uCARe

You Can Always Reduce Emissions

because you care

GA 815002

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uCARe consortium

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All consortium partners	

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Executive summary

The overall aim of uCARe is to reduce the overall pollutant emissions of the existing combustion engine vehicle fleet by providing vehicle users with simple and effective tools to decrease their individual emissions and to support stakeholders with an interest in local air quality in selecting feasible intervention strategies that lead to the desired user behaviour. Progress towards this overall aim was made within the uCARe project and a number of exploitable results have been produced. These results include a wide array of possibilities to reduce vehicle emissions by making changes to driver behaviour. In summary the following exploitable results were produced:

1 A taxonomy for vehicles and technology.
2 Augmented Emission Maps (AEMs) for different vehicle types and emission species.
3 Three paths for cheap monitoring systems which can be used as feedback to vehicle users.
4 Citizen science videos.
5 The car-specific software for emission estimation.
6 The webtool GUI for trip analysis.
7 Evidence of factors that encourage or discourage change.
8 A set of methods used to collect data and impact evaluation indicators.
9 Teaching material aimed at changing driver behaviour
10 Effectiveness of behavioural measures
11 Evaluation of the expected air quality impact

A number of these results have already been exploited within the context of the uCARe project. The exploitation of these results outside of the context of the uCARe project has already occurred in the following projects:

1. Policy study on preventing and opposing emission fraud with road vehicles requested by the Flemish government.
2. Study requested by the Flemish government regarding emission factors of plug-in hybrids.
3. The LIFE project MILE21
4. The H2020 project CARES
5. Internally within a number of partner organisations: TNO, EMPA, INFRAS, TUG, LAT.

The further exploitation of these results outside the context of uCARe is currently planned on the short-term in a number of projects. These projects are:

1. Input for adaptation of the VERSIT+ emission factors and updating of the Dutch emission registry.
2. Input for the adaptation of the HBEFA emission factors used by authorities, private consultants and universities and represents an important input for other emission calculation tools like COPERT, EcoTransIT or TREMOD.
3. Updating the CONOX remote sensing database.
4. Licencing the software with the webtool GUI for trip analysis for vehicle fleet owners to reduce fuel costs and emissions.

The results of uCARe can also be exploited in other future projects. The possibilities for this include:

1. Providing input for emission tool builders
2. Enabling the standardised exchange of vehicle emission data
3. Raising awareness amongst citizens on how their emissions can be reduced
4. Raising awareness amongst stakeholders to help setting up projects to reduce vehicle emissions
5. Giving shape projects to reduce vehicle emissions by changes in driver behaviour
6. Evaluating projects to reduce vehicle emissions by changes in driver behaviour

Future research in the field should be focussed on three areas. Firstly, different strategies for reducing vehicle emissions by changing user behaviour should be investigated. Secondly, future research should focus on the application of the uCARe tools to battery electric and plug-in hybrid vehicles. Finally, additional training strategies to further improves the behavioural changes achieved in this study further research.

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1 Introduction

1.1 Background uCARe

With four million people dying annually due to outdoor pollution, improvement of air quality has become one of society's main challenges. In Europe, traffic and transport have a large effect on air quality, specifically passenger cars and commercial vehicles and to a lesser extent non-road mobile machinery. While technical improvements and more stringent legislation have had a significant impact, traffic and transport emissions are still too high and air quality is still poor. Although the use of electric and other zero-emission propulsion technologies may drastically reduce the pollutant exhaust emissions from traffic, the slow introduction of such vehicles as well as the trend of increasing vehicle lifetimes means that vehicles with internal combustion engines are expected to dominate the fleet beyond 2030. This project is the first opportunity to improve emissions of vehicles, not by improving vehicle technology, but by actively involving vehicle users and enabling their contribution to clean driving.

So far, expertise on pollutant emissions has mainly been used to advise European policy makers on limited effectiveness of emission legislation (through real-world emission factors such as HBEFA and COPERT) and how to reduce traffic and transport pollutant emissions. The numerous mitigation methods are rarely extended to include the perspectives of users uCARe enables a next essential step: providing user targeted emission reduction measures. These measures will be implemented and evaluated in real-life pilot projects.

The overall aim of uCARe is *to reduce the overall pollutant emissions of the existing combustion engine vehicle fleet by providing vehicle users with simple and effective tools to decrease their individual emissions and to support stakeholders with an interest in local air quality in selecting feasible intervention strategies that lead to the desired user behaviour*. The overall aim is accompanied by the following objectives:

1. To identify **user-influenced vehicle emission aspects** (such as driving behaviour and vehicle component choice).
2. To determine the **emission reduction potential** of each vehicle emission aspect with help of the uCARe model developed within a toolbox.
3. To develop a **toolbox**, containing models and emission reduction measures, that enables stakeholders to identify the most appropriate intervention strategies that reflect the specific users and their motivation.
4. **Support policy makers** and other **stakeholders with an interest in air quality,** such as municipalities and branch organizations, **in identifying intervention strategies** that translate the measures into desired behaviour of the user.
5. **To test and evaluate** intervention strategies in a set of pilot projects conducted with various target user groups in at least four European countries. The pilot projects illustrate effectiveness and feasibility of the toolbox and intervention strategies developed on its basis.
6. Perform an **impact assessment** of the intervention strategies effectiveness, in terms of cost, penetration, achieved emission reduction and lasting effects.
7. **Actively feed** European cities and international parties with uCARe learning and results, via awareness raising campaigns, communication tools, interactive web application and other dissemination activities. Open access to the broad public to the toolbox, data and developed tools.
8. Summarise the findings **in blueprints for rolling out** different user-oriented emission reduction programmes, based on successful pilots.

<Include here Work Package specific background/state-of-the-art>

1.2 Purpose of the document

This exploitation report provides an overview of the results produced in the uCARe project. Following this, the exploitation by the uCARe consortium partners as well as uptake by organisations outside the consortium is described.

The method used to compile this exploitation plan is:

- Create a list of all results
- Ask all partners about all foreseen and hoped for exploitation
- Check the validity and modify/extend where needed the foreseen exploitation of results as presented in section 2.2.1 of the uCARe proposal

1.3 Document Structure

This deliverable gives an overview of the key exploitable results developed within each work-package of the uCARe project. Following this, the exploitation of these results is described. This includes the exploitation of results that has already occurred, exploitation planned on the short-term and other possibilities for exploiting results. Finally, conclusions are drawn and recommendations for future research are provided.

1.4 Deviations from original DoW

1.4.1 Description of work related to deliverable as given in DoW

This report evaluates the exploitation of results from the project by other parts of the project. Mainly WP1 and WP2 results are foreseen to be used in WP3 pilots. Furthermore, based on the exploitation within uCARe, the foreseen exploitation of uCARe results by partners and other organisations is described.

1.4.2 Time deviations from original DoW

Because of the COVID-19 pandemic the project has been extended with six months. Therefore the deliverable due date has been postponed with six months.

1.4.3 Content deviations from original DoW

No content deviations.

2 Key exploitable results

This chapter provides an overview of the key exploitable results per work-package.

2.1 WP1 – Assessment of user impact

The objective of WP 1 was to provide the knowledge and data necessary for the remaining work packages. This included establishing the relationship between driving behaviour and emissions for a wide variety of vehicle models and pollutants. The effect of ambient conditions, cold start and payload were also included. Additionally, an assessment of the types of avoidable and observable malfunctions which lead to high emissions, which can be solved with simple maintenance were included. An overview of simple means of detecting malfunctions and tampering, which can be proposed as augmentation of periodic inspections was also included. Finally, the forms of vehicle adaptions, such as retrofit solutions and software updates, that will improve the emission performance of different engine technologies was covered.

Progress towards these objectives have been achieved within work package 1 by developing a number of key exploitable results. These results include:

1 A taxonomy for vehicles and technology.
2 Augmented Emission Maps (AEMs) for different vehicle types and emission species.
3 Three paths for cheap monitoring systems which can be used as feedback to vehicle users:
4 An analysis of the current emission situation for non-road mobile machinery, powered two-wheelers and heavy-duty vehicles.
5 Citizen science videos

2.1.1 A taxonomy for vehicles and technology

The vehicle taxonomy is a controlled vocabulary and vehicle classification system for all passenger cars on the road. The taxonomy has 11 levels; two parts can be distinguished: the vehicle part and the engine part. The engine is a child of the vehicle. The vehicle code contains the make and model, the transmission type, all-wheel drive capability and the battery capacity. An example of the vehicle part of the taxonomy is shown in Figure 1 and an example of the engine part is shown in Figure 2.

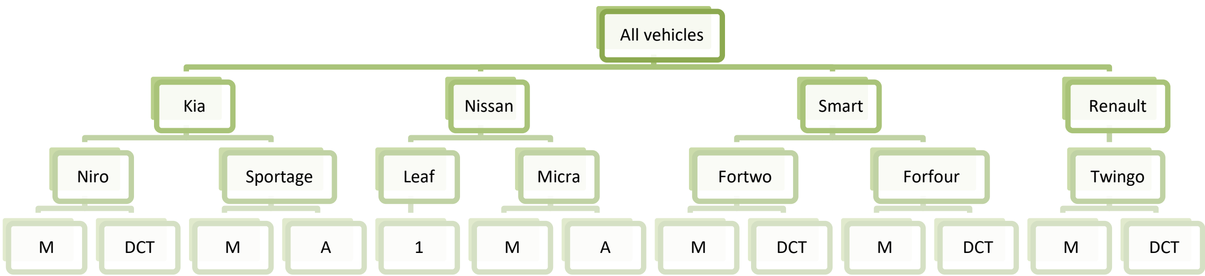

Figure 1 Example of vehicle part of taxonomy: first three layers. Gearbox layer: M=manual, A=automatic, DCT=dual clutch transmission, 1=single speed

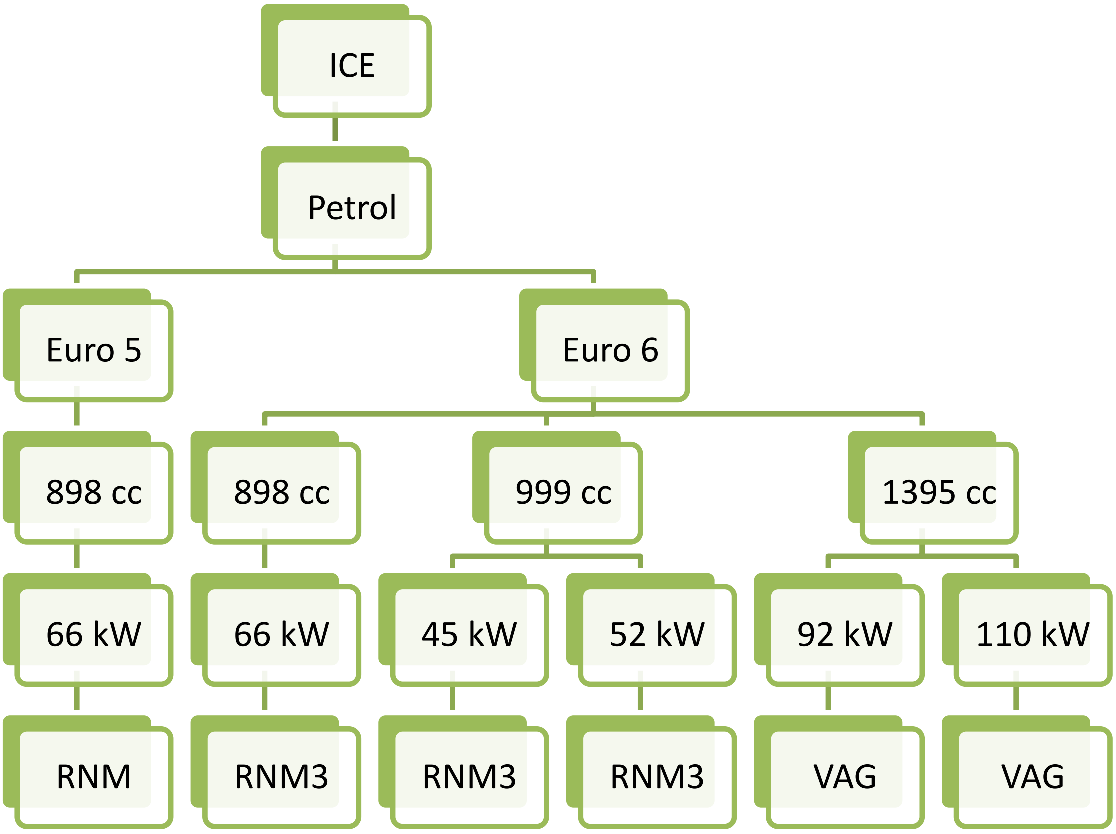

Figure 2. Example of engine part of taxonomy

2.1.2 Augmented emission maps

Augmented emission maps (AEMS) are a standardized way of presenting detailed measurement-based emission data. Figure 3 shows an example of such a map for a random vehicle/group of vehicles. AEMs and their surrounding framework allow tool-builders, researchers, and policy makers to give data-driven advice, to engage and encourage drivers to modify their behaviour, and thereby reduce pollutant emissions. The AEMs have been made freely available via the OpenAire platform Zenodo under a Creative Commons Attribution 4.0 International Public License to which new data can and will continually be added as new measurements become available.

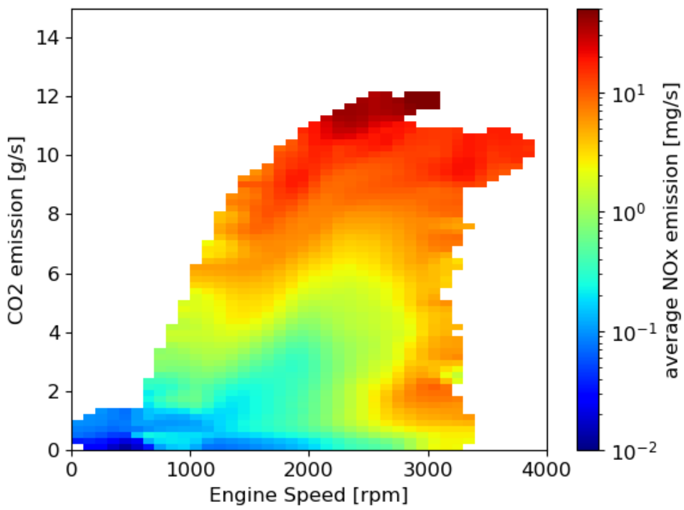

Figure 3 Example emission map for average NO_x emission from a Euro 6 diesel engine

2.1.3 Paths for cheap monitoring systems

Five cheap and simple monitoring solutions were created. Additionally, videos were produced on each of these solutions and used in WP3 to inform interviewees and the use of these solutions as direct feedback tools towards the vehicle user were evaluated. The five paths investigated were:

1. The NOx feedback tool. This extracts data and signals from the CAN and/or directly from the OEM sensors.
2. The Crossyn sensor data logger. This makes use of installed (non-OEM) sensors to measure and use the emission concentration.
3. A particle sensor, based on a cheap smoke detector. This is capable of detecting severely damaged/removed DPR.
4. A 'mini-PEMS'. This consists of cheap testing solutions to measure different components, incl. non-regulated emissions: Particle sensor, Mini-PEMS and portable FTIR.
5. A portable FTIR. This is a universal tool for measurement of nearly all gaseous pollutant and is suited as an alternative for PEMS.

2.1.4 Citizen science videos

uCARe created a number of videos on citizen science [3]. This allows drivers to check the performance regarding pollutant emissions for their own vehicle. By doing this, awareness can be raised amongst citizens on the different sources and species of emissions of their vehicles.

2.2 WP2

The objective of WP2 was to develop tools to provide an assessment of behavioural emission reduction options for consumers. This included an analysis of behavioural changes and the effect that each of these has on emissions. This objective was reached within this work-package with the delivery of the following key exploitable results:

1 The webtool with car-specific software for emission estimation.
2 The webtool GUI for trip analysis.

2.2.1 The car-specific software for emission estimation

A "virtual PEMS" was developed to analyse and evaluate trips. This model allows drivers to access information about the emission levels they cause with their driving style. In addition to this, a special module in the software was developed, which simulates the trip as a virtual "super-eco" driver. The comparison between the actual emissions calculated with the real trip data and the super-eco driver provides the reduction potential for emissions by improved driving style. The tool also gives recommendations to the driver how to improve driving. The model runs with a simple plug & play application of an OBD dongle that is plugged into the vehicle. This automatically transmits trip data (velocity, engine speed, road gradient) to a server, where the so-called "virtual PEMS" simulates the trips. This software is implemented in the uCARe webtool shown in the screenshot below. This tool analyses driver's trips and provides feedback on driving behaviour including tips to reduce emissions.

2.2.2 The webtool GUI for trip analysis

A webtool with graphical user interface was produced in this work package. This tool allows drivers to register the Dongle and vehicle on the platform, to log-in and view their trips which are evaluated using the car specific software for emission estimation and feedback is given. Additionally, tips are provided to the driver on how they can reduce their emissions. Figure 4 below shows a screenshot of the webtool.

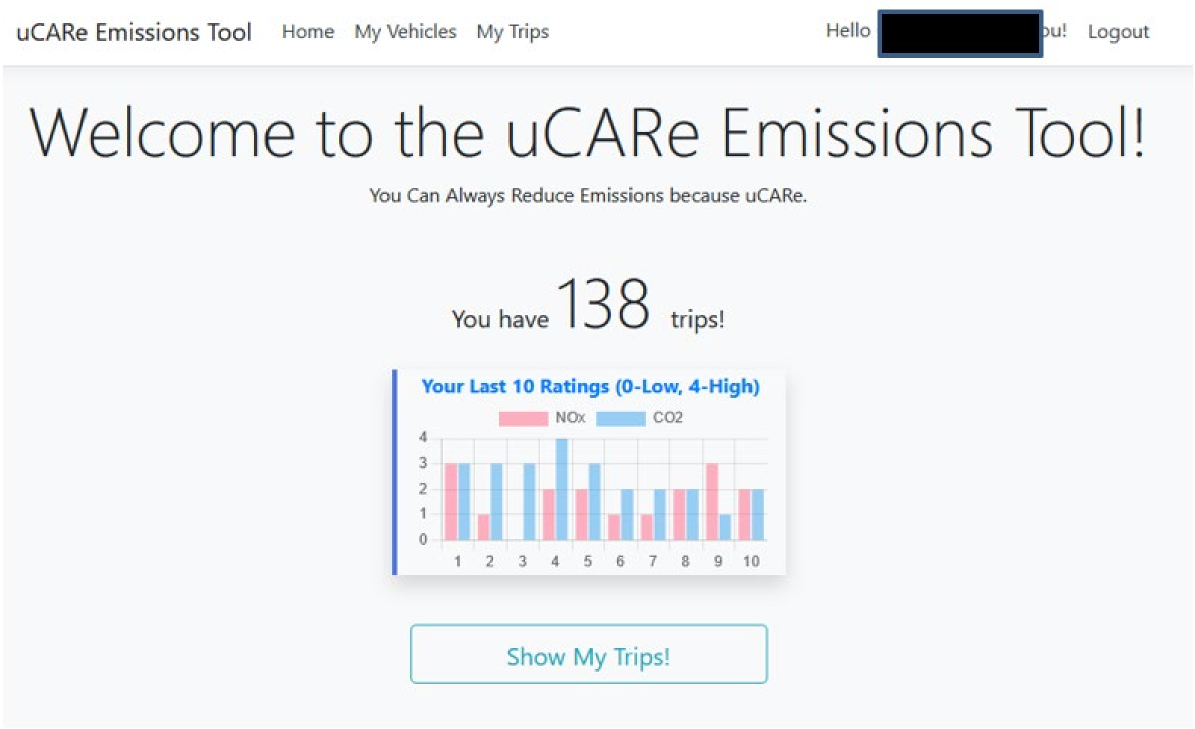

Figure 4 Home after Login (identified e-mail)

2.3 WP3

The objective of WP3 was to encourage drivers to adopt behavioural changes aimed at decreasing vehicle emissions. This was done within pilot projects in which the tools developed in WP1 and WP2 were tested. This work package resulted in the following three key exploitable results:

1. Evidence of factors that encourage or discourage change.
2. A set of methods used to collect data and impact evaluation indicators.
3. Teaching material aimed at changing driver behaviour.

2.3.1 Factors encouraging or discouraging change

A full overview of eco-driving behaviours categorised on strategic, tactical and operational levels was developed in this project. This covers all possibilities for drivers to adapt their behaviour to reduce their vehicle emissions. This includes behavioural changes in maintaining their vehicles, choosing their routes and also adapting their driving style.

2.3.2 Methods used to collect data and impact evaluation indicators

The methods for collecting data on behavioural change were developed and tested within this project. This included the evaluation of on-road measurements using an OBD data collection device and self-evaluation using surveys. These methods were evaluated to determine which is the most effective.

2.3.3 Teaching material aimed at changing driver behaviour

A number of teaching materials were produced in this project which can be used to communicate with drivers on how they can reduce their emissions when driving. This includes videos, presentations and pamphlets. Figure 5 shows the teaching material aimed at drivers which provides background information on vehicle emissions and driving style tips for reducing emissions.

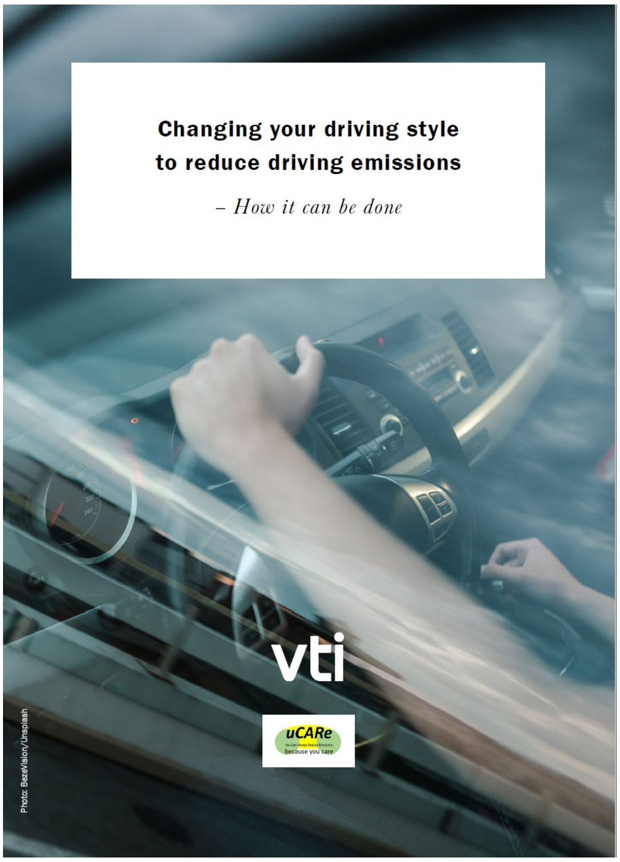

Figure 5 uCARe teaching material

2.4 WP4

WP 4 quantified the effects of the behavioural changes aimed at decreasing vehicle emissions. Additionally, the goal was to translate the effects of pilots to pan-European effects if behavioural changes are adopted on a large scale. The key exploitable result of WP4 are:

1 The effectiveness of behavioural measures.
2 The expected air quality impact in Gothenburg, Zurich and Amsterdam.

2.4.1 Effectiveness of behavioural measures

The actual emission reduction achieved by the pilots was determined. Additionally, the effects of individual measures on NOx, PN, CO2 was simulated. This was done for a number of emission species and for three different years. Finally, the uptake of each of the measures by drivers was determined. This full analysis of pilot and measure's effectiveness can be used to inform stakeholders who want to take measures in the future. This will allow for specific intervention to be selected and implemented in future projects to reduce vehicle emissions. Figure 6 below shows the evaluation of various changes to driving behaviour and the effect on NOx emissions for the years 2020, 2025 and 2030 for a typical vehicle.

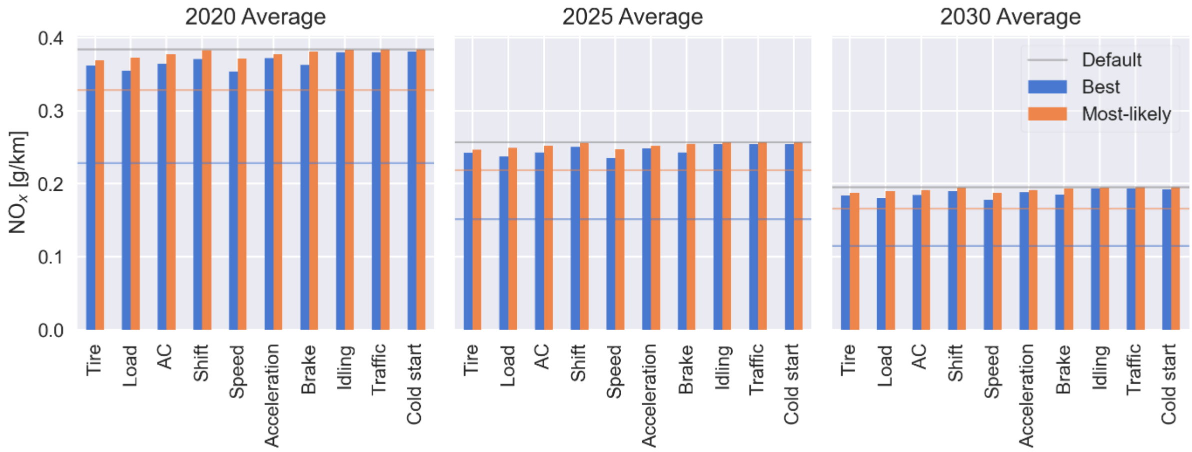

Figure 6. Theoretical emission factors for NOx emissions for average driving conditions and average European cars in the years 2020, 2025, and 2030 under different interventions. Horizontal lines show overall emission savings combining all interventions.

2.4.2 Evaluation of air quality impact of measures

The consumer behaviour measures investigated within the uCARe project reduce emissions of passenger cars. The impact of these measures on average annual air pollutant concentrations was investigated for the cities of Zurich, Gothenburg and Amsterdam for the years 2019/2020 and 2030. Figure 7 below shows a comparison of the results for PM and NO2 for the three cities for two scenarios. These results can be used to inform stakeholders on the impact of measures and how they can improve air quality in cities. Additionally, it provides guidance on where and when such emission reduction measures can have the most impact. This is generally in cities and highly populated areas with a lot of vehicle traffic. Additionally, the measures have the most impact in the period 2019/2020 relative to 2030. This means that the earlier measures are taken the greater the emission reduction will be.

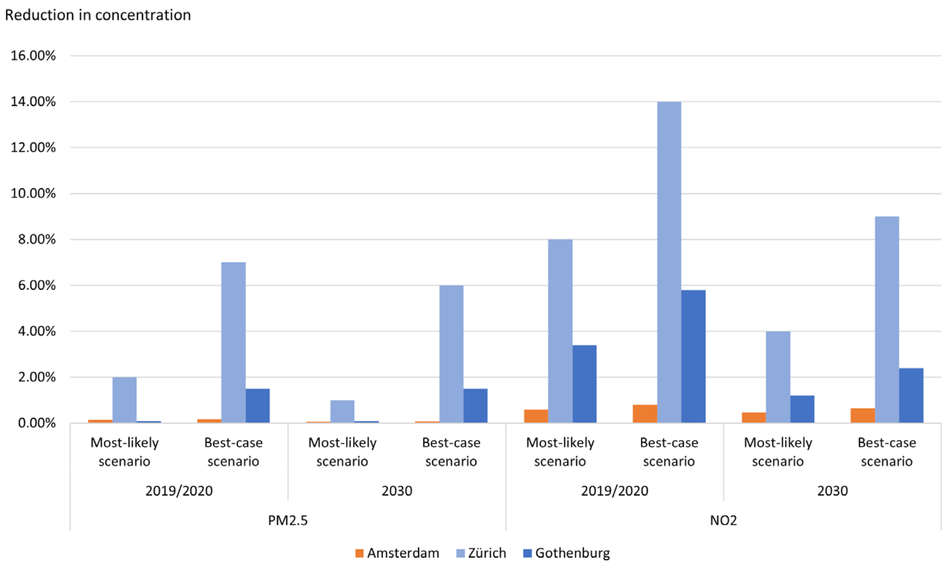

Figure 7 Comparison of reduction in air pollutant concentration for the three cities for different scenarios.

3 Exploitation of results

This chapter provides an overview of the exploitation of the key results developed in this project. This includes the exploitation of results that has already happened and the planned exploitation of results on the short term. Finally, other possibilities for exploiting results are also covered.

3.1 WP1

The results of WP 1 were extensively exploited within the other work-packages of uCARe. The exploitation of each of these in other contexts is provided below.

3.1.1 A taxonomy for vehicles and technology

The vehicle and technology taxonomy has already been adopted by the CARES project and the LIFE project MILE21. Considering the fact that already two projects benefitted from the structure of the taxonomy, further update by scientists and/or projects for structuring emission related data will be likely. TNO, TUG and LAT will actively promote this use of the taxonomy in future projects. Additionally, EMPA is already using the taxonomy internally and will use it in future projects. IVL will implement the taxonomy in the existing CONOX remote sensing database.

3.1.2 Augmented emission maps

Augmented Emission Maps (AEMs) have been developed as a means to share emission data of vehicles. The exploitation of these AEMs can be done in one of three general ways:

- On one hand a standard for the AEM has been developed. The standard will be exploited whenever a new AEM is created according to this standard.
- The AEMs for various types of pollutant emissions have been published on the Zenodo platform under a Creative Commons Attribution 4.0 International Public License.
- Various tools to create and find the proper AEMs have been created. These tools have been submitted to the public domain and are exploited by creators and users of AEMs.

TNO will use all three forms of exploitation of AEMs. Concretely, this will be done in developing an air quality model for the whole of the Netherlands. This model will allow for air quality simulations on a 25m scale and the AEMs will facilitate the determination of road transport emissions. Additionally, the AEMS will be used in the CARES project.

LAT will use AEMs in future research activities aiming in smart processing of data to further evaluate the behaviour of both recent but mostly older vehicle technologies of vehicles. The aim is to reflect the results of such activities in improved vehicle emission modelling.

The Zenodo platform has been used to share the AEMS outside of the uCARe consortium. This allows tool makers and software developers to download all AEMs. This constitutes the exploitation of these AEMs and is already seen in the more than 12000 cumulative downloads across all of the available vehicle types.

3.1.3 Paths for cheap monitoring systems

The cheap monitoring systems developed in this project can each be exploited in the following ways:

- The NOx feedback tool can be used in a pilot to provide drivers with insights into the real-time NOx emission of their vehicle.
- The Crossyn system can be used to log the data received from both sensors and the OBD signals of the vehicle.
- The particle sensor is capable of detecting severely damaged/removed DPR.
- Mini PEMS can be used for all gaseous pollutant and particulate matter and is suited for vehicles with small engines.
- The portable FTIR is a universal tool for measurement of nearly all gaseous pollutant and is suited as an alternative for PEMS. The exploitation of these tools is mainly foreseen in future pilots. Either the equipment can be installed in the vehicles of a few tens of drivers, or the equipment can be used in fairground events.

The following partners intend to exploit these tools in spin-off pilot-like projects with stakeholders after the uCARe project has ended: TNO, CVUT, TUG and LAT.

3.2 WP2

The results of WP2 were used extensively within WP3 and WP4 of the uCARe project. The exploitation of these results in other contexts is provided below.

3.2.1 The car specific software and webtool for emission estimation

TUG will use the uCARe model methodology for the development of tools allowing real time evaluation of vehicle emission performance. Such tools may be combined with small emission measurement systems (SEMS) and portable emission measurement systems (PEMS) to both enhance the data derived from them but also provide guidance during execution of on-road experiments.

The improvements in the emission simulation methods, especially the cold start and non-exhaust particle emission simulation, can be used in future work producing emission factors, elaborating emission abatement and air quality plans. TUG will use the new tools in the next update of the HBEFA (www.hbefa.net). TNO can use this in future projects with national or local governments to evaluate traffic related measures proposed. For example, the effect on emissions of a reduction in speed limits could be evaluated.

EMPA plans to use the uCARe software in future projects to further analyse the differences resulting from different driving styles, with a focus on fuel consumption.

3.2.2 Webtool GUI for trip analysis

The webtool GUI can be exploited in future projects with stakeholders. This application can be especially useful for owners of large fleets to reduce fuel consumption and emissions and to demonstrate GHG reduction policy activities. Possible customers, such as package suppliers, insurance companies are already contacted to initiate test phases using the package of software, webtool and GUI.

VTI wants to exploit the uCARe software for trip analyses as basis for further emission reduction projects in Northern countries where studded tyres are used. Some additions and modifications are expected for this. Except for airborne particles, VTI would also like to use the model also for total emission of tyre wear particles (TWP) which is a dominating source of microplastics. The model, or specific subroutines, might also be possible to combine with the NORTRIP emission model, which is specifically developed to describe non-exhaust and road dust emission, which are periodically high in Northern countries.

3.3 WP3

The results of WP3 can be exploited in future pilot projects for new stakeholders or in larger scale campaigns based on the pilot projects.

3.3.1 Factors encouraging or discouraging change

LAT intends to exploit intervention strategies and any information collected during the validation and evaluation of the pilot projects in future research activities elements aimed at improving the emission performance of vehicles. More specifically, the aim is to combine these elements with engine and vehicle technological measures to maximize the expected emission reduction in future research activities. One example is the inclusion of uCARe measures in in-vehicle equipment (driver assistance, ECU software etc.).

TNO intends to perform pilot like projects in collaboration with other governmental stakeholders. For example, in cities where changes such as a reduction in speed limit is proposed, TNO can first simulate the effects using the results of WP 2 and provide input on the expected effects of such projects. Finally, the data collected in the pilots can be added to the TNO data on average driving behaviour.

3.3.2 Methods used to collect data and impact evaluation indicators

The monitoring tools developed in this project can be exploited in other pilot projects. As was noted in D4.2, measuring actual parameters on driving behaviour is a more effective tool than self-evaluation. Therefore, it is proposed to make use of a system for measuring driving parameters to evaluate the emission reduction.

3.3.3 Teaching material aimed at changing driver behaviour

The teaching materials can be exploited in future pilot projects. VTI intends to exploit the education material produced in WP 3 as well as successful pilots in further research and emission reducing activities.

The University of Leeds hopes to enhance their reputation among stakeholders that are not yet connected with the university. This will help in the translation between academic results and policy decisions. They can use this project as evidence in the Impact Statement in their Research Excellence framework submission to the UK.

3.4 WP4

The results of WP4 will primarily be used outside the context of the uCARe project. The possible routes of exploitation are described below.

3.4.1 Effectiveness of behavioural measures

TNO will use these results to communicate with cities to show them the emission reductions that are possible without making changes to the vehicle fleet. The results of this analysis can be shared with the city of Amsterdam. Additionally, TNO will adapt the VERSIT+ emission factors based on the uCARe measurements including the work on cold-start emissions and wear emissions. This is used in national emission reports in the Netherlands.

The main goal from the uCARe project for INFRAS was validating, and possibly improving, the emission factor application HBEFA (Handbook of Emission Factors for Road Transport), which INFRAS develops in collaboration with TU Graz, EMPA, Heinz Steven and other partners outside uCARe. HBEFA is used by authorities, private consultants and universities and represents an important input for other emission calculation tools like COPERT, EcoTransIT or TREMOD. This goal was met within the uCARe project. As a result of the significant amount of real driving data collected in the uCARe project the driving cycles have been thoroughly validated and will likely be improved in the next version of HBEFA. Furthermore, additional validation was possible regarding driving aspects such as average trip lengths, cold start behaviour, as well as non-driving aspects, such as tire pressure, carrying of external loads and use of air conditioning.

VUB performed the analysis of the likeliness of uptake of measures. The task exploited the driving and survey data collected during the pilots. The results were also used as input for INFRAS' work on the extrapolation of pilots. The goal was to understand the willingness and effectiveness of drivers to reduce their emissions with ecodriving.

3.4.2 Evaluation of air quality impact

ICCT will try to make sure that all results will be used by various stakeholders after the project. ICCT will do this by continuously talking about these results to policy makers and regulators. ICCT is involved in MILE 21 and CARES and will suggest using results from uCARe in those projects. LAT will try to exploit results with regional and national authorities in Greece aiming at the execution of local projects for the improvement of air quality via uCARe measures. IVL will try to exploit the pilot results in Sweden among their stakeholders, such as national authorities, municipalities and cities.

4 Conclusions and future work

4.1 Conclusions

The uCARe project has produced a number of exploitable results. These results include a wide array of possibilities to reduce vehicle emissions by making changes to driver behaviour. In summary the following exploitable results were produced:

1 A taxonomy for vehicles and technology.
2 Augmented Emission Maps (AEMs) for different vehicle types and emission species.
3 Three paths for cheap monitoring systems which can be used as feedback to vehicle users.
4 Citizen science videos.
5 The car-specific software for emission estimation.
6 The webtool GUI for trip analysis.
7 Evidence of factors that encourage or discourage change.
8 A set of methods used to collect data and impact evaluation indicators.
9 Teaching material aimed at changing driver behaviour
10 Effectiveness of behavioural measures
11 Evaluation of the expected air quality impact

A number of these results have already been exploited within the context of the uCARe project. The exploitation of these results outside of the context of the uCARe project has already occurred in the following projects:

1. Policy study on preventing and opposing emission fraud with road vehicles requested by the Flemish government.
2. Study requested by the Flemish government regarding emission factors of plug-in hybrids.
3. The LIFE project MILE21.
4. The H2020 project CARES.
5. Internally within a number of partner organisations: TNO, EMPA, INFRAS, TUG, LAT.

The further exploitation of these results outside the context of uCARe is currently planned on the short-term in a number of projects. These projects are:

1. Input for adaptation of the VERSIT+ emission factors and updating of the Dutch emission registry.
2. Input for the adaptation of the HBEFA emission factors used by authorities, private consultants and universities and represents an important input for other emission calculation tools like COPERT, EcoTransIT or TREMOD.
3. Updating the CONOX remote sensing database.

The results of uCARe can also be exploited in other future projects. The possibilities for this include:

1. Providing input for emission tool builders.
2. Enabling the standardised exchange of vehicle emission data.
3. Raising awareness amongst citizens on how their emissions can be reduced.
4. Raising awareness amongst stakeholders to help setting up projects to reduce vehicle emissions.
5. Giving shape projects to reduce vehicle emissions by changes in driver behaviour.
6. Evaluating projects to reduce vehicle emissions by changes in driver behaviour.

4.2 Future research

A number of steps were made towards the objectives of the uCARe project. This forms a thorough scientific basis for future research. This future research revolves around three main topics:

1. Pilots for additional options to reduce emissions
2. Advanced training strategies
3. Electric and hybrid vehicles

4.2.1 Pilots for additional options to reduce emissions

Due to the effects of COVID the pilots executed in this project were more limited than anticipated during the proposal phase of this project. The effect of this was that the focus of pilots was mainly on driving behaviour and on vehicle emissions. In WP 1 the effects of tampering and ageing of a vehicle were also shown to have a significant effect on vehicle emissions. The owner of a vehicle can play a role in reducing these emissions by repairing vehicles correctly and avoiding tampering with the vehicle. Future research should focus on measures to address these elements of user behaviour.

4.2.2 Advanced training strategies

One area for future research that became apparent in WP 4 is that even after driver training, drivers were still mostly unable to drive optimally. That is, while driver performance improved due to driver training, there was still much more room for improvement. It could be interesting to further examine different driver training strategies to see which training methods could provide the most long-term improvement with the lowest cost – which would be important when scaling driver training to a European-wide level.

4.2.3 Electric and hybrid vehicles

Finally, the effects of changes in user behaviour on vehicle emissions in this study were focussed on internal combustion vehicles. In future research the effects of user behaviour on energy consumption of plug-in hybrid and battery electric vehicles should also be investigated. The behavioural changes for these vehicle types differ from those of conventional vehicles to some extent.