1st CARES Stakeholder Advisory Board Meeting

10:00	Welcome & introduction, incl. tour-de-table	Ake Sjodin, IVL Harald Jenk, BAFU
10:15	CARES project overview & objectives	Peter Mock, ICCT
10:30	Current status of hardware developments - plume chasing and point sampling	David Carslaw, University of York
10:55	Standardizing remote sensing data management processes	James Tate, University of Leeds
11:20	Five minutes break	
11:25	Using remote sensing for monitoring and enforcement purposes	Jens Borken-Kleefeld, IIASA
11:50	Wrap up & next steps	Ake Sjodin, IVL
12:00	End of meeting	

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Meeting participants – tour-de-table

Stakeholder Advisory Board

CITA/Bilprovningen, SE
CITA/GOCA, BE
City of Krakow, PL
City of Prague, SZ
EPHA
European Commission
Federal Office of Environment, CH
Fia Foundation
Government of Flanders, BE
Hong Kong EPD, CN
Ministry of Transport, SZ
Ministry of Transport, IT
Transport Scotland, UK
VECC, CN

CARES Partners

Airyx, DE
City of Milan, IT
Czech Technical University, CZ
ICCT, DE
IIASA, AT
Innovhub, IT
IVL Swedish Environmental Research Insitute
Krakow Smog Alert, PL
Technical University Graz, AT
TNO, NL
Tsinghua University, CN
University of Leeds, UK
University of York, UK

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Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of the Environment,
Transport, Energy and Communications DETEC

Federal Office for the Environment FOEN
Air Pollution Control and Chemicals Division

ReMOVES - (Remote Monitoring of Onroad Vehicle Emissions in Switzerland)

- Research project of the Federal Road Office
- Consortium: EMPA, AFHB, Innet (HEAT, OPUS) ICCT/Jens Borken
- Goal: test RSD as a tool for detecting NOx high emitters in Switzerland (market surveillance, tuning, Adblue-emulators), cars and HDVs
- Data: measurement campaigns with OPUS and EDAR/HEAT in 2021, with a focus on highways
- Start: spring 2020, end: 2022

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The CARES project

An overview of the objectives and possibilities for engagement of member states and stakeholders

1st CARES Stakeholder Advisory Board Meeting

Dr. Peter Mock, International Council on Clean Transportation (ICCT)

Web-meeting – May 28, 2019

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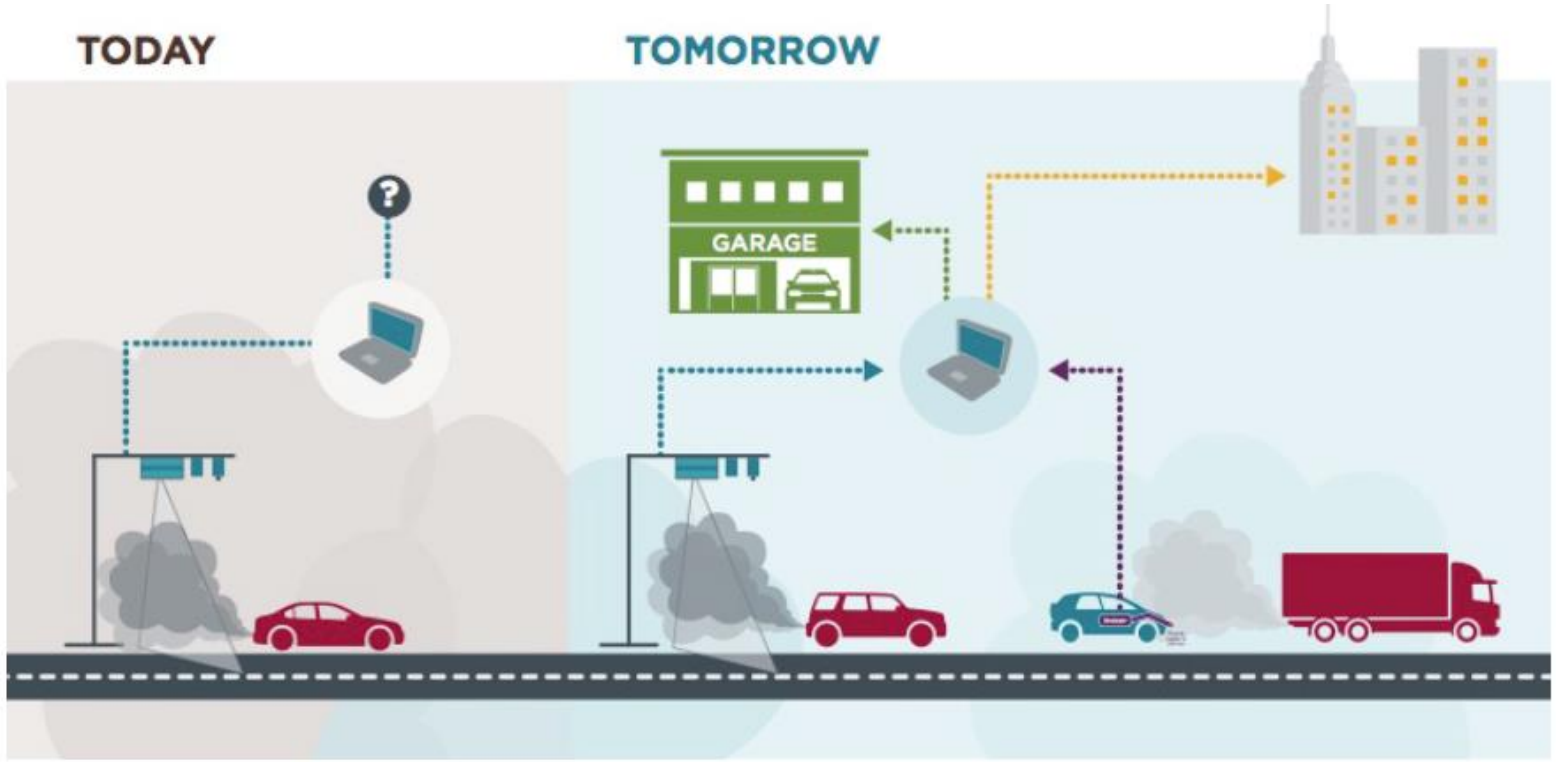
CITY AIR REMOTE EMISSION SENSING

What is CARES?
Working towards a joint project goal

“Reduce the hurdles for practical applications of remote emission sensing and to make it a widespread means of both, monitoring as well as enforcing, improvements in road vehicle emissions.”



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What is CARES?
Responding to the Horizon 2020 Work Programme

- [...] **further technological development of available techniques** is needed to improve performance, reduce costs, facilitate use by unskilled personnel and achieve a broader deployment potential;
- Establishment of a **proper data infrastructure** built around vehicle registration databases, traffic management measures and air quality monitoring systems;
- **Demonstration** of the system **in several cities**; [...]

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What is CARES?

Bringing together remote sensing experts

AGENZIA MOBILITÀ AMBIENTE TERRITORIO

Airyx

CRAES

International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

INNOVHUB STAZIONI SPERIMENTALI PER L'INDUSTRIA
innovation and research

ivl Swedish Environmental Research Institute

FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Empa
Materials Science and Technology

KRAKOWSKI ALARM SMOGOWY

LAT
LABORATORY OF APPLIED THERMODYNAMICS ARISTOTLE UNIVERSITY OF THESSALONIKI

TNO

TU Graz

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

UNIVERSITY OF LEEDS

UNIVERSITY of York

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

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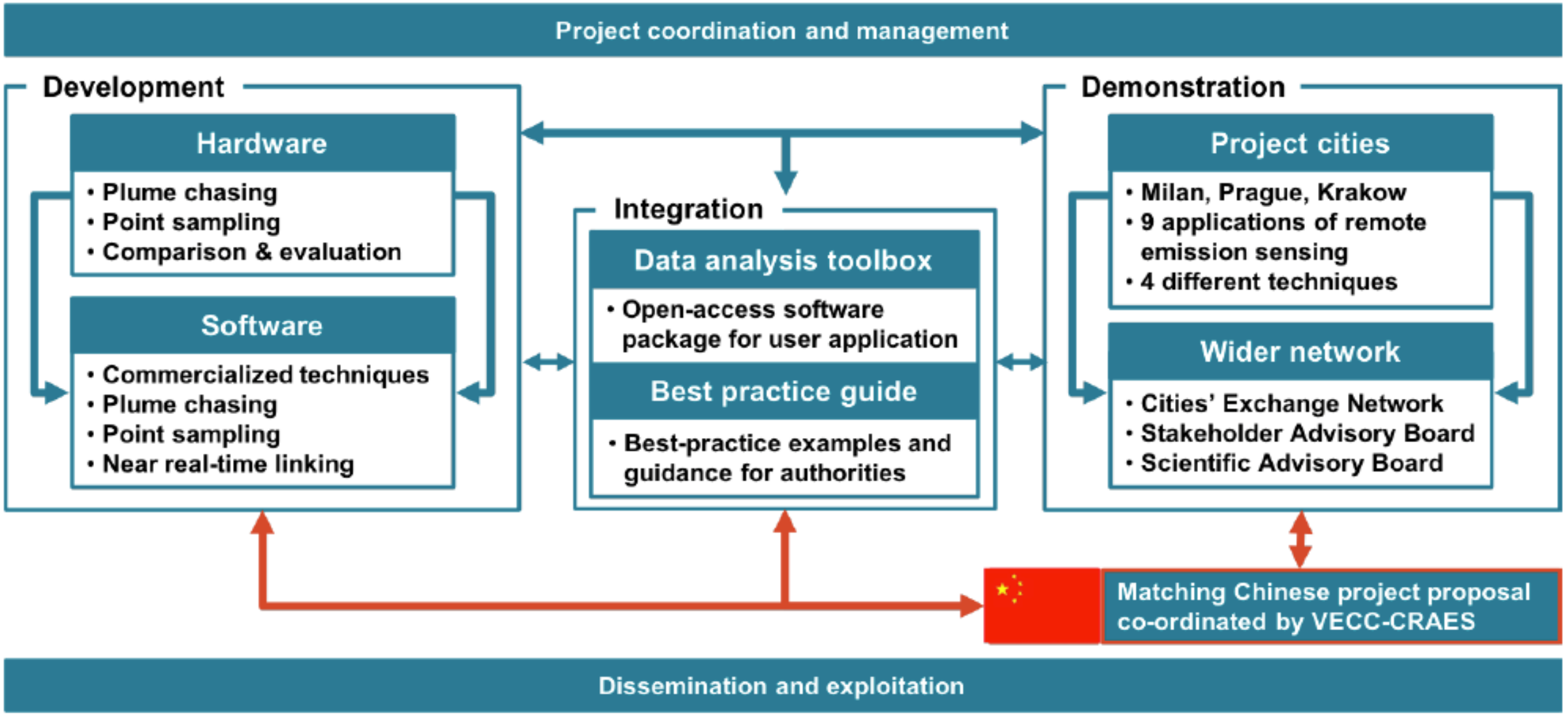
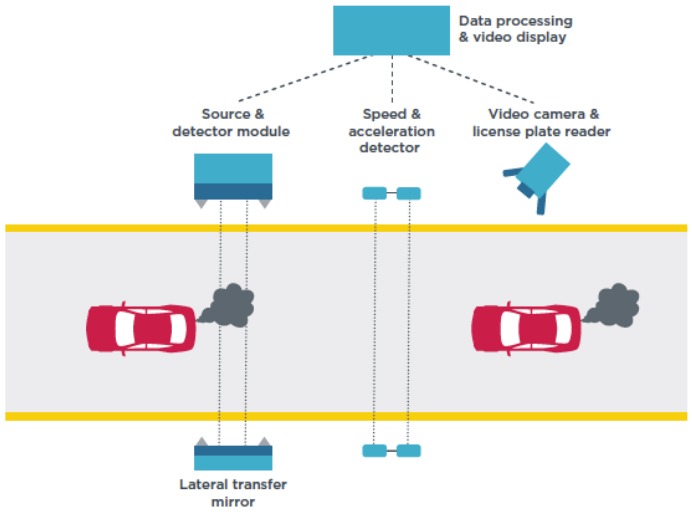
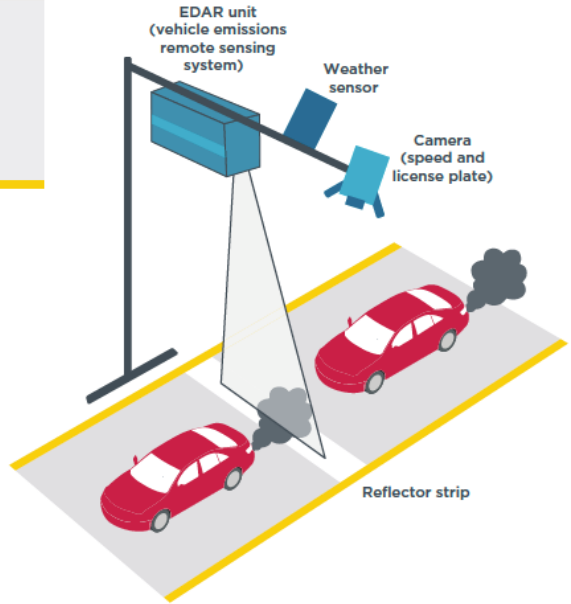
What is CARES?
Overall project structure



Working package #1
Hardware development

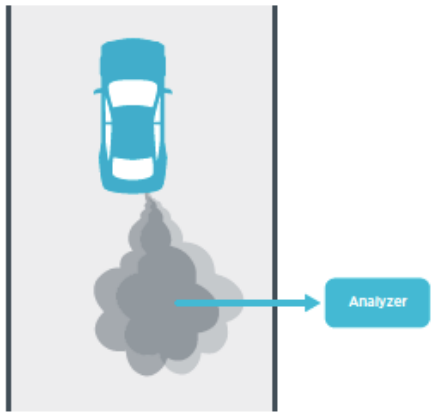


Schematic of cross-road remote emission sensing device.



Schematic of top-down remote emission sensing device.

Schematic of plume chasing remote emission sensing device.



Schematic setup of point sampling remote emission sensing device.

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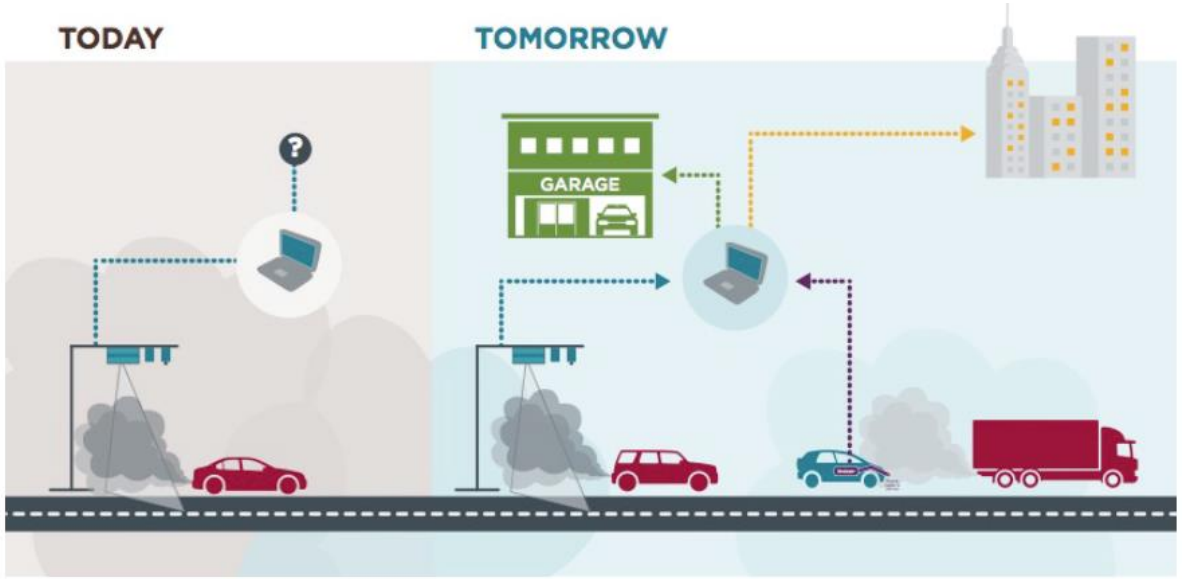
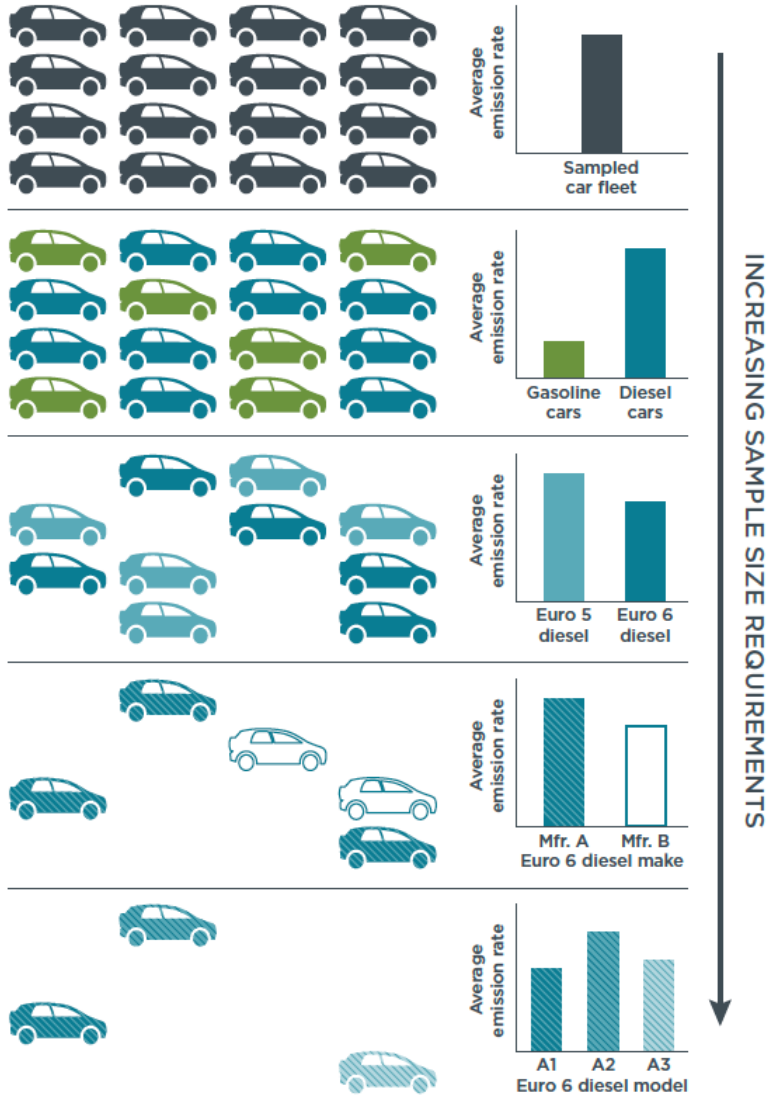
Working package #2

Software development





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Working package #3

Potential applications of remote emission sensing

1) Identification of individual **high (or low) emitters**
2) Generation of real-world **emissions factors**
3) Steering **new policies**
4) Tracking **policy effectiveness**
5) Track **technology effectiveness**
6) Screen fleet for **market surveillance**
7) Monitor a **single fleet**
8) Understand the **impact** of specific driving and ambient conditions
9) Inform **purchasing decisions**

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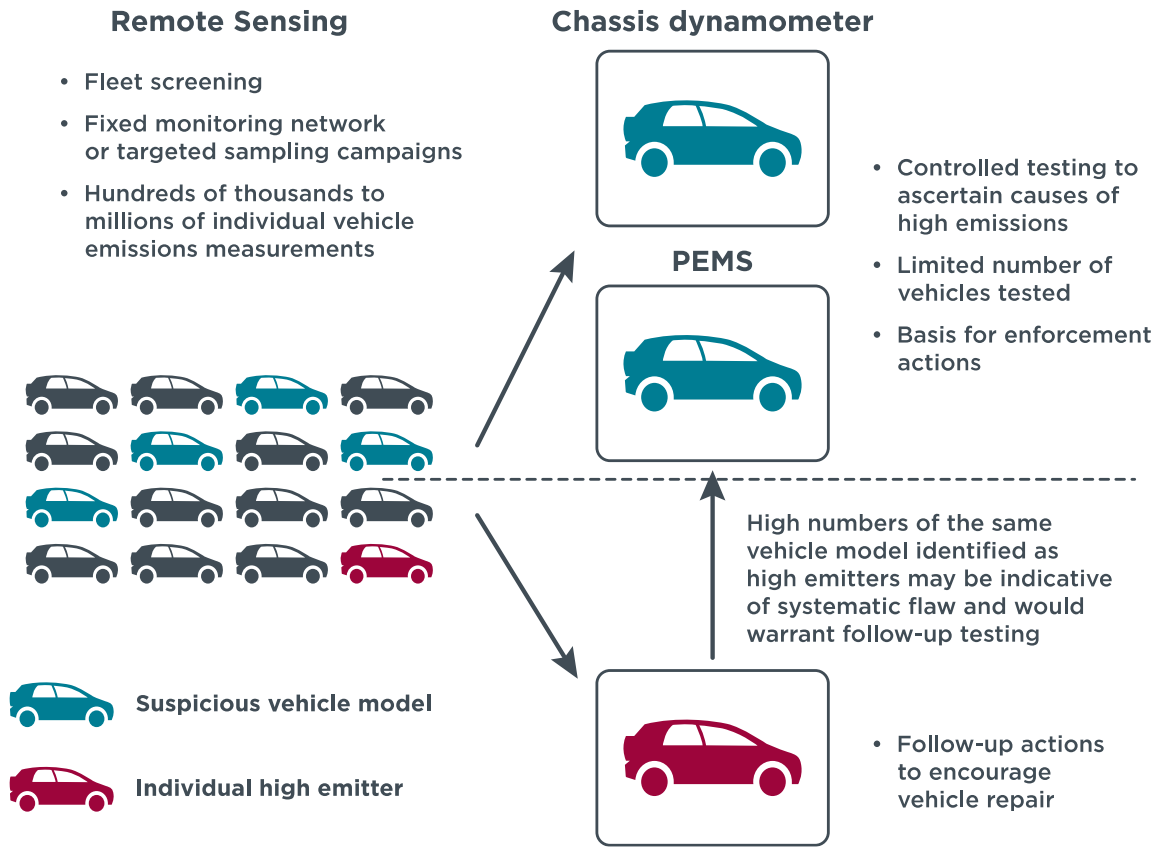
Working package #3

Planned city demonstrations

- **Prague**
  Identification of individual high emitters
- **Milan**
  Track policy effectiveness
- **Krakow**
  Steer new policies



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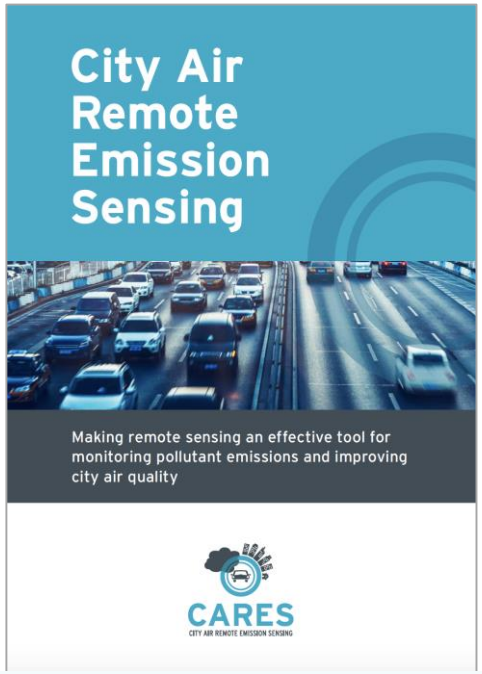
Working package #3

Knowledge exchange

- Between **cities**
- Including **member states** and **stakeholders**
- With our **Chinese partners**



https://cares-project.eu

@cares_project

https://www.linkedin.com/company/city-air-remote-emission-sensing-cares

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WP1 – Further developing plume chasing and point sampling techniques

David Carslaw and Naomi Farren University of York

Denis Pöhler, Christina Schmidt, Stefan Schmitt Airyx GmbH

Markus Knoll, Alex Bergmann Graz University of Technology

Norbert Ligterink, Paul Tilanus, Gerrit Kadijk TNO

Karl Ropkins University of Leeds

Åsa Hallquist IVL

1st Stakeholder Advisory Board Meeting

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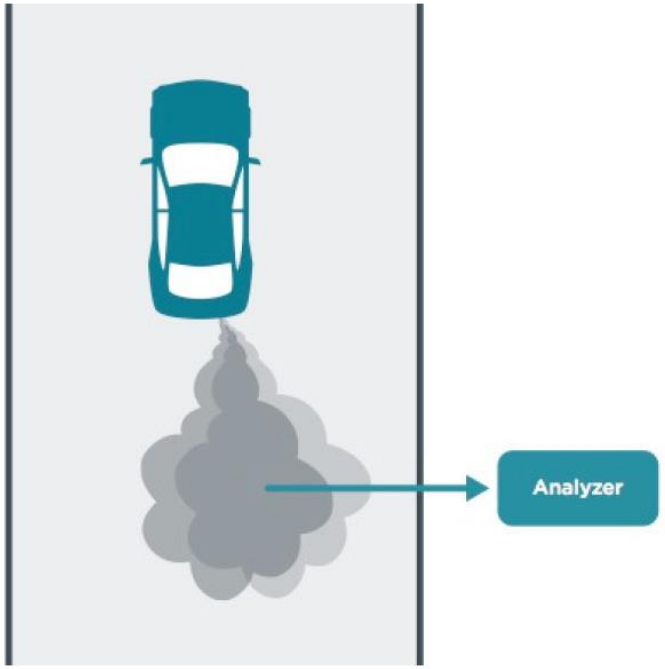
WP1 – Further developing plume chasing and point sampling techniques

- Brings together a range of **remote emission sensing** (RES) techniques
- Focus is on hardware development
  - Plume chase
  - Point sampling
  - [Remote sensing] Already commercially available



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WP1 – Brief summary of main tasks

- Task 1.1
  - Hardware development for **plume chasing** (**Airyx,** UoL, TNO)
- Task 1.2
  - Hardware development for **point sampling** (**TUG,** IVL, UoY)
- Task 1.3
  - Controlled **characterization experiments** (**TNO,** IVL, UoY, UoL, TUG) **Tentatively postponed until end October 2020**
- Task 1.4
  - Technology **hardware evaluation** (IVL, UoL, **UoY**, TUG, UoH, ICCT, IIASA)

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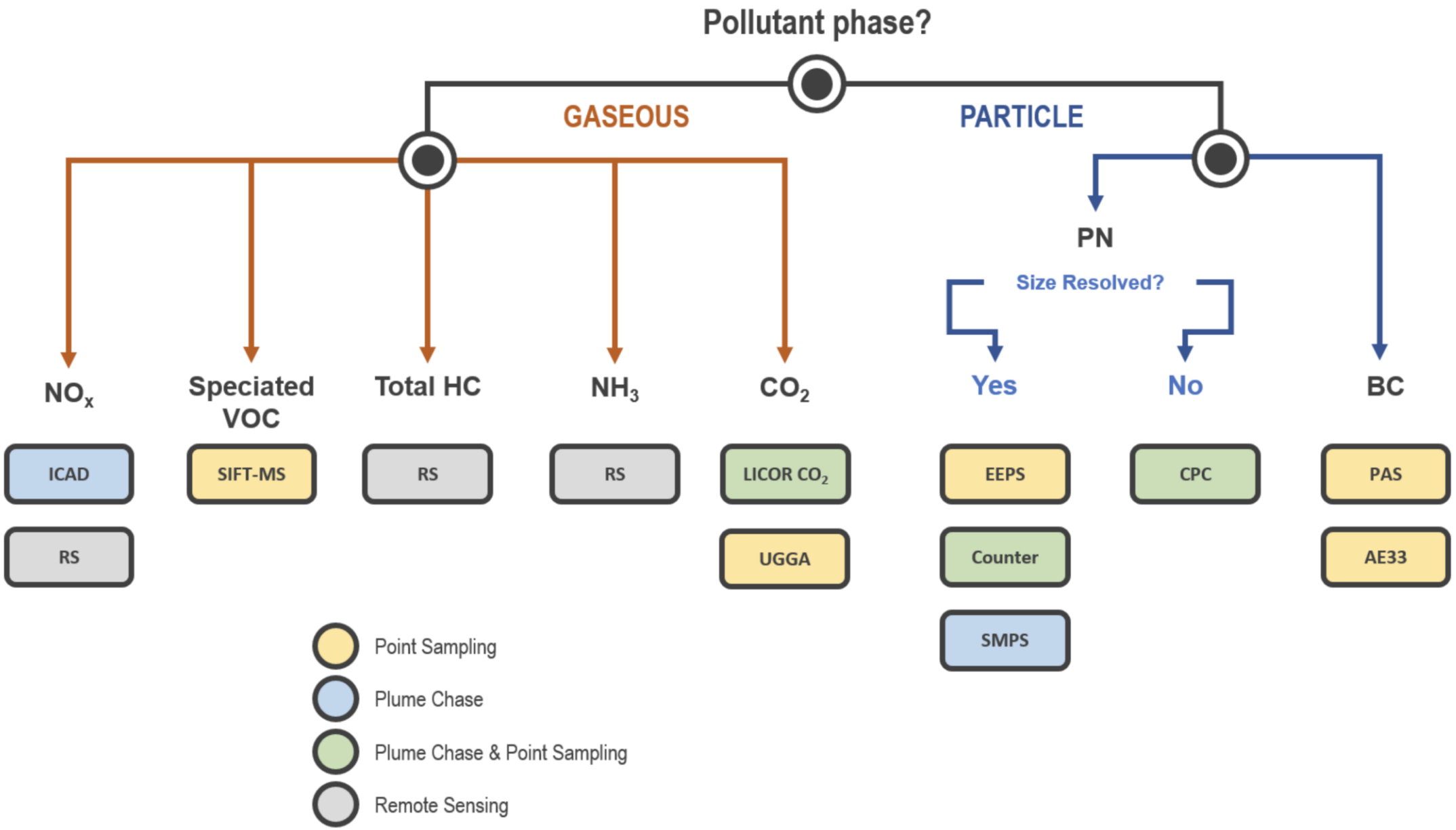
WP1 – Measurement overview



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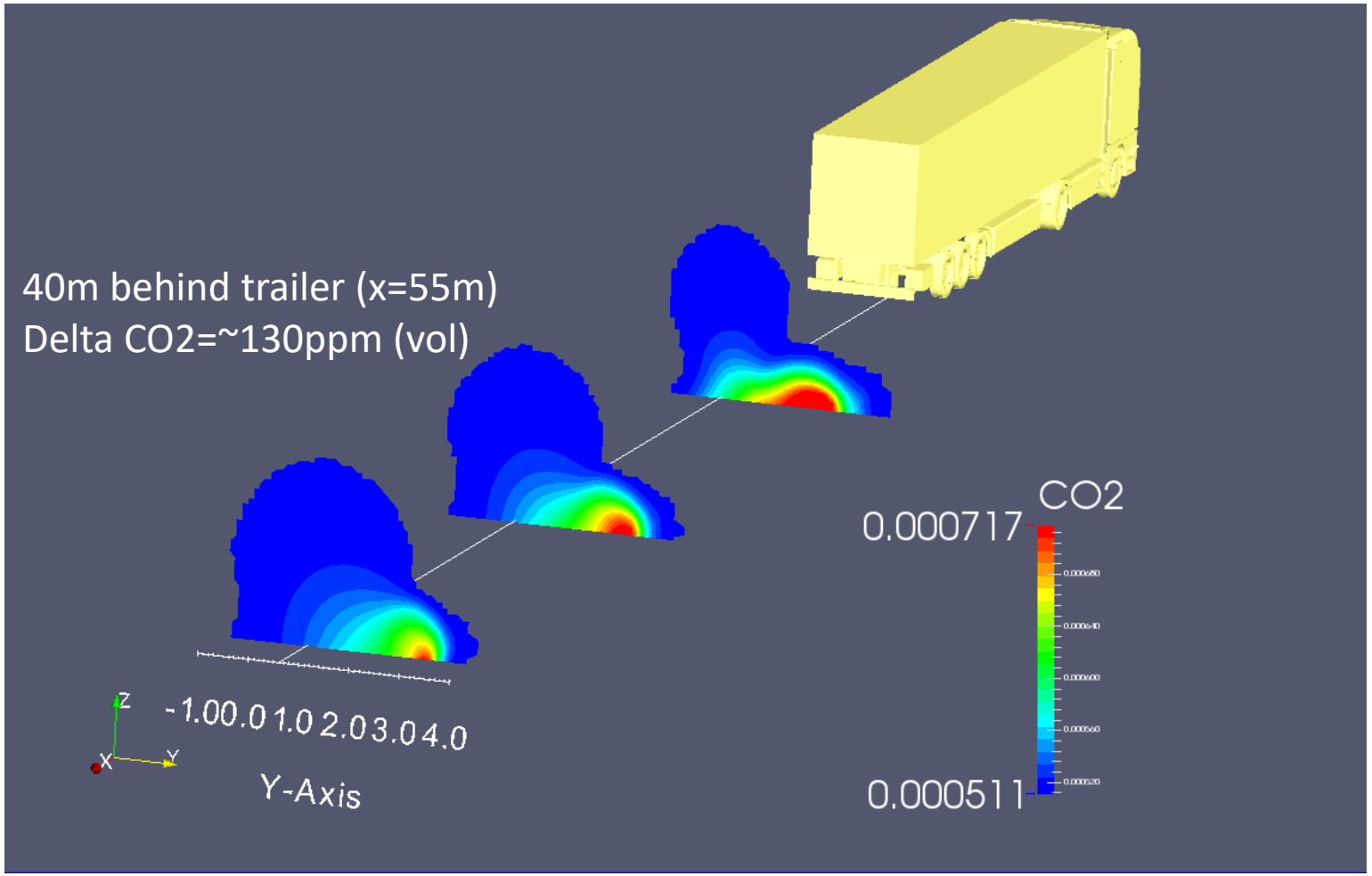
Plume chase – CFD modelling (TNO)



- Where best to measure for plume chase vehicles?
- Hope to complement with visible plume tests during characterisation testing

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Plume chase – Sniffer vehicle set up

Inlet positions and instruments:

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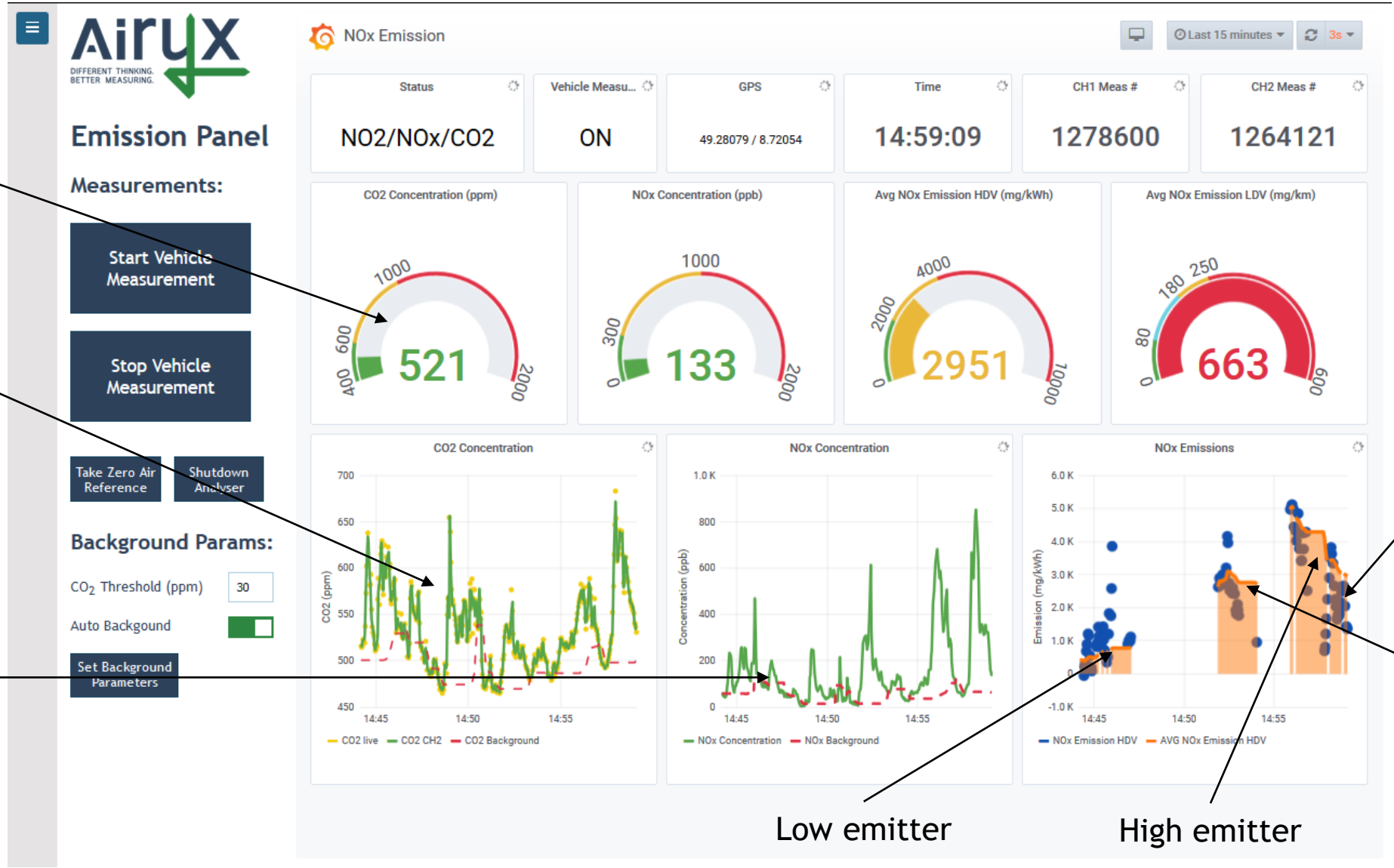
Plume chase – Live information

Current CO_2 conc. → plume signal strength

Time series CO_2 conc. & estimated CO2 background

Time series NO_x conc. & estimated NO_x background



Low emitter

High emitter

Time series NO_x Emission factors:

instantaneous (blue)

Average since „Start“ (orange) → one result per vehicle saved in extra file

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Point sampling

- Photoacoustic Sensor Development (black carbon + other components)
- Diffusion Charging (particle number)
- Other instruments to help evaluation

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Photoacoustic Spectroscopy

$$S(\lambda) = F \cdot \alpha(\lambda) \cdot P_0(\lambda)\ [1]$$

S … *photoacoustic signal*
F … *properties of the applied environment (cell constant)*
α … *absorption coefficent of the analyte*
P_0 … *optical power of the light source*

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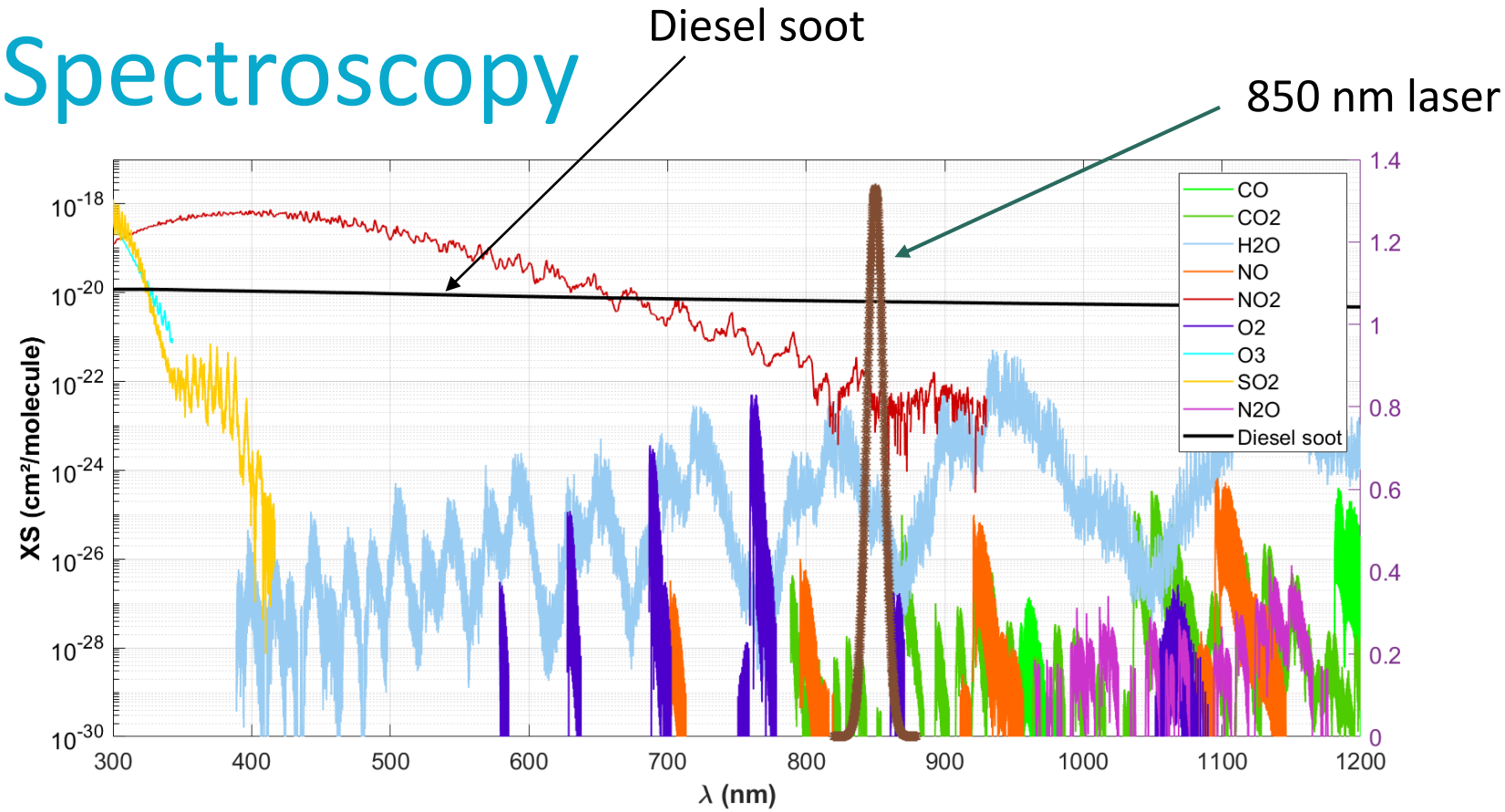
[1] Christoph Haisch. “Photoacoustic spectroscopy for analytical measurements.
”In: Measurement Science and Technology 23 (1 2012). doi: 10.1088/0957-0233/23/1/012001.

Photoacoustic Spectroscopy

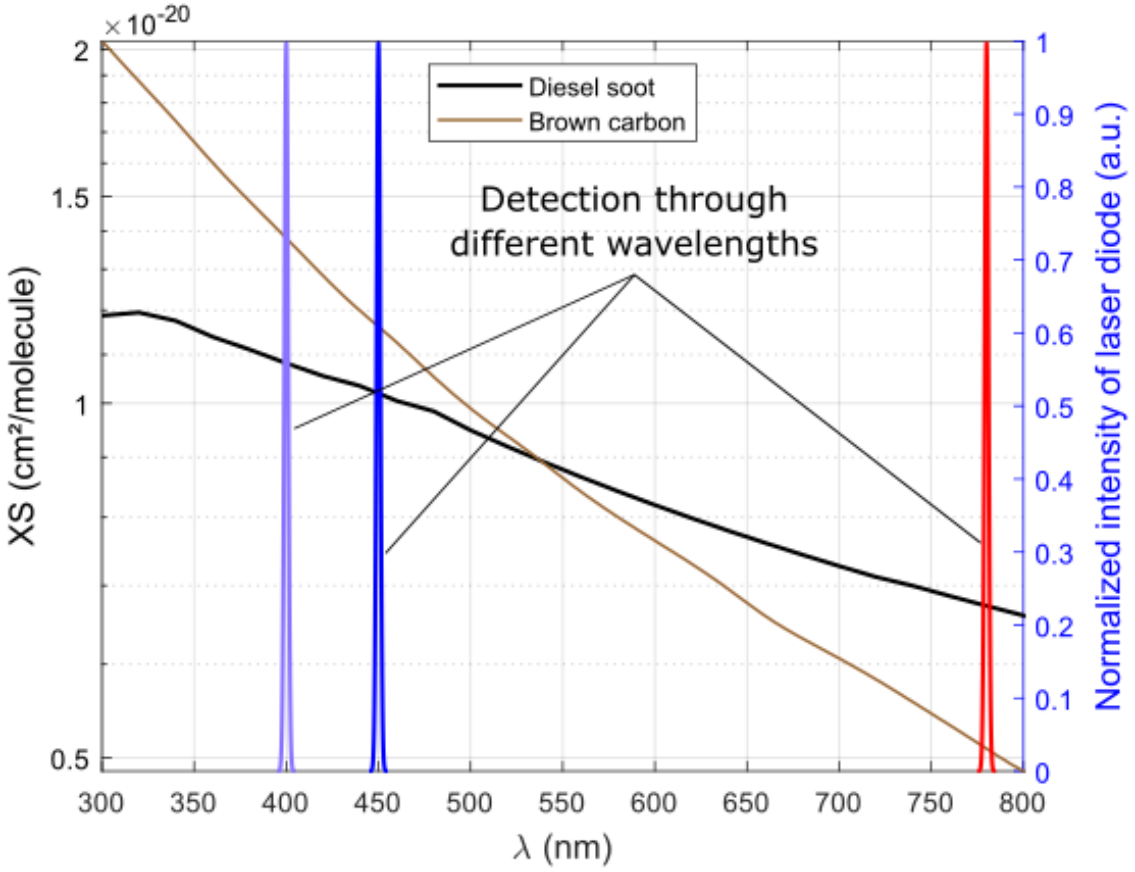
- Soot: Broadband absorber → absorption coefficient decreases with increasing wavelength
- Selection of proper wavelength → No interference with other particles / gases
- E.g. 850 nm proper choice to avoid interference with O_3, SO_2, CO_2, CO, …



Source Appointment

- Source Appointment → Are the measured particles vehicle combustion based?
- Detection of black carbon (soot)
  - Faults of exhaust after-treatment system
  - Faulty diesel particulate filter
- Distinction of different pollutants with a multi-wavelength approach. Distinction between automotive exhaust and other sources (for example domestic fuel burning)
  - Black carbon
  - Brown carbon
  - Tyre, break particles …

Absorption cross section of Diesel soot, brown carbon and normalized intensities of light sources



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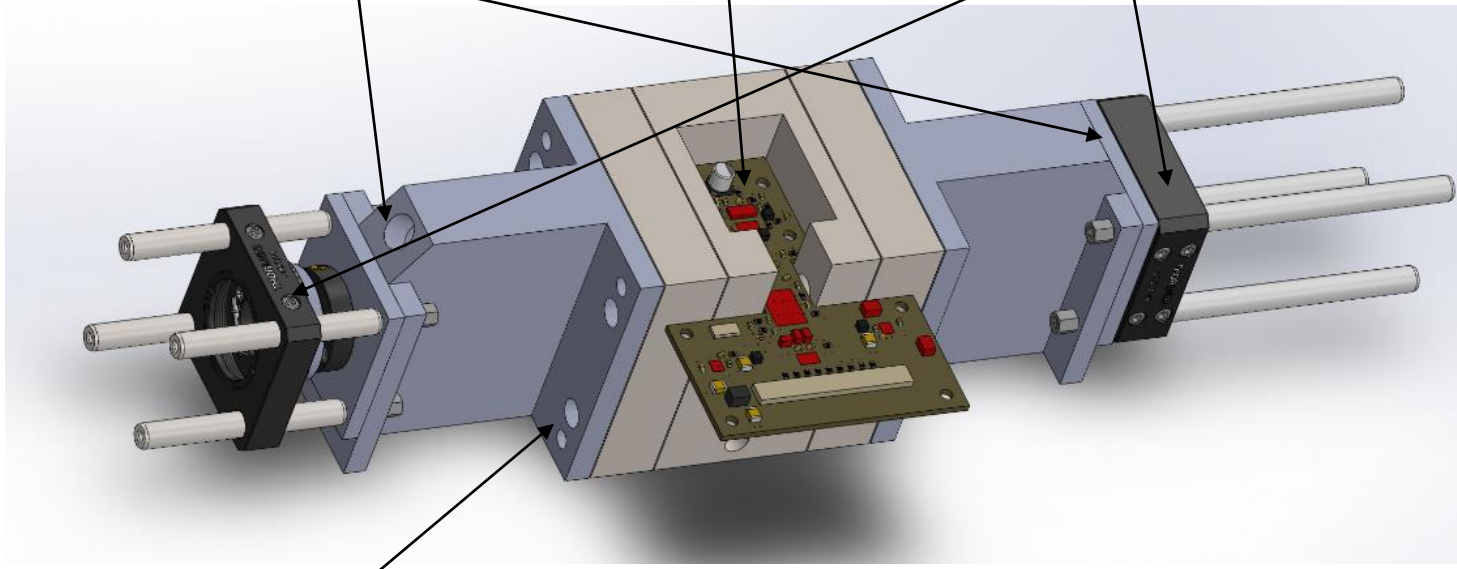
Photoacoustic Cell Design

- Second generation cell design
- Analog signal conditioning is directly at the sensor performed
- Heating cartridges for temperature stabilization
- Optics directly attached to the cell
- External components
  - Mainboard (Flow control, temperature stabilization, Signal processing, Data handling)
  - Laser driver



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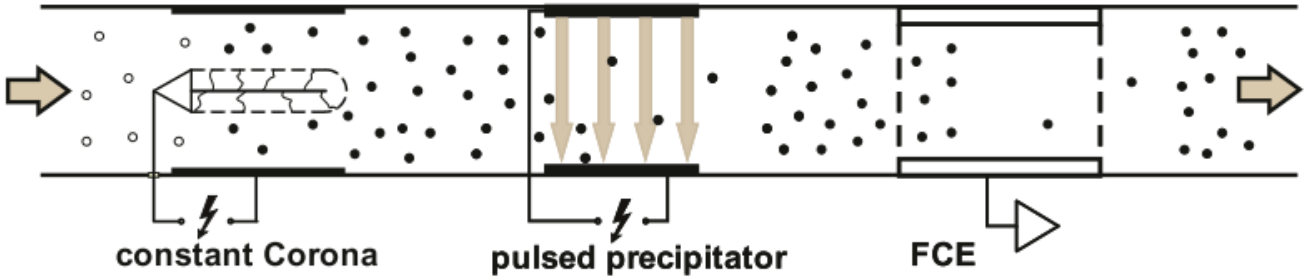
Diffusion Charging

- **Particle number measurement**
- Principle: Electrical charging of particles and subsequently measurement of the resulting current
- Sensor response can be correlated with PN → Pulsed Mode Diffusion Charger (PMDC)
- Measurement range appropriate for detection of exhaust after-treatment failures related to particles (DPF, …) → 10^3 – 10^7 particles / cm^3



[2] Schriefl A., Bergmann A., Fierz M. . Design Principles for Sensing Particle Number Concentration and Mean Particle Size With Unipolar Diffusion Charging. IEEE Sensors Journal. 2019.

[3] Schriefl M.A., Nishida R.T., Knoll M., Boies A.M., Bergmann A. . Characterization of Particle Number Counters Based on Pulsed-Mode Diffusion Charging. Aerosol Science and Technology. 2020.

- Used in plume chase experiments

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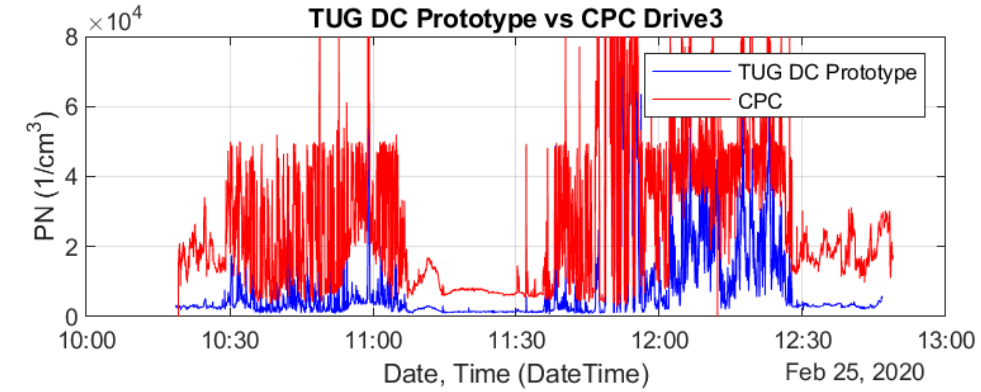
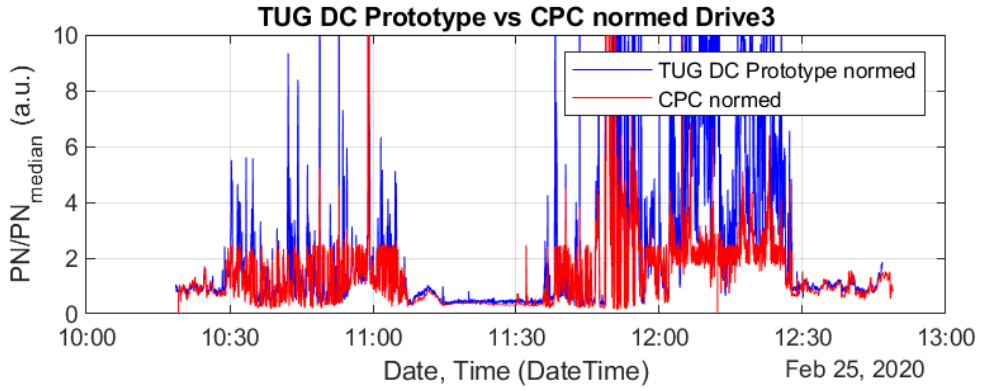
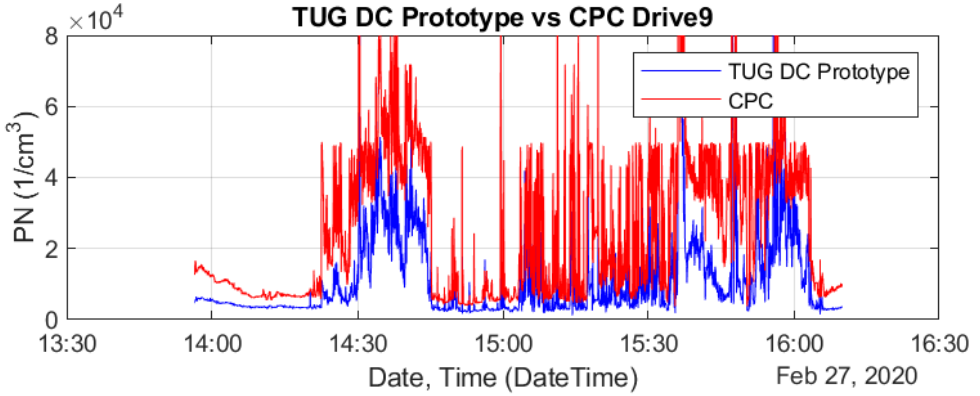
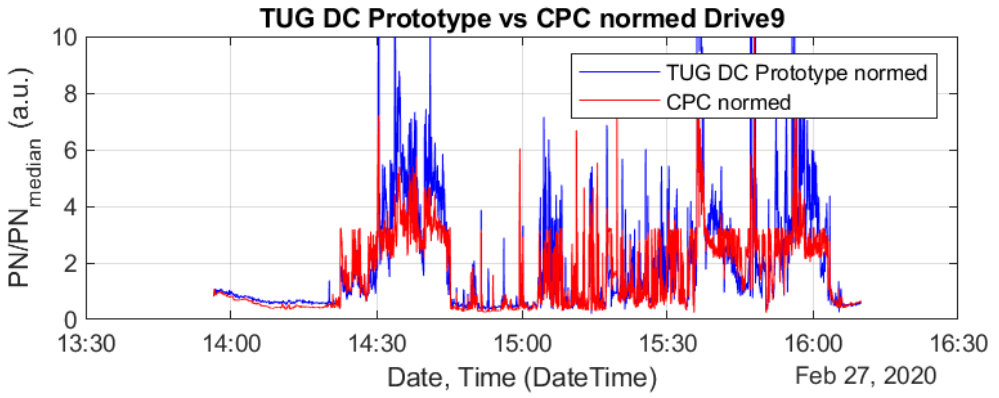
Diffusion Charging – Plume Chase Experiments









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CITY AIR REMOTE EMISSION SENSING

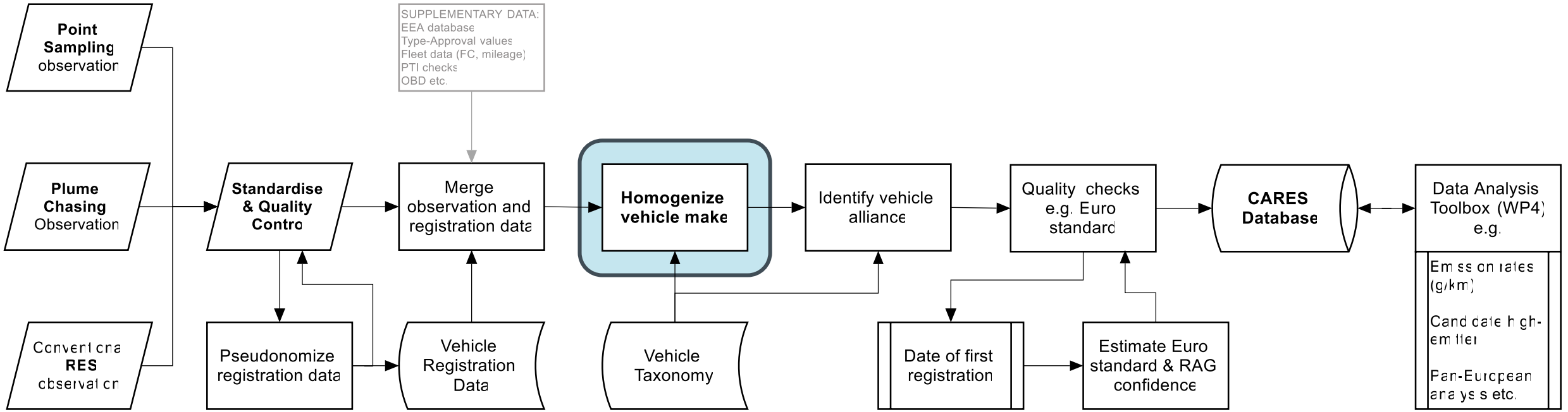
WP2: Standardizing remote sensing data management processes

Maximizing the potential of remote sensing observations

Work Package #2

Software development

- Supporting more efficient and standardized (robust) RES data handling
- Organise, analyse, enrich and link different types of RES data
- Make RES data accessible to enforcement agencies, cities & scientists



Work Package #2

MSCW Prioritization Approach for Database Entries

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CITY AIR REMOTE EMISSION SENSING

Conventional Remote Emission Sensing, Plume Chasing and Point Sampling measurements will all be entered into the CARES database following a standard form. The requirements for the CARES database entries are prioritized using a *MoSCoW* approach:

		EXAMPLES:
M	**Must have:** Non-negotiable requirements that are mandatory for further work to proceed.	• **Emissions measurement** • **Anonymized vehicle specifications**
S	**Should have:** Important includes that, whilst not vital, add significant value.	• **Pseudonomized License Plate Data** • **Meteorological Data**
C	**Could have:** Nice to include to enhance data, but may only have small impact if not available	• **Country of Origin** • **Emissions After-treatment System Data**
W	**Will not have:** Not a priority at this time. May return to these later in the project or as future work.	• Vehicle Color • License Plate record

Work Package #2

Software development

Homogenize vehicle make: Example Swiss (CH) data from the 2018 and 2019 campaigns

e.g.

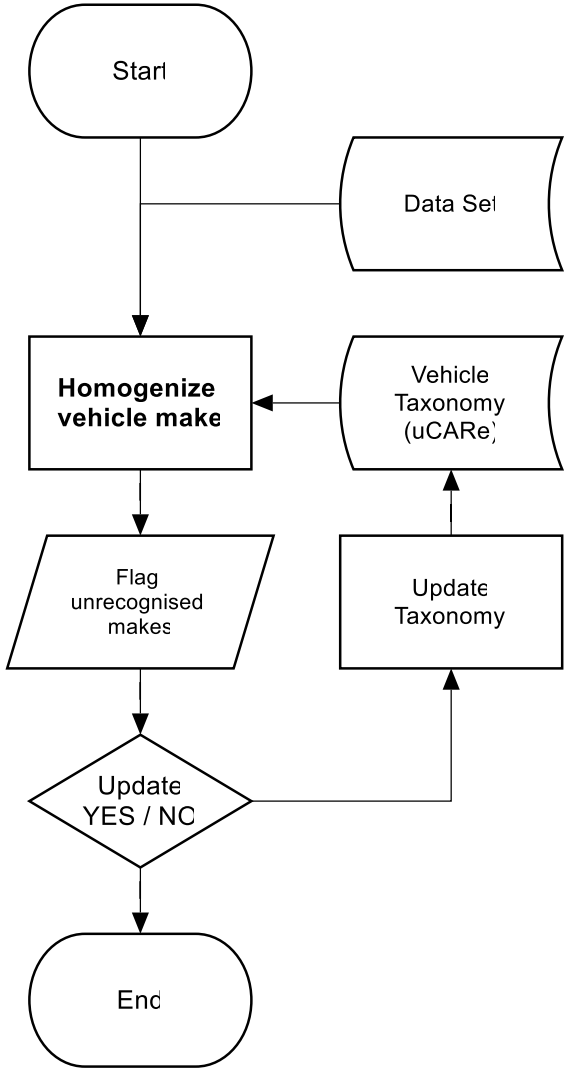
Daimlerchrysler AG

Mercedes

Mercedes-AMG

Mercedes-Benz

Mercedes



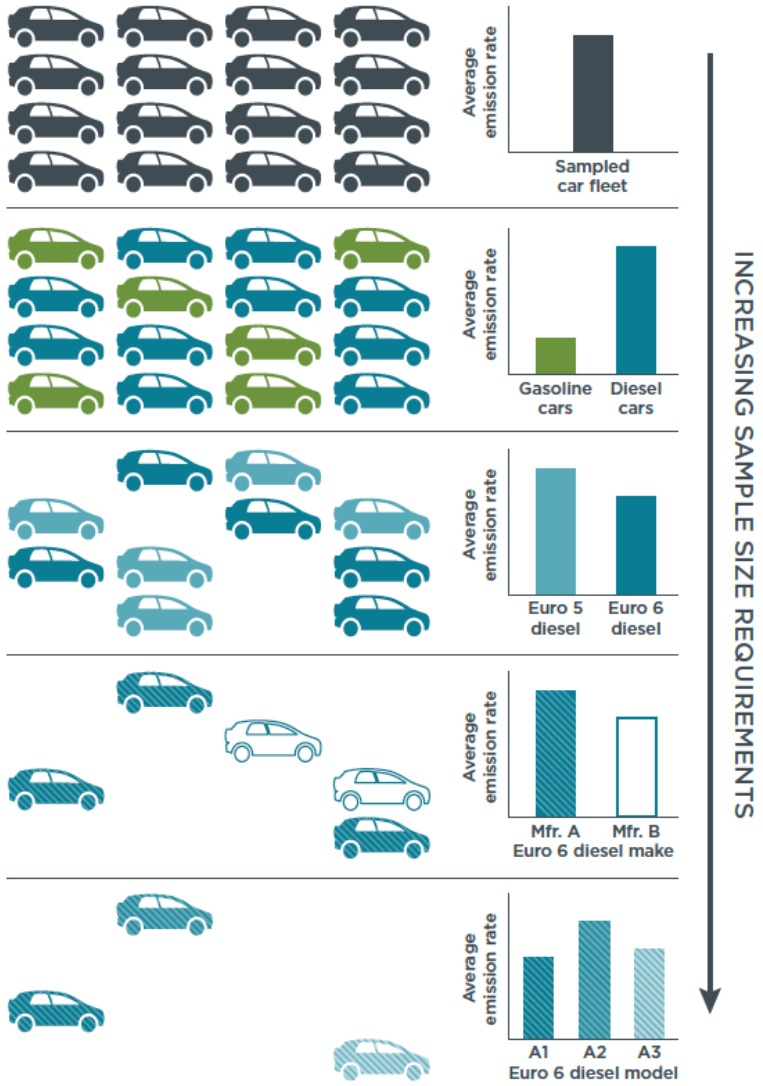
Switzerland Passenger Car Data

2018	2019
71622 records **4.2% flagged** **10 unrecognized makes** **9 new makes identified** Alfa, Mini UK, Smart, Fortwo, MG, Quattro, Mercedes-AMG, Buick, Pontiac **1 unidentified / others** Ovriga*	**69349 records** **0.2% flagged** **3 unrecognized makes** **2 new makes identified** Triumph, Hummer **1 unidentified / others** Ovriga*

*Ovriga translates to 'Others' in Swedish.

Work Package #2 and #4

Software development >> Data Analysis Toolbox



- Distance-Based Emission Factors (grams.km^{-1}) from Vehicle Emission Remote Sensing Measurements [1]
- Identify candidate high-emitters
- Calculation of minimum sample sizes [2]
- Pan-European analysis [3]

[1] Davison, J., Bernard, Y., Borken-Kleefeld, J., Farren, N., Hausberger, S., Sjödin, Å., Tate, J., Vaughan, A., Carslaw, D. 2020. Distance-Based Emission Factors from Vehicle Emission Remote Sensing Measurements. Science of the Total Environment. Accepted publication May 2020.

[2] Chen, Y., Zhang, Y., Borken-Kleefeld, J. 2019. When is Enough? Minimum Sample Sizes for On-Road Measurements of Car Emissions. Environ. Vol 53, 22, pp13284–13292, DOI: 10.1021/acs.est.9b0412

[3] Sjödin, Å., Borken-Kleefeld, J., Carslaw, D., Tate, J., Alt, G.-M., De la Fuente, J., Bernard, Y., Tietge, U., McClintock, P., Gentala, T., Vescio, N., Hausberger, S. (2018), Real-driving emissions from diesel passenger cars measured by remote sensing and as compared with PEMS and chassis dynamometer measurements-CONOX Task 2 report, Commissioned by the federal Office for the Environment (FOEN), Switzerland, IVL C294

Monitoring of in-use vehicle emissions – helping their enforcement (Work package #4)

All developments to measure vehicle emissions quickly, reliably, representatively => Monitor & help enforce in-use emissions!

Applications by partner (cities) concerned with high vehicular pollution:

1) Determine real-world **emissions**
2) Informing **policies**

3) Tracking **policy effectiveness**

4) Screen for **market surveillance (model) &**
   Screen fleet for **high emitter detection (individual vehicle)**

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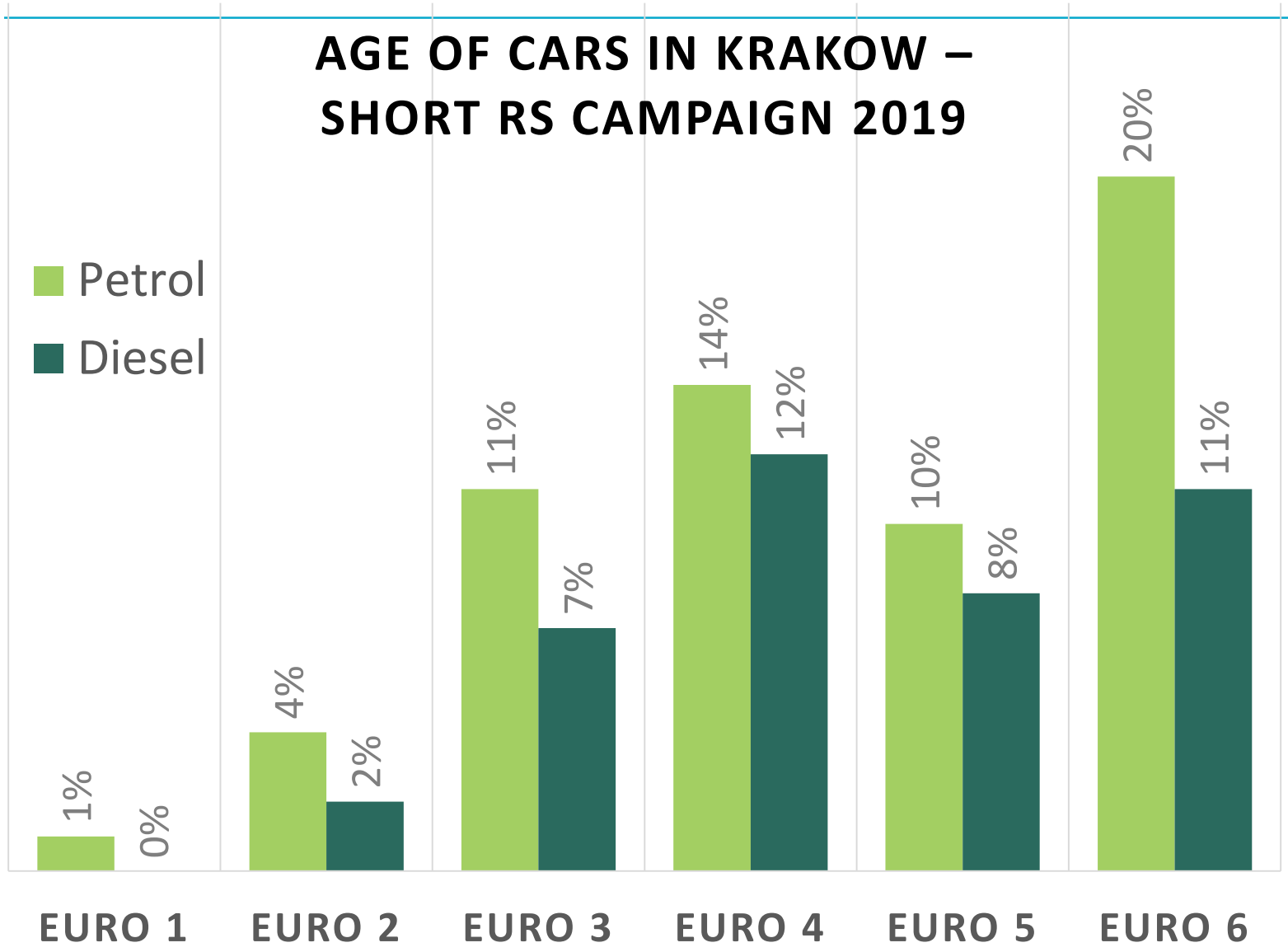
Krakow: RS campaign Oct 2019 – informing the situation



Petrol:
16% Euro 3 or older
(15 years+)

Diesel:
29% Euro 5 or older
(5 years+)

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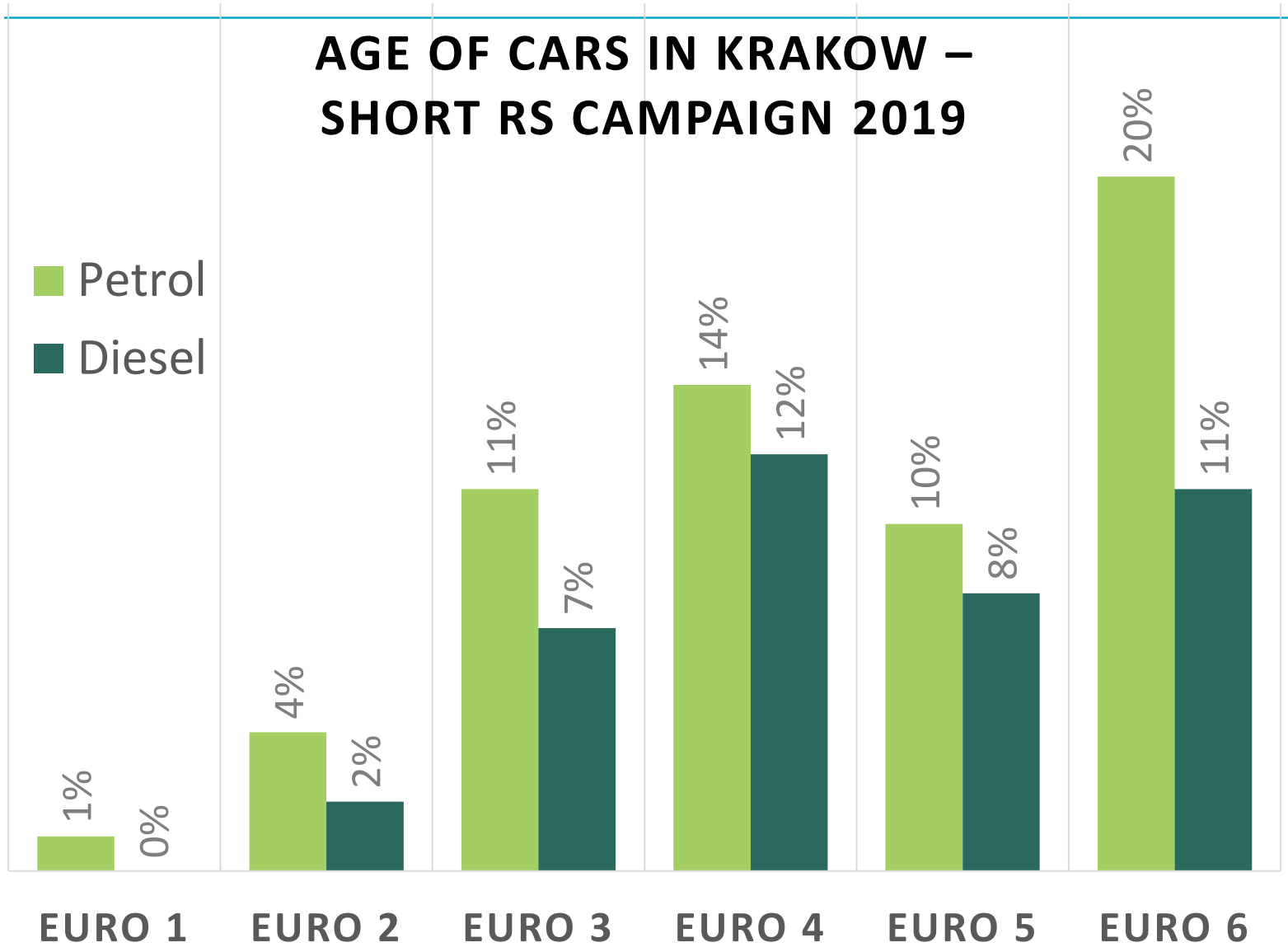
Krakow: RS campaign Oct 2019 – informing the situation



Petrol:
16% Euro 3 or older
(15 years+)

Diesel:
29% Euro 5 or older
(5 years+)

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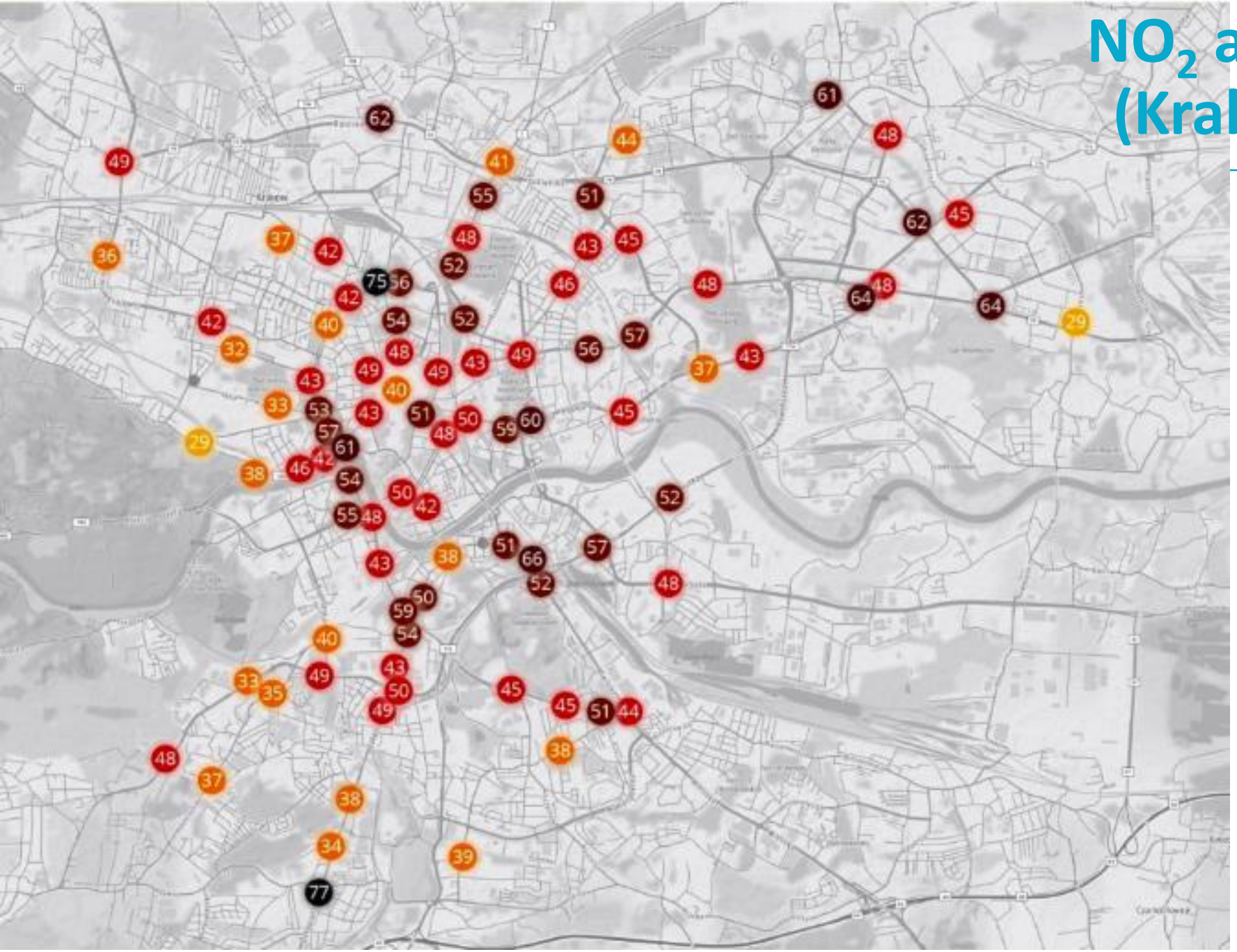
NO_2 ambient samples (Krakow - Nov. 2019)



Inner city between 40 – 60 µg/m³ NO_2

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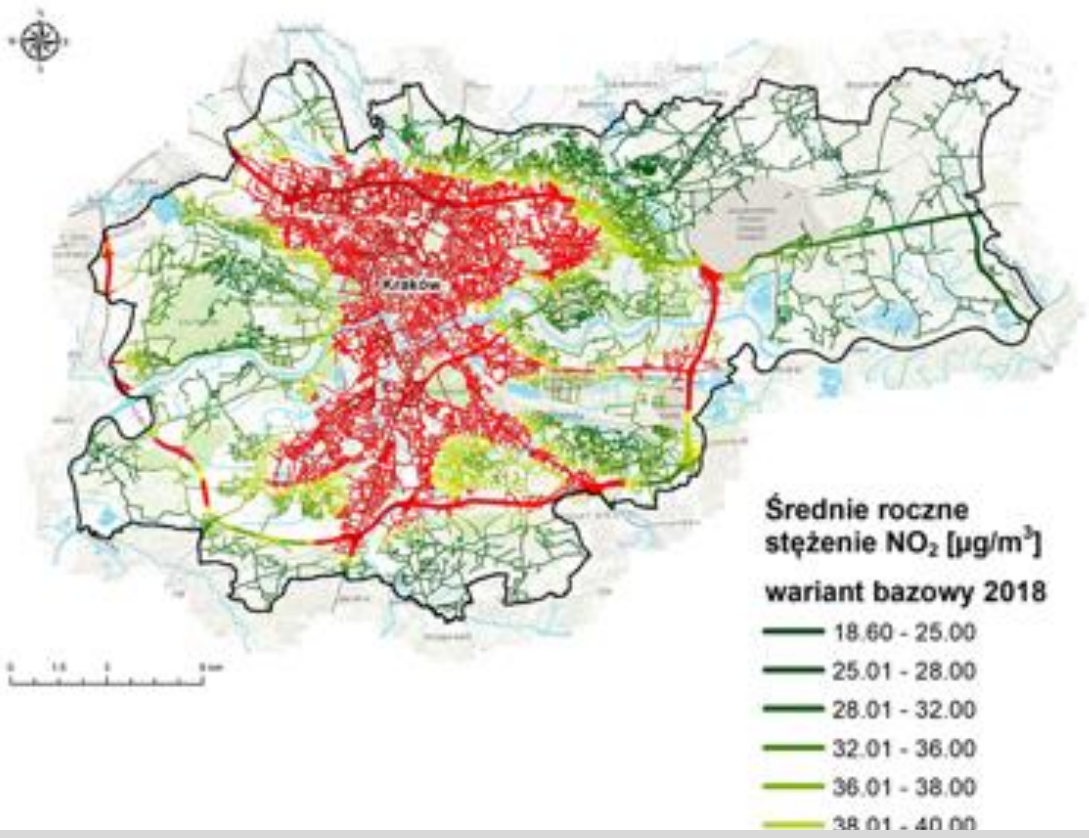
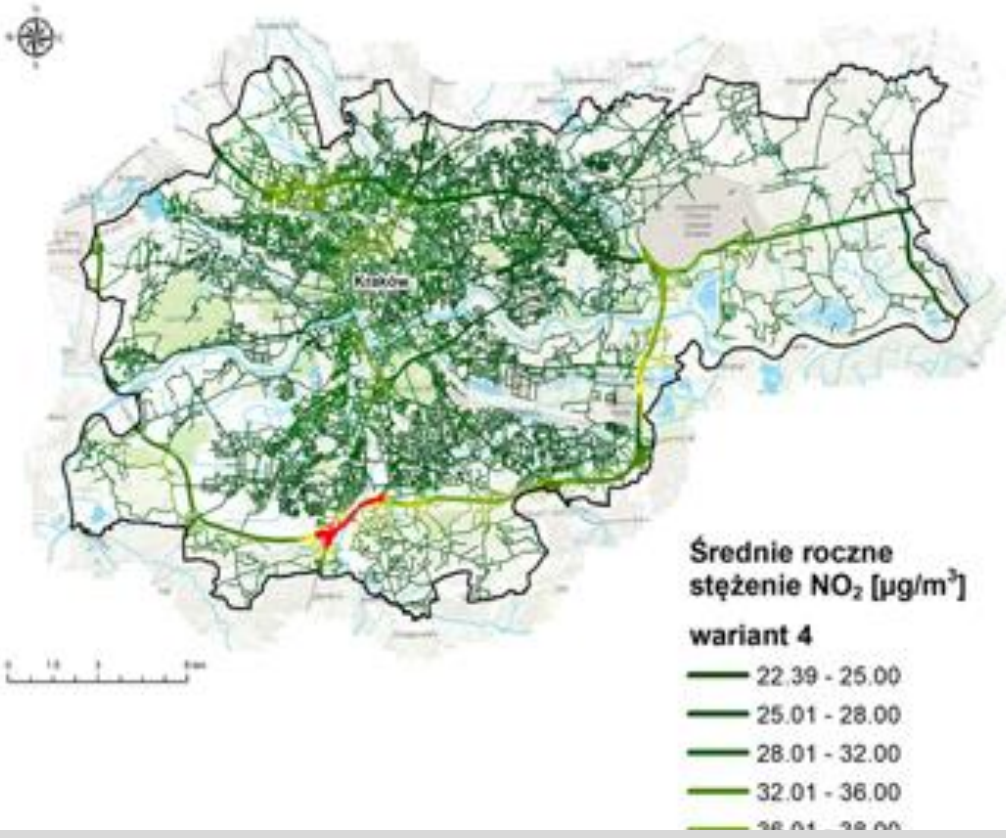
2020 Air Quality Program – LEZ proposal

NO_2 concentrations – base year 2018



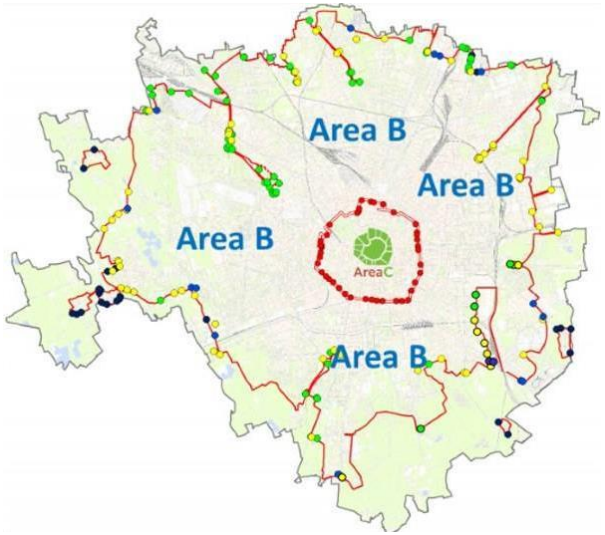
NO_2 concentrations – LEZ proposal: EURO 4 for petrol and EURO 6 for diesel



RS measurements to better inform –
and test possibilities for monitoring & enforcement

City of Milan – Innovhub SSI & AMAT

Milan: Persistent exceedances of PM and NO_2 AQ limits.
LEZ for center (AREA C, 8 km^2) and AREA B, 128 km^2 ⇔
No diesel vehicle up to EURO 4. Guarded by electronic gates.



Will NO_2 problem be solved with presumably clean Euro 6 vehicles?
(Track policy effectiveness). Ideally, also detect NH_3, soot, PM/PN!?

RES campaign
Top-down RS & point samplers deployed at 2 spots in city aiming for ~100,000 vehicle emission records.
Add-on partner components: PEMS validation tests and possibly air quality monitoring

Endorsement and availability of **Ministry of Transport** to share vehicles registration and PTI data.
Cooperation with the **Municipality of Milan**
(AMAT is developing the Municipality Air Quality and Climate Plan)

Milan campaign open points (in progress)

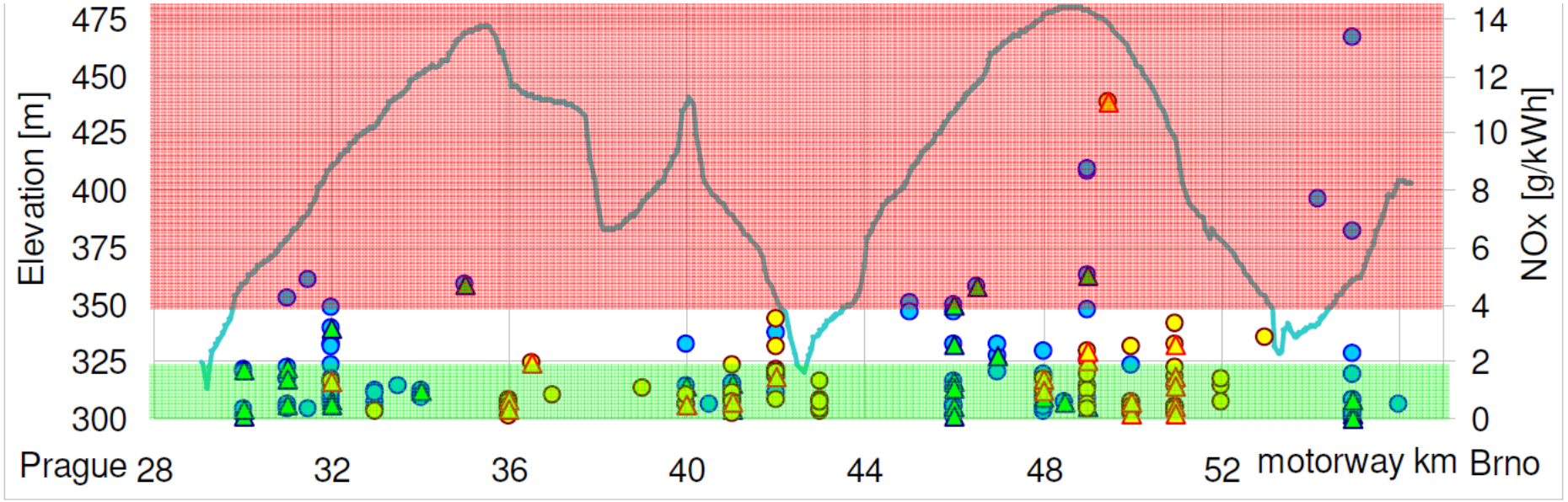
- Keen interest in PM and PN measurements. Accuracy?
- Ammonia (NH_3) emissions significant. Instrument available?

- Can point samplers be deployed at sites from the center to the limit of the city?
- Can they discriminate emission rate from single vehicle over a two or more lanes road?

- Set-up: Deploy top–down (EDAR) RS instrument and point sampler at
  - a one lane road;
  - a two lanes road next to an Area B (or Area C) electronic gate.
- Maybe also plume chasing validation? Following one high emitter with a PEMS on board, to compare with plume chase vehicle emissions?

Prague: Focus on high-emitter detection

- Understanding fleet and identifying contribution from high-emitting vehicles
  - Heavy-duty vehicles ⇔ plume chase vehicles
  - Cars (taxis), buses ⇔ cross-road remote sensing
- Done: some probing campaigns on PM roadside and highway plume chase
- Cooperation with Customs Office, Ministry for Environment, City of Prague



CARES

Monitoring of in-use vehicle emissions – helping their enforcement (Work package #4)

All developments to measure vehicle emissions quickly, reliably, representatively => Monitor & help enforce in-use emissions!

Applications by partner (cities) concerned with high vehicular pollution:

1) Determine real-world **emissions**
2) Informing **policies**

Your views, questions, experiences?

3) Tracking **policy effectiveness**

4) Screen for **market surveillance (model) &**
   Screen fleet for **high emitter detection (individual vehicle)**

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CITY AIR REMOTE EMISSION SENSING

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