Noise and **E**missions
MOnitoring and Radical Mitigation

Research and Innovation Action

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Final Exploitation Plan

WP9, Task 9.5

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Abbreviations and acronyms

Acronym	Description
RSD	Remote Sensing Device
CAGR	Compound Annual Growth Rate
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCCA	Life Cycle Cost Analysis
NBS	Nature Based solution

Executive Summary

The H2020 NEMO project is an Innovation Action, where different cutting-edge technologies have been developed, tested and piloted in different environments. This portfolio of solutions aims to monitor transport emissions and noise, for a selective and more effective enforcement on highly emitting vehicles, as well as implementing mitigation technologies and smart policies to reduce or mitigate the effect of transport emissions and noise on human beings.

This document explores the exploitation potential of the NEMO technologies and proposed solutions. The report includes recommendations to guarantee the continuation research and business models after NEMO.

NEMO technologies can be applied for different applications and can be directed to different end-users. They are targeted for almost any country worldwide. Some solutions are more suitable for advanced economies, while other solutions have a very interested role for developing countries. The market size is expected to grow at 30% CAGR until 2027.

NEMO's technologies have achieved a high functional level, even though the objective of the project was to develop prototype solutions.

These technologies are fully market-ready or remarkably close to market readiness. All partners intend to continue to invest in these solutions, improve them and bring them to the market for commercial exploitation.

There are immediate plans to put these solutions on the market, first in Europe and then elsewhere (mainly USA and Asia). Certain regulatory barriers in Europe need to be overcome for these solutions to truly scale. There is end-customer interest in using the technologies, but the lack of regulation is limiting commercial adoption, as they cannot yet be used in Europe to regulate the circulation of high-emitters.

NEMO has opened many doors for future research and development, as well as combining other technologies or improving existing ones. Partners will benefit greatly from the results of this project to boost their businesses and offer even more comprehensive sustainability solutions.

Keywords

Remote sensing, transport, emissions, noise.

1 Introduction

1.1 Purpose, scope and target group

The H2020 NEMO project is an Innovation Action, where different cutting-edge technologies have been developed, tested and piloted in different environments. This portfolio of solutions aims to monitor transport emissions and noise, for a selective and more effective enforcement on highly emitting vehicles, as well as implementing mitigation technologies and smart policies to reduce or mitigate the effect of transport emissions and noise on human beings.

This document explores the exploitation potential of the NEMO technologies and proposed solutions. The report includes recommendations to guarantee the continuation research and business models after NEMO.

1.2 Contribution partners

Table 1: Contribution of partners

Partner nº and short name	Contribution
CART	All
MLL	All
MRAIL	All
M+P	All
AUD	All
UC	All

1.3 Relation to other activities in the project

Table 2: Relation to other activities in the project

Task	Description
8.1.3	Policy proposals described in this task are used as input for this report.
8.2	Demos impact assessment are considered to evaluate the readiness of NEMO technologies for the market. The economical evaluation is used as input to consider the potential impacts of a large-scale implementation of NEMO technologies.
9.4	The feedback from cities and different targeted dissemination activities to them are used as input for this report, to evaluate the market acceptance of NEMO solutions.

2 Overview of NEMO technologies

RSDs, Nautilus, pavement, barrier

There are four key technologies developed in the project:

- Vehicle emissions remote sensing devices (E-RSD)
- Vehicle noise remote sensing devices (N-RSD)
- Remote sensing data platform (NAUTILUS)
- Porous and photocatalytic asphalts (Nemo Pavements)
- Multifunctional barrier (ASWALL)

2.1 Vehicle emissions remote sensing devices (E-RSD)

Road vehicle emissions remote sensing devices (RSDs) exist since several decades. The first prototype was patented by the University of Denver in the late 1980s, and different upgrades and commercial systems have been developed and marketed since then, both by researchers and private entities. In Europe, the only manufacturer of such a technology is Opus Remote Sensing (ORSE), which is also worldwide the only ISO-17025 accredited entity to conduct this type of measurements.

ORSE and OTS have developed a new prototype of this technology, called E-RSD. It provides different new capabilities, explained in detailed in other deliverables, but in essence, it can be applied to already existing markets of road transport monitoring and enforcement. The main improvements of the E-RSD technology are related to 24/7 operation and infrastructure integration capabilities. Traditional RSDs were portable and required a substantial manpower for its daily use. NEMO developments have resulted in a new technology that provides a device with fully autonomous capabilities. Another interesting feature is that this new system can monitor emissions from 2-lane roads.

This device has been validated by the JRC in Ispra, and deeply tested for road traffic in Florence and Madrid. It was also tested in a short experiment in Valencia to measure gaseous emissions from diesel locomotives.

A different approach was used for ship gaseous emissions remote sensing. The same conceptual approach to analyze emission plumes (calculating polluting ratios to CO_2) was applied for ship emissions using fast-response air quality sensors.

Altogether, NEMO's vehicle emissions remote sensing devices can monitor pollutant emissions (NOx, CO, HC, NH3, SO2 and PM) from road, sea and rail vehicles.

2.2 Vehicle noise remote sensing devices (N-RSD)

In a similar way, a system to measure noise emissions from individual circulating vehicles was developed in the NEMO project. The partners MBBM and MRAIL developed different solutions that combine commercial microphones deployed on the roadside or gantries to measure noise levels from passing road vehicles or trains. These technologies were fully tested in Rotterdam, Florence, Madrid and Haaren.

In an analogous method to vehicle emissions remote sensing, this solution relates the individual sound levels to each passing vehicle (or wagon).

2.3 Remote sensing data platform (NAUTILUS)

The E-RSD and the N-RSD can operate alone or combined. Obviously, the combination of noise and emissions sensing is a highly valuable and novelty solution. Operators could monitor and control both the pollutant emissions and noise levels from each vehicle, by combining these sensors.

Both technologies (E-RSD and N-RSD) were co-located in the NEMO project in Florence and Madrid, with very positive results. The combination of these systems can also result in efficiency savings. For instance, a unique video camera (for license plate recognition) and a unique power source was used for both systems simultaneously. In this type of setup, all instruments are deployed together (or within a limited space around a certain road site).

There can be some cases where both technologies should be deployed in a combined fashion, but physically separated from each other, at different roads and streets. The reason is that each type of sensing technique may require some ideal requirements, and these may be found at different spots of a city or a motorway. In these cases, the E-RSD and the N-RSD are deployed with all their associated peripherals at each site.

For both cases, synchronizing or matching the information from each sensor is a critical task. There needs to be a solution that associates the measured emissions and noise to each vehicle and each vehicle passage. This solution was also developed in the NEMO project, and is called NAUTILUS.

NAUTILUS is a data platform that combines data from any number of E-RSDs and N-RSDs deployed on a certain territory. It creates unique reading records to each vehicle, so that end-users can use the data appropriately. It also provides a solution to integrate technical data information from vehicle registry databases, and provides a control panel and a dashboard for data analytics. The NAUTILUS platform has also the potential to be transferred to the market, as a software solution that enhances the capabilities of the E-RSD and the N-RSD.

2.4 Low noise asphalt mixtures (Nemo Pavements)

The ability of a road surface to mitigate traffic noise emissions depends on the fleet composition and traffic conditions. In the NEMO project, the UC and M+P have developed two specific formulas, one for urban and one for peri-urban areas.

The design of the asphalt mixtures was carried out based on previous research on tire/road interaction models. The tire/road interaction model applied for the acoustic design of the mixtures allows calculating the mechanical loss in the rolling tire. Thus, through a design optimization process, the optimal combination of high noise reduction and low rolling resistance was defined for two different fleet composition and traffic conditions, one specific for urban areas and one specific for peri-urban roads.

Apart from minimizing noise and rolling resistance, the new formulations present a very good mechanical performance. The two mixtures have been tested through an Accelerated Pavement Test at the pavement fatigue carrousel of IFFSTAR. The two mixtures have been produced and paved on a real scale and evaluated in terms of their mechanical and functional performance (skid resistance, rolling resistance and noise mitigation). The mixture design for urban roads (NEMO-urban) has been implemented in a real road section in Florence where its noise mitigation capacity has been assessed and compared with a conventional pavement. Targeted mitigation noise values have been largely achieved.

For the optimal design of the asphalt mixtures by UC in terms of noise and rolling resistance, target values for flow resistivity, acoustic absorption, texture wavelength spectrum and r.m.s were defined by M+P based on the tire/road interaction models. The UC carried out the mixes development to comply with these specifications, ensuring that a good mechanical performance was also ensured, at the level of the reference mixture.

The ability of the mixtures to retain microparticles in their porous structure was also evaluated at the IFFSTAR's fatigue carrousel. Based on the results, it seems that both mixtures (urban and peri-urban) allowed the collection of more particles than conventional dense mixtures at the beginning of their service life (1 to 3 years) but later this effect is reduced.

An environmental and economic assessment (LCA and LCCA) of the NEMO pavements comparing to conventional pavements have been carried out (including the effect of noise reduction). The results indicate a huge environmental and economic benefit when high traffic and population density is affected.

2.5 Multifunctional barrier (ASWALL)

With the objective of improving the acoustic and air quality in urban areas the multifunctional barrier solution it focused on the mitigation of the main pollutants of traffic in cities. Multifunctional barrier combines an acoustic barrier, designed specifically for this project, with an innovative biofilter. More specifically, the aim of this system is the reduction of levels noise, nitrogen oxides (NOx) and particulate matter (PM) from road traffic in urban areas.

Traditional acoustic barriers are focused on mitigating noise pollution from road traffic, mainly, ad creating more pleasant and healthier urban environments. Materials such as concrete or acrylic, in transparent acoustic barriers, are traditionally used. Moreover, vegetation-based noise barriers, known as "green walls" or "living walls," were gaining popularity. These barriers incorporate vegetation to absorb and reflect sound, providing a Nature Based solution (NBS).

To improve of state of the art, NEMO multifunctional barrier, commercially called ASWALL (Acoustic Solution Wall), has integrated noise mitigation and the use of Nature-Based Solutions (NBS) into a single system. ASWALL, developed by AUDIOTEC and CARTIF and demonstrated in the city of Valladolid, Spain, has achieved positive results in reducing noise levels and the targeted pollutants, NOx and PM.

3 Market analysis

In this chapter the market of the NEMO solutions is defined and analysed.

3.1 Market opportunity assessment

NEMO technologies can be applied for different applications and can be directed to different end-users. Two different groups are distinguished, as they have different markets, use cases and objectives:

- Monitoring solutions: The E-RSD, the N-RSD and NAUTILUS are designed to measure and control road/rail/sea individual vehicles' noise and emissions.
- Mitigation solutions: the pavements and the barrier are designed to mitigate the noise and emissions emitted by road vehicles.

It is estimated that the monitoring solutions have a large market opportunity worldwide, while the mitigation solutions have a more limited, but very niche market opportunities for (mainly) cities.

The following graph gives an overview of the main applications of the monitoring solutions:

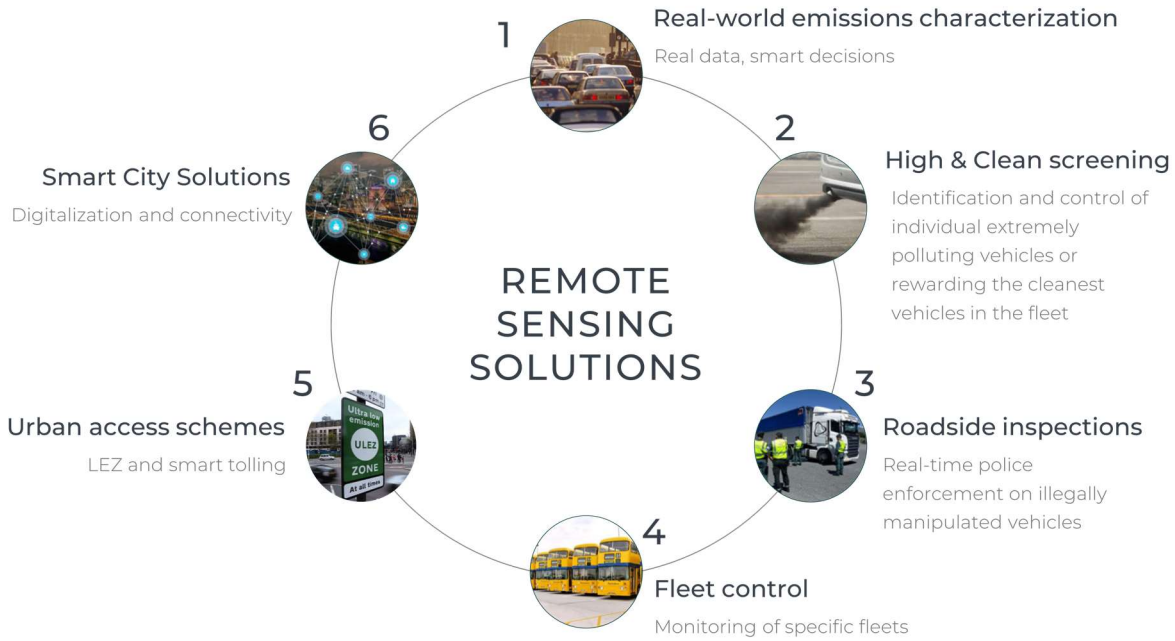

Figure 3-1. Road-traffic remote sensing applications

Each of these applications are described below.

1. Real-world traffic emissions characterization:

The RSD provides data of real-world traffic emissions in order to make decisions based on REAL and ACTUAL data. What is not measured, cannot be improved. The first step in almost any large-scale program is to analyse the traffic data collected at all different points in the city, which leads to many other potential applications. his application is related to large-scale data acquisition to try to answer several critical questions, such as:

- How much pollution is produced by road transport in a specific city?

- How much does each group of vehicles contribute to total pollution?
- How do the actual emissions from vehicles in my city compare to other similar cities?
- What is the relationship between actual vehicle emissions and the different areas of my city?
- How often do hybrid vehicles run in electric mode in each area of my city?
- How do my current emission inventories compare to actual emissions from the fleet in circulation?

This application is remarkably interesting for cities and environmental agencies.

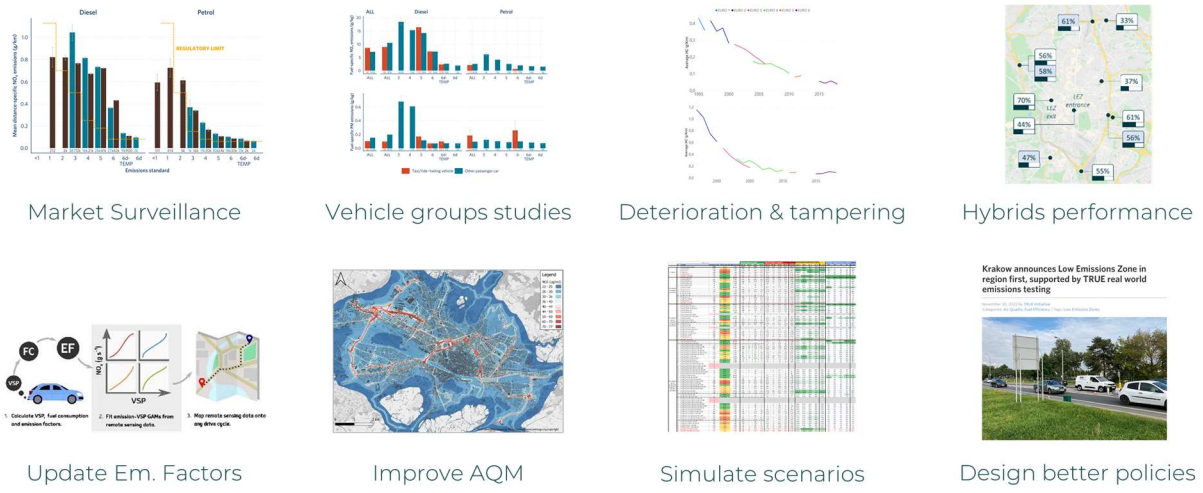

Figure 3-2. Examples of studies that are done with this application

2. High and Clean screening:

The RSDs are used for the identification and control of individual extremely polluting or noisy vehicles or rewarding the cleanest vehicles in the fleet. This is the main application foreseen in the NEMO project.

Remote sensing can identify the worst polluting vehicles circulating in urban or non-urban areas, enabling government agencies to target only those that cause the biggest problems for air quality. Deploying a set of devices all across a certain territory, in an itinerant scheme, authorities can issue notices of violation, requiring the worst polluting vehicles to return for re-inspection at an inspection station, excluding them from low emission zones or immediately pulling them over for a hands-on roadside inspection.

A "High Emitter Identification Program" is a program that is established in a given region to identify the worst polluters and take some action on them. Generally, and for legal protection of the vehicle owner, the identification of these vehicles is not punitive, but helps the Authorities to notify the vehicle owner to perform an extraordinary check of his/her vehicle, a practice that is usually contemplated in most international traffic regulations.

These programs have evolved in the USA to identify not only the most polluting. but also the cleanest vehicles. This activity is called "Clean Screening". Clean Screen offers owners of the lowest polluting vehicles exemption from their next station-based emission test. Vehicles identified as clean on the road by an RSD then get a Clean Screen notice in the mail. All they need to do is pay the test fees - and they are done. There is no need to visit an inspection station. Clean Screening is the most profitable business regarding vehicle emission remote sensing and is a positive measure to reduce air pollution.

3. Roadside inspection:

The RSD is an excellent tool for the police. It can be used as an "alert system", detecting highly emitting vehicles, which can give an indication of a potential illegal manipulation of the vehicle. In recent years the use of RSDs for the identification of illegally manipulated trucks at police controls has increased in Europe. The versatility of the RSD and the fact it can be deployed and started in minutes, is perfect for surprise roadside checks.

It is known that many heavy-duty vehicles (HDV) circulating on European roads may have some form of emission control manipulation. These vehicles constantly cross the borders of many countries, making the problem a very serious one. The most common manipulation nowadays is to disconnect the AdBlue injection that reduces NOx emissions in diesel trucks. European legislation requires that the diesel vehicle monitors the level of AdBlue in the tank. If the tank is empty, the engine is prevented to be started. This manipulation is done thanks to many different tricks, some of them with the so-called "AdBlue killers", which are devices that can be purchased for a very low price on the Internet and can be easily installed into driver's cabin. The AdBlue killer makes the computer believe that it is injecting AdBlue when it is not. In some cases, the device is very well hidden and finding the infraction is cumbersome.

Finding and sanctioning the owners of these vehicles is a desire of most traffic police forces worldwide. Most laws in the world allow the police to make these roadside checks. In Europe, the directive 2014/47/EU even says that RSD can be a system to fine these vehicles.

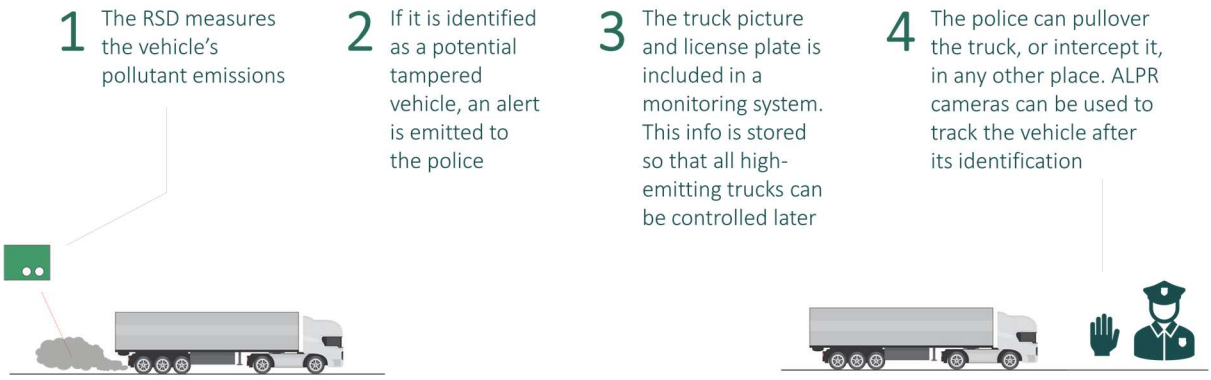

Figure 3-3. Roadside inspections triggered by remote sensing pre-alert

4. Fleet control

High exhaust vehicle emissions are associated to non-efficient fuel combustions, which also means elevated fuel consumption. By identifying high-emitting vehicles with remote sensing, private companies can save fuel (and pollutant emissions) in their fleets. Also, there are plenty of possibilities by evaluating controlled fleets of vehicles, for instance estimating the reduction of emissions by repairing or retrofitting some individual vehicles.

Fleet owners want to know the status of their fleets. They want to know if all vehicles are working properly or if any of them may be deteriorated or is close to a failure. They also want to check that any vehicle of their fleet is illegally manipulated by subcontractors or drivers. On the other hand, Public Authorities want to know if the concessionary companies comply with the regulations; they also want to audit the real emissions of their public buses or carry out specific evaluations of some groups of vehicles in terms of real emissions, like taxis or other public vehicle fleets.

For all those cases, The RSD is the most cost-effective solution, as vehicles can be evaluated without interrupting their normal operations.

5. Urban Vehicle Access Regulations

The road infrastructure network can be leveraged to create large-scale solutions that massively monitor road traffic emissions. On-road gantries already equip systems and infrastructure that can be enriched with RSDs. The integration of these technologies transforms the way urban transport is managed. Urban tolls can be implemented, charging for access to cities based on the emissions emitted by each vehicle and the flow of traffic, in real time and under 5G connectivity.

It is critical to reduce traffic congestion and improve air quality in most large cities. By creating solutions that prevent access to the most polluting vehicles (high-emitters), both factors can be improved, enhancing the well-being of citizens on multiple levels. Urban tolls are the best solution to ensure that the externalities generated by the use of private vehicles (air pollution) are reflected in the cost of their use (access fee). In this way, the social cost incurred by each driver when using their vehicle is internalized.

Networks of sensors and intelligent systems can be deployed throughout the city and its main access roads. The sensor networks can be integrated into a unified Digital System and the 5G network. Through these sensor networks, vehicle accesses to cities or specifically to Low Emission Zones can be managed. The circulation of high-emitters on certain roads can be charged or denied.

The following diagram shows a possible urban toll model, combining vehicle access fees by environmental label and preventing access to the most polluting vehicles:

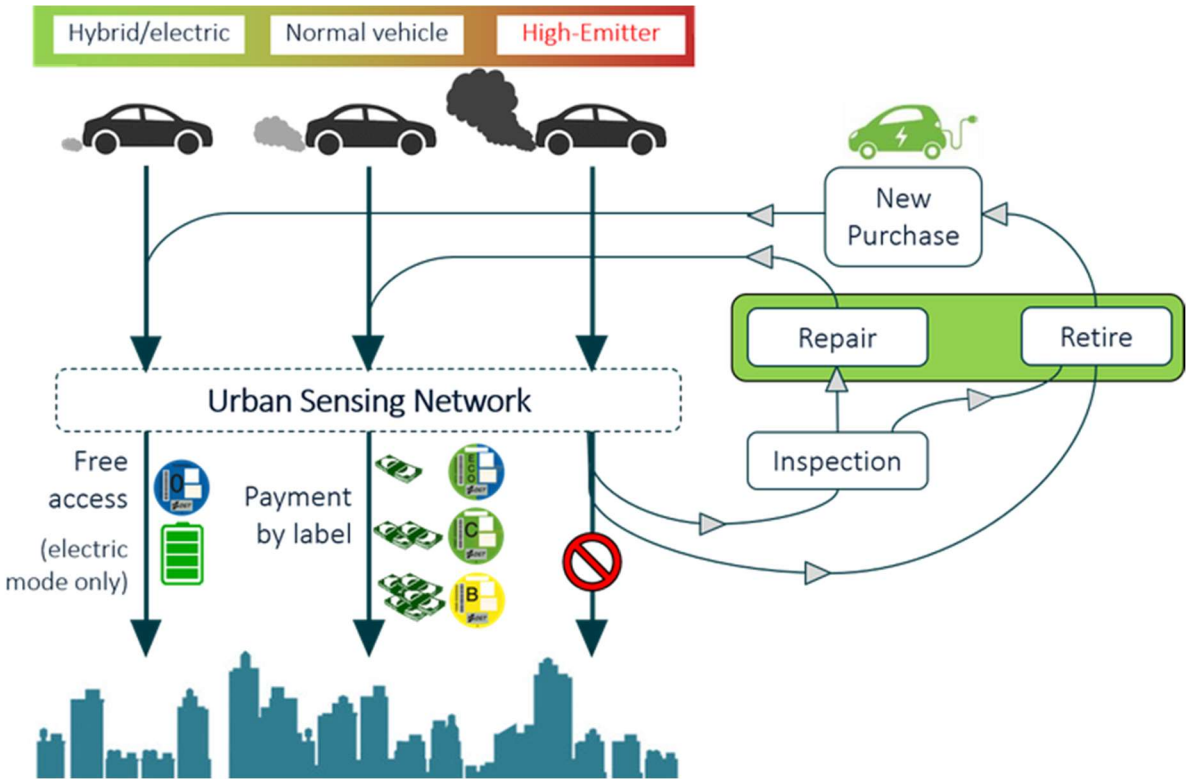

Figure 3-4. Conceptual scheme of an advanced vehicle access regulation policy using a network of RSDs

6. Smart City solutions

Creating an intelligent city requires the implementation of technologies that allow for the capture of actual, real-time information about the city and its moving elements (citizens and vehicles), and the integration of all captured data into digital data management and decision-making platforms.

Technologies of real value and low-cost are needed to sensor the city on a large scale. Connectivity and digitalization must be the basis of everything else, to take advantage of the potential of the technologies and apply the decisions in real time, to inform pedestrians, drivers ad connected vehicles anytime, anywhere, in real-time.

We propose the creation of a sensing network (which can be used to manage urban traffic), which operates under an integral digital platform, unifying RSDs and many other deployed sensors.

RSDs report real-time emissions levels to drivers or directly to connected cars. Secure web portals for citizens to consult the emissions of their car in real-world conditions are possible. All the process can be integrated with traffic authority IT and be customized to each jurisdiction and objectives.

Mitigation solutions:

The mitigation solutions (asphalt and barrier) are different than the monitoring solutions. Their applications are targeted to cities (both pure urban and peri-urban areas), to mitigate the local effects of air pollution and noise from the vehicles. Thus, the market is related to the installation of both in cities, either as urban furniture or replacing existing pavement roads.

3.2 Target markets, segments and market size

NEMO technologies are targeted for almost any country worldwide.

Some solutions, like the pavement and the multifunctional barrier, are suitable for advanced economies, with high-quality infrastructure in cities, but where citizens and authorities seek for better mitigation solutions.

The E-RSD and the N-RSD, on the other hand, are targeted for both developed economies or countries under development. For the first, authorities want to push the efforts on the vehicle fleet emissions, to meet their challenging sustainable goals; high-emitters are more accused in “clean” fleets, so a solution to find and enforce these vehicles is critical. For the countries under development (i.e. South America, Southeast Asia and Africa), que fleet is typically in a much worse state; some of these countries do not even have Inspection and Maintenance programs (like PTIs), so NEMO technologies can help them in the reduction of traffic emissions and digitalize their economy.

According to Markets&Markets analysis[1], the global automotive exhaust sensing market size alone is projected to grow from USD 76M in 2022 to USD 147M by 2027. That is a consistent CAGR of 14,1% from 2022 to 2027. This study was done without considering the new developments from NEMO. ORS estimates that the market growth can be closer to 30% now, thanks to the new capabilities of the technology (fully autonomous, 24/7 capabilities, better performance, dual-lane capability, etc.).

[1] https://www.marketsandmarkets.com/Market-Reports/remote-automotive-exhaust-sensing-market-202934663.html

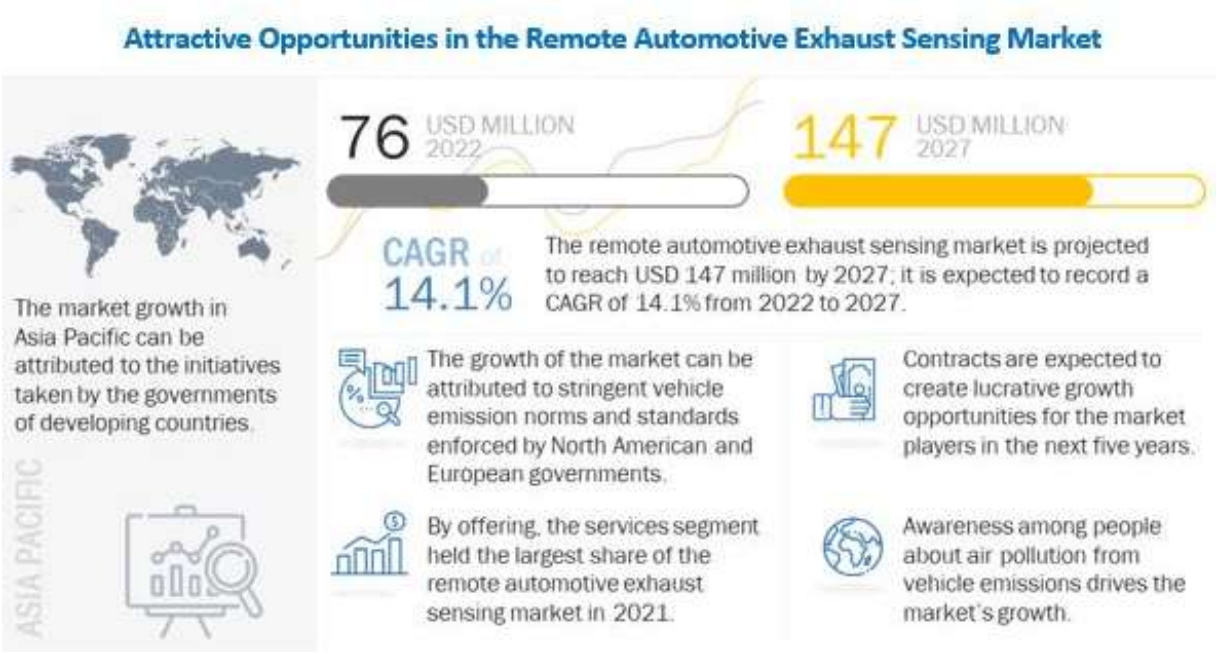

Figure 3-5. Capture from Markets&Markets report

3.3 Competitive landscape

NEMO solutions have an outstanding selling proposition. These are very unique technologies, with limited competitors worldwide.

ORSE is worldwide the market leader of vehicle emissions remote sensing. Its technology has been used in dozens of countries across the five continents, with large-scale massive programs in the USA, and other smaller, but also long-standing programs, in Asia. There are just 2 or 3 competitors in USA and China, so the leadership position is a remarkable ground to scale-up the NEMO E-RSD.

MBBM, M+P and MRAIL are leaders in noise monitoring and analysis services too. There are a few relevant competitors with similar products as the N-RSD, like the Medusa system from Bruitpariff. Nevertheless, the flexible concept of NEMO N-RSD and its algorithm capacities may have a competitive advantage.

NAUTILUS is a very unique solution too. Only ORSE has a similar solution, but it is proprietary. With NAUTILUS, ORSE could still offer its own private data platform, but other partners could use the NAUTILUS data platform on their own. Having these two IT solutions in the market is a very attractive scenario for competition and innovation growth.

The NEMO pavements have an excellent noise mitigation capacity and can be used by road administrations to mitigate noise both in urban (with speeds of 50km/h) and peri-urban environments (speeds of 80km/h). The methodology and materials used for the development of these mixtures have been published in open access, so free use of it is possible by constructors, asphalt plants and road owners. The methodology can be re-applied for the design of new mixtures for areas in which the fleet composition and traffic conditions are different.

And finally, the multifunctional barrier, which is an innovative solution focused on urban environments. It adapts to the demands of citizens, who request more and more spaces in cities free of noise and air pollution. The multifunctional barrier reduces noise levels and is especially focused on protecting terraces, which are increasingly common in our cities. There are several hoteliers and city councils that

show interest in implementing this solution due to the possibilities of adaptation to the environment of the solution and its effectiveness.

Regarding the acoustic solution, the barrier protects people from the noise of road traffic and improves acoustic comfort by improving the sound absorption conditions in the space occupied by people and without penalizing the landscape impact. The trend in this market is expected to move towards low-rise, high-efficiency solutions that are manufactured from environmentally friendly materials.

Concerning the biofilter only, the competitive landscape is likely to continue evolving as new technologies and strategies emerge to combat urban pollution. Currently, measures to reduce pollution in cities focus on the reduction of pollutant sources, mainly related to road traffic. In this respect, the biofilter system is intended for this function and is therefore presented as a complementary measure. The adaptability of the biofilter system makes it possible, on the one hand, to act in the purification of pollutants once they are in the atmosphere by generating small spaces with reduced pollution, which is the case of the system integrated in the multifunctional barrier. This system is analogous to the air purification systems used in indoor environments. On the other hand, the biofilter system can be adapted to low-intensity stationary urban sources such as high-intensity underground parking and tunnels, by acting directly on the polluting source.

The technology used in the solution for acoustic and pollution protection is fully developed and integrated into the multifunctional barrier and it is estimated that in the short term it can be mass-produced if the market demands it.

4 Technology Transfer

This chapter details how the NEMO technologies will be transferred into the market, what upgrades or further developments are required to put these solutions into the end-users' hands and how the IP is organized among the consortium.

4.1 Licensing and Intellectual Property

As defined in NEMO's Grant Agreement, each partner keeps the Intellectual Property of its own development. Considering this, each partner will transfer its developed technologies into the market, keeping its right to commercialize it worldwide.

ORSE will fully commercialize the E-RSD and will keep the Intellectual Property of this system.

MBBM and MRAIL will fully commercialize their respective N-RSD solutions and will keep the Intellectual Property of the systems.

M+P will fully commercialize the NAUTILUS platform and will keep the Intellectual Property of this software.

UC and M+P will publish in open access the methodology and results obtained during the development and testing of the mixtures at the laboratory. The results and conclusions from the large implementation of the mixtures at the fatigue carrousel at IFFSTAR and the results obtained from the pilot in Florence will also be published by UC, M+P, IFFSTAR and ARPAT.

AUDIOTEC CARTIF will fully commercialize the multifunctional barrier and will keep the Intellectual Property of this solution.

4.2 Ready-to-market strategy

As an innovation project, NEMO technologies are developed from scratch or a very low TRL, reaching a TRL 6 at the end of the project. In order to fully transfer these technologies to the market, a final development push must be done by each solution responsible.

The E-RSD reached a TRL 6 at the end of the project. The performance was fantastic, but there were a few barriers or technical limitations found during real-world testing. In particular, the quantum cascade laser technology needs a higher maturity level, to provide higher endurance in harsh road environment. At the same time, the top-down deployment was found to be not recommended. ORSE will continue to investigate and develop this prototype. Nevertheless, in the meantime, ORSE has already been able to transfer some of the solutions of NEMO into its commercial RSD. That way, the new RSD 6000 will be able to measure 24/7, without any human presence on the road, and it will also be able to monitor vehicles circulating in 2-lanes roads. Thus, the RSD 6000 will receive a technological transfer from the E-RSD to obtain its key capabilities pursued in this project. The RSD 6000 will be ready to be marketed in January 2024 (TRL 10) and is already in the sales pipeline for several customers.

The N-RSD reached TRL 6 at the end of the project. The performance was also very good, and it has been determined that by simply upgrading some components (microphones, computers, modem and electronic sound board), the solution will be fully ready-to-market. Some improvements on the algorithms and data processing are foreseen too. MBBM is already doing these upgrades and looks for its real-life implementation during 2024 too.

The NAUTILUS platform reached TRL 7 at the end of the project. It is almost ready-to-market and would only need a real customer to integrate this solution into the customers premises or existing IT infrastructure. There is a lot of room for improvement, but it is a solution that can already be sold and transferred into the market.

The NEMO-urban mixture reached TRL7 at the end of the project. The manufacturable version of the mixture (real scale manufacturing) is now working on an environment which addresses all the operational requirements for the product. For reaching higher TRL a higher number of road sections would be needed to be implemented and monitored. The evolution of the mechanical and functional performance (noise mitigation) needs to be monitored during the mixture's service life. The NEMO-peri-urban mixture reached TRL6 at the end of the project, since a functional version of the product worked on a realistic environment able to draw conclusions on the technical and operational capabilities of the product (fatigue carrousel).

The barrier reached TRL 8 at the end of the project. ASWALL is ready to-market in several urban settings. Potential locations identified include rest areas, as demonstrated, hospitality terraces, streets with high noise and pollution levels, etc. In addition, the biofilter can operate autonomously, making it a solution for low-intensity stationary urban sources such as high-intensity underground parking and tunnels.

In October 2023, the European Commission's EIT gave the NEMO partners two awards for the E-RSD and N-RSD, declaring their successful state of "ready-to-market". This external recognition reinforces all the results obtained in the project and encourages the consortium to exploit these solutions.

4.3 Partnerships and Collaborations

Even if each partner will keep the IP and commercialization rights of its own developments, there are existing agreements to jointly put these technologies together in the market:

- ORSE and KAPSCH are discussing a formal collaboration to market together the E-RSD in certain territories. KASPCH can offer existing ITS solutions and holistic traffic control solutions, while ORSE can act as a technological provider.
- ORSE and MBBM are exploring potential cases where the E-RSD and the N-RSD are co-located inside cities, for a complete monitoring of road traffic noise and emissions. The companies will reach to specific agreements on a case-by-case basis, depending of each opportunity scope.

Additionally, ORSE will leverage existing partners outside the NEMO consortium to put the E-RSD into the market. This can also trigger opportunities for other NEMO solutions, especially for the N-RSD.

Finally, collaborations with other research groups are in place too. Again, ORSE is in conversations with some partners of the CARES project to integrate CARES solutions into the NEMO solutions. If this collaboration reaches the market, it will indeed be an example of how two similar EU-funded projects can join forces to provide better combined solutions. Many of the CARES partners are long-standing partners of ORSE, so the possibility of fulfilling these collaborations is high.

5 Barriers and Challenges

The NEMO solutions are on a strategic and promising situation. There are huge market opportunities, and the different technologies are fully or near ready-to-market level. This is by itself a major achievement of the project, but there are always barriers that need to be eliminated to facilitate a large-scale marketing.

5.1 Technical

The remaining developments or upgrades to have fully ready-to-market technologies were already explained in section 4.2. There are no other relevant technical barriers found, although real-world use cases may awaken unseen requirements. However, no critical technical barrier should limit the marketing possibilities of NEMO solutions.

5.2 Regulatory

Regulations (and for specifically, the lack of them) are the main barrier to put NEMO monitoring solutions in the market. This has been explained in other deliverables, including a document with policy recommendations, to solve this problem.

The European Union would certainly make a good use of the E-RSD and the N-RSD. Many cities have the will to use these technologies to identify find high-emitters and act selectively on them. Road tolling operators have identified that these technologies could be integrated in their roads to applied variable tariffs, with polluters-pay schemes and selective restrictions (or changing) to city centers.

However, as the European Union has not regulated vehicle emissions or noise remote sensing, and the cut-points to define what a highly-emitting vehicle is, end-users are very limited to use these amazing technologies.

Curiously, as other countries in America and Asia do have this already introduced in their legislations, NEMO solutions could have a better market adoption outside the EU. Of course, it is very positive if Europe exports high-value technology to other countries, but it would be outside any logic if the financial investments of the EU to develop these European technologies are not broadly implemented because the EU has not regulated them. It would, of course, be a conflict with the very own intentions of the Horizon 2020 Call.

NEMO partners are pushing as much as possible so that legislators regulate the remote sensing technologies.

The pavement and the barrier have no major regulatory limitations. Both can be deployed today with existing regulations.

5.3 Market acceptance

Market acceptance is a critical factor to allow the commercialization of NEMO technologies. The pavement and the barrier full acceptance from authorities and general public, as these are solutions that cannot have any inconvenience neither negative effect.

On the other side, the monitoring solutions can be a more sensible solution, as they require a change of mindset and policy strategies. The most important potential of the E-RSD and the N-RSD is to find high-emitters. By identifying high-emitters, authorities can act selectively on these vehicles to reduce air pollution and noise annoyance. However, this requires an action on the HE vehicle:

a) Sending the vehicle to an inspection center.

b) Restricting the circulation of this vehicle (temporary or permanently, limited to a zone or to a whole city, etc.).

c) Emitting a fine.

d) Charging this vehicle (tolling roads, public parking, city charging areas, etc.).

In any of these cases, the vehicle owner or driver is affected. This means that the public may be reluctant to this new policy.

NEMO has also worked in the mitigation of this barrier. As cities are now encouraged or legally forced to implement vehicle access regulations (such as low-emission zones), the public acceptance (and thus the market acceptance) is low in some European regions. A strong public dissemination is needed to show how tacking high-emitters is a fair (there is an empirical measurement) and efficient (very few vehicles would be affected) policy to improve our quality of life.

This public acceptance must be linked to authorities' acceptance. The continuous growth of vehicle emissions remote sensing over the last years, beyond the NEMO project, is a very good sign that this barrier is failing fast.

6 Business Model

This chapter explores how the business model can be implemented for the NEMO technologies.

6.1 Revenue model

There are different business models to generate revenue with NEMO technologies:

1. Sale

The solutions can be sold to a customer as a unique payment. This model can fit all NEMO technologies. The pavement and the barrier are especially suitable for this revenue model, as both are installed/deployed and do not require any other further activity. Both the E-RSD and the N-RSD can be sold to a customer, and the sellers or third parties can take care of their operation and maintenance, in a separate service contract. The NAUTILUS platform could be sold as a SW solution, although a service contract for updates and maintenance would be recommended.

This model also includes the possibility to add a license model, including especial features, that could be paid on a monthly basis.

2. Leasing

The E-RSD, the N-RSD and NAUTILUS could also be offered as a leasing. Users could pay for the temporary use of these solutions, on a monthly basis.

3. Service

Finally, there are some cases where all these technologies are offered as a service, alone or coupled with other solutions. For instance, real-life high-emitting screening programs in different countries are offered as a service. The service contract specifies the scope, objectives and economical retribution of the service.

6.2 Sales and distribution

The partners will use their existing sales channels to position these solutions in their portfolios. ORSE and MBBM are already offering these solutions to different clients and there are reasonable opportunities to commercially exploit the solutions in the short term.

The partners will also use the partnerships and collaborations mentioned in section 4.3 to expand the distribution and sales strategy.

7 Impact and Benefit

The NEMO consortium has already done a very extensive study about the impact-cost analysis of implementing the NEMO solutions.

The results are clear and powerful; in all modelled scenarios (more or less optimistic), the net benefit for society outweighs the cost of implementation:

The ***high-emitters*** programme is shown to have a positive net present value (i.e. deliver a net benefit for society) across all four methods for identifying high emitters. In other words, the benefit achieved through reduction in air pollution and noise emissions, outweigh the costs of the system to identify and incentivise the vehicles, and the costs of repairing these vehicles.

For the ***pavement solutions***, there is a clear pattern of effects. For the paving solution itself, NEMO-urban delivers a clear net benefit relative to the reference case. This is because alongside delivering a noise emission benefit for local residents, which will deliver positive health impacts, there is also an implementation cost saving given the agency costs of installing the NEMO-Urban technique are less than those of the reference case. For the photocatalytic material, the costs of applying the technique substantially outweigh the modelled air pollution benefit achieved.

Figure 7-1. Summary costs and benefits – high emitters programme (EURm, 2022 prices, discounted to implementation year, over 10-year appraisal period). NPV

8 Implementation Plan

Each partner will be responsible to implement their technologies into the market. As mentioned before, alliances between the partners and support from external partners will be used as well.

The E-RSD will be implemented into the market in 2024, with some commercial cases and experimental pilots in several sites of Europe. In late 2024 or early 2025, the NEMO solutions, either directly through the E-RSD or implemented into an adapted RSD6000 (using technical developments from the E-RSD), will be implemented in the USA and Asia:

- Q1 2024: installation of a fixed system in a 1-lane road. Continuous monitoring.
- Q2 2024: Installation of a fixed system in a 2-lane road. Continuous monitoring.
- Q3-Q4 2024: Installation of a fixed system in a tolling plaza. Continuous monitoring.
- Q3-Q4 2024: Variable tolling tests (pay-per-real-emissions) in 2 different territories.
- Q1 2025: Sale of systems to USA and Asia.

The N-RSD will be further tested in the Netherlands by MBBM, exploiting existing or new contracts. As the device will be upgraded, as mentioned in Chapter 4, it will be latter marketed in other European countries.

The pavement mixtures will require further research and testing. The University of Cantabria will look for a research continuation in 2024, as well as real-world implementations in other places.

AUDIOTEC and CARTIF are already doing efforts to put the barrier into the market. They plan to repeat the pilot in Valladolid in a second Spanish city in 2024. In addition, opportunities are being sought for the installation of the biofilter as a treatment system in low-intensity stationary urban sources.

Conclusions

NEMO's technologies have achieved a high functional level, even though the objective of the project was to develop prototype solutions.

These technologies are fully market-ready or very close to market readiness. All partners intend to continue to invest in these solutions, improve them and bring them to the market for commercial exploitation.

There are immediate plans to put these solutions on the market, first in Europe and then elsewhere (mainly USA and Asia). Certain regulatory barriers in Europe need to be overcome for these solutions to truly scale. There is end-customer interest in using the technologies, but the lack of regulation is limiting commercial adoption, as they cannot yet be used in Europe to regulate the circulation of high-emitters.

NEMO has opened many doors for future research and development, as well as combining other technologies or improving existing ones. Partners will benefit greatly from the results of this project to boost their businesses and offer even more comprehensive sustainability solutions.