequently, the International Energy Agency (IEA), among other organizations, is involved in research on this topic. The IEA maintains several dozen research programs – Technology Collaboration Programs, or TCPs for short. Among them is the TCP Advanced Motor Fuels project in which the SFOE is a member of the Executive Committee and in which experts from 14 countries deal with a range of issues relating to sustainable transport.

The research group Task 61 investigates the question of whether exhaust emissions from light and heavy duty vehicles can be reliably measured with stations placed along roadways. The measurement technology used therefore is called Remote Emission Sensing (RES). A team of researchers from Empa in Dübendorf has been working on RES as part of the ReMOVES research project, which is funded by the Federal Roads Office (FEDRO). The SFOE supported the project and made it possible to integrate it into the international IEA context.

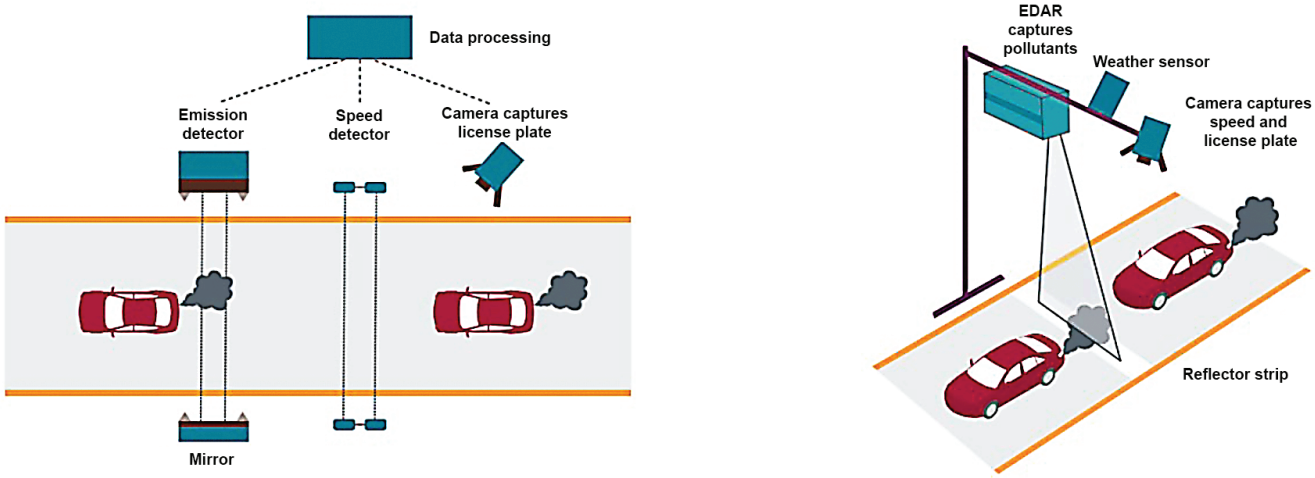
Many vehicles captured in a short period of time

In recent years, exhaust gas measurements using RES technology have been carried out as part of research programs, for example in the canton of Zurich, but also in separate projects in cities and regions worldwide. They are to be distinguished from the test bench measurements that vehicles must undergo for homologation. While test benches determine exhaust emissions for specific driving situations, RES measurements only provide a snapshot. But they have other advantages, as Empa scientist Panayotis Dimopoulos Eggenschwiler says: "RES exhaust gas measurements in moving traffic detect a large number of vehicles in a short time. This can be used to identify potential high polluters and to create emission inventories that summarize the pollution caused by different vehicles . Thanks to the large number of vehicles covered, it is even possible to create emission characteristics of different powertrain types, manufacturers and possibly even single vehicle models, as well as to investigate the ageing effects of the catalytic converters." RES systems are suitable for measuring the emissions of individual vehicles but are not determining the pollutant amounts in the ambient air. For this purpose, immission measurements are carried out in many cities using separate measuring stations.

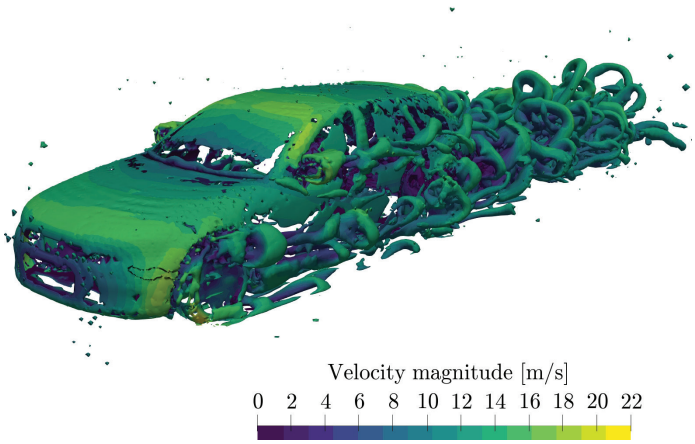
Today, two RES measuring systems are in use: In OPUS, a laser beam is sent across a road, reflected, and at the starting point, collected and analyzed. In the EDAR system, the laser light source is located above the road and a scanning laser beam is reflected back by a reflector strip mounted on the road surface (see Figure at the bottom).

Laser detects the level and type of pollutant

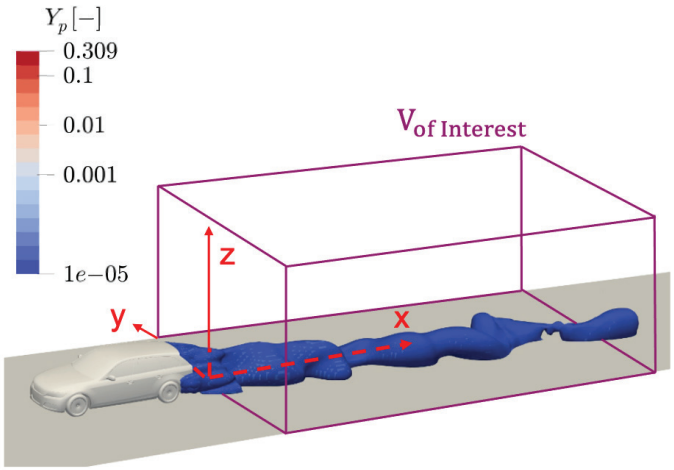
The quantity and composition of exhaust gases are then determined using absorption spectroscopy. The more the laser beam has been weakened by the exhaust gases, the higher the concentration of pollutants. Given that different pollutants absorb different wavelengths, the laser can distinguish among the different exhaust components (hydrocarbons, carbon monoxide/CO, carbon dioxide/CO_2, nitrogen



There are two main technologies on the market in the field of RES: The OPUS RSD 5500 system (left) transmits a laser beam across the road, while the EDAR (right) system uses a laser beam source above the roadway. The first system measures the exhaust gas concentration in one dimension, while the latter allows a two-dimensional measurement. Illustration: Jens Borken-Kleefeld, Tim Dallmann, DOI: 10.1021/es00055a001, 2018, ICCT/edited by B. Vogel



Simulation of air flow (not exhaust gases!) around a moving vehicle. For the simulation, Empa researchers use mathematical equations to describe transient turbulent flows (transient Reynolds equations/ URANS). Although these equations represent reality in a simplified way, they can be solved with a reasonable amount of computational effort. Illustration: Empa

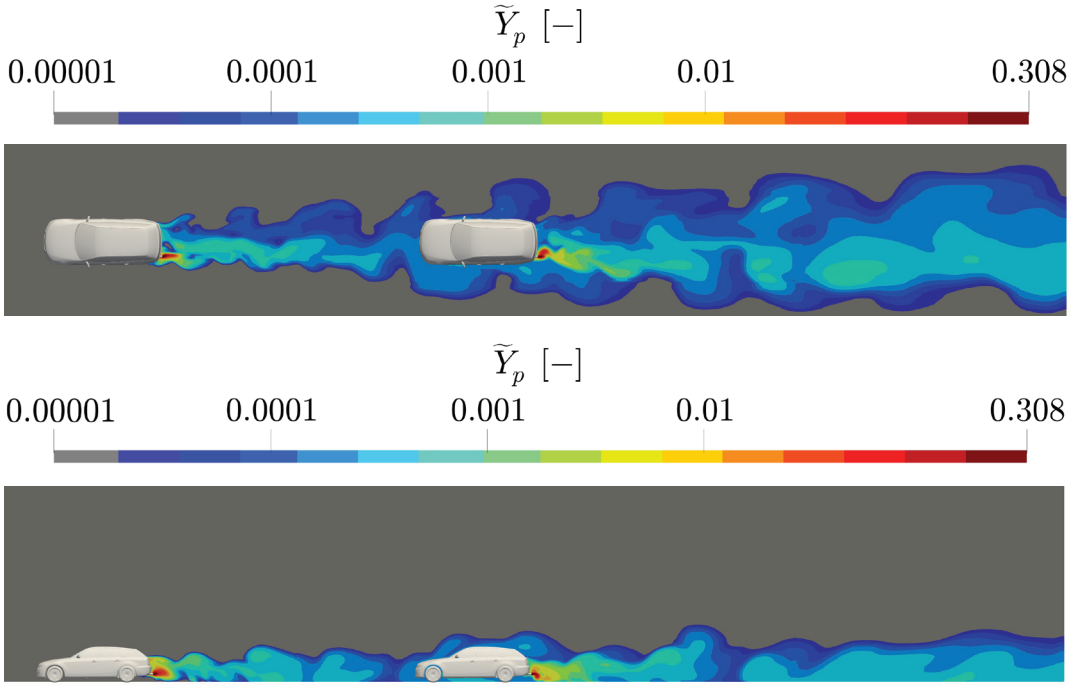


To describe the pollutant emissions of a vehicle, the researchers use a three-dimensional coordinate system. The exhaust gas flow is described by computing the exhaust gas concentration for each point in the volume marked in purple. Diesel soot particles cannot yet be reliably captured by RES. Illustration: Empa

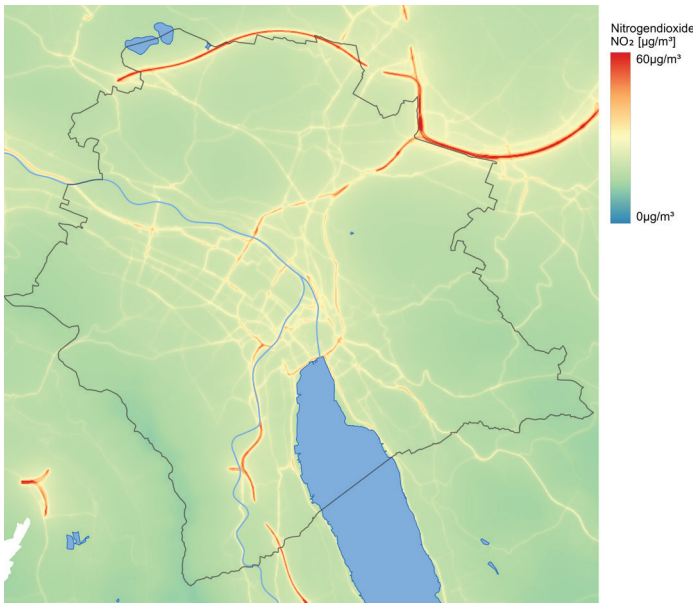
oxides/NO_x). In addition to emissions, RES measurements also record the speed and acceleration of the vehicles – as well as their license plate. This makes it possible to query the technical data of the vehicles (such as emission class, powertrain type, vehicle type and age) and correlate them with the emission readings.

RES measurements have not yet been certified, and the quality of the data obtained is under discussion. Against this background, Empa scientists examined RES measurements in more detail in their project and compared them with other measurement methods (test bench; portable emission measuring devices/PEMS).

In order to be able to assess the quality of the measurements, they created numerical simulations of the distribution of the exhaust gas components in the wake of the vehicles. In this way, the behavior of the exhaust gas flow can be described realistically – and at the same time researchers can check whether the RES measurements are correct.



Exhaust gas distribution of two vehicles driving at a speed of 50 km/h at a distance of 10 m. The upper figure shows the exhaust gas concentration at the level of the exhaust (30 cm above the road), the lower figure in the intersecting plane that passes through the exhaust. Illustration: Empa



The City of Zurich uses its monitoring network to continuously record the environmental impact of air pollutants. The map shows a model of nitrogen dioxide (NO_2) pollution for the year 2020. Along busy roads, NO_2 pollution is visibly higher. Such measurements depend not only on the emissions of vehicles, but also, for example, on the weather. In contrast, emissions measurement technologies such as Remote Emission Sensing measure air pollutants at their point of origin. Illustration: Office for Waste, Water, Energy and Air of the City of directly Zurich

Reliable method, but...

In their final project report, the Empa researchers generally give the RES measurement technology a good judgement: "The extensive research work and measurements have shown that RES is a reliable method for determining the real emissions of vehicles in road traffic." However, the measurement method is not suitable for reliably determining the emissions of individual vehicles. For example, if a vehicle accelerates (or brakes) strongly at the moment of the measurement, the value is not representative of the vehicle. RES has its strength where the exhaust gases of a large number of vehicles are to be determined. There is an important caveat: In the case of heavy duty vehicles, i.e. trucks, there are considerable doubts about the reliability of RES measurements, the Empa researchers conclude (see below).

Thanks to their simulations, the Empa researchers have made several conclusions that include:

• Exhaust gases can be detected by RES in the first 1 to 2 meters behind vehicle. With increasing distance downstream am the vehicle, the exhaust gas concentration dilutes rapidly. From 1.5 to 3 meters downstream, no significant proportion of the exhaust gas is measurable in the air flow. This is the reason why today›s RES measurements are probably unreliable for trucks: The engine and exhaust are often located in the front part of the vehicle. This means that the distance from the exhaust to the measuring point behind the vehicle is too great to achieve reliable results.

• If several vehicles are driving in a row, RES does not measure a higher exhaust gas concentration than the exhaust of one vehicle. This finding confirms the effectiveness of RES, as the system is only intended to record the emissions of each individual vehicle at a time.

• The simulations of the Empa researchers show that the core exhaust cloud takes on a compact form as vehicle speed increases (due to the vacuum created at the rear of the vehicle). At speeds above 120 km/h, RES measurements become unreliable.

• Crosswinds do not affect RES measurements because the lateral deflection of the exhaust gas flow is minimal at the location of the measurement.

Linked to the internal combustion engine

The results of research in Switzerland and other countries will help to further improve RES. The role that measurement technology will play in the future depends to a large extent on the

The EDAR measurement system during the project test phase in Switzerland. Illustration: Empa/InNET Monitoring AG, 6460 Altdorf

further development of vehicle powertrain technologies, as Empa researcher Dimopoulos Eggenschwiler notes: "As long as vehicles with combustion engines are on our roads, RES offers a good solution for monitoring pollutant emissions. For Battery electric Vehicles with its emission-free engines, on the other hand, the method is meaningless."

- More information on the research into Remote Emission Sensing within the framework of the International Energy Agency's Technology Collaboration Program "**Advanced Motor Fuels**" can be found at: https://iea-amf.org/content/projects/map_projects/61

- The **final report** of the research project "Recording and Assignment of Emission Data in Real Road Traffic by Remote Emission Sensing" is available at: www.aramis.admin.ch/Texte/?ProjectID=47374

- **Information** on the research project can be obtained from Stephan Renz (info@renzconsulting.ch), external head of the SFOE research program Combustion Based Energy Systems.

- **Further articles** on research, pilot, demonstration and flagship projects in the field of combustion can be found at www.bfe.admin.ch/ec-verbrennung.

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