Final report for publication by the EC

*This section will be edited by the Commission as such. The length of this part should not exceed 40 pages. This report should address a wide audience, including the general public. This summary report has to be updated at the end of each reporting period.*

*Please provide an executive summary. The length of this part cannot exceed 1 page.*

Space heating accounts for more than 50% of the energy consumption of public & residential buildings, and reduction of this energy demand is a key strategy in the move to low energy/ low carbon buildings. The careful management of air flow within a building forms part of this strategy through the control of inlet fresh air and exhaust air, maximising air re-circulation, and minimising the amount of fresh air which is often drawn in through a heat exchanger. However, there is a high risk that the air quality is reduced.

Continued exposure to environments with poor air quality is a major public health concern in developed and developing countries. It is estimated that the pollutants responsible for poor air quality cause nearly 2.5 million premature deaths per year world-wide. Significantly, around 1.5 million of these deaths are due to polluted indoor air, and it is suggested that poor indoor air quality may pose a significant health risk to more than half of the world’s population. Due to its link with industrialisation, societal health problems associated with poor air quality disproportionately affects developed and developing nations – it is estimated that air pollution is responsible for the premature deaths of 370,000 EU citizens annually, with average life expectance reduced by nearly 9 months.

Perhaps surprisingly, remedial action to improve air quality is often easy to implement once airborne pollutants have been detected.

The *INTASENSE* project has developed the technology to allow a comprehensive, air quality monitoring system which can detect the main pollutants that contribute to poor indoor air quality (volatile organic compounds (VOCs), combustion gases and particulates).

The technical advances have been made in several technologies and these have then been engineered to create a flexible system capable of use in several applications based on a standard communication module which can link into a wide area wireless network. The use of a Wi-Fi enabled platform extends the opportunities for retro fitting and temporary installations.

The sensor systems are connected through a bespoke microfluidic system which allows even flow and measured rates past each sensor providing the basis for the first quantitative online measurement of air pollution and particulate distribution that is within a price range accessible for general built environments.

In addition to the technical development the understanding of air quality management has been improved including the development of a list of key pollutants in the indoor environment based on likely impact and toxicity.

*Please provide a summary description of the project context and the main objectives. The length of this part cannot exceed 4 pages.*

The key problem is the ability to monitor continuously and quantify air quality and identify the nature of the pollutants themselves. A number of technologies exist that can be used to measure the various concentrations of all the individual major pollutants. Similarly, there already are a number of geographic national outdoor air quality measurement networks that allow the generation of an air quality index (AQI) to inform citizens of potential hazards. These network measurement nodes use a combination of on-line monitoring and periodic sampling followed by off-line analysis to determine the AQI. The monitoring systems and analytical equipment used in these networks is bulky, expensive and cannot provide real-time comprehensive air quality monitoring required to sufficiently protect public and worker indoor and enclosed air spaces. Member States dedicate very considerable resources to measuring and monitoring outdoor ambient air quality and informing the public of the state of ambient air quality - but people actually spend 90% of their time indoors. Although indoor air quality is partially determined by ingress of polluted outdoor air, in modern sealed or semi-sealed buildings most indoor air contaminants arise from sources within the building itself. Hence reliable, integrated, cost-effective monitoring of indoor air quality is a very high priority for human health protection.

*The INTASENSE concept is to integrate a number of micro- and nano-sensing technologies onto a common detection platform with shared air-handling and pre-conditioning infrastructure to produce a low-cost miniaturised system that can comprehensively measure air quality, and identify the nature and form of pollutants.* Such a measurement device will allow the intelligent control of remedial actions and air treatment systems to reduce worker and public exposure to poor air quality, while supporting the move to more energy-efficient buildings with reduced heating demands. Moreover, the capability to use remedial systems more effectively and economically, will promote the wider implementation of air purification. This will lead to an overall improvement in public health and citizens’ quality of life.

The measurement and characterisation of particulate matter (concentration, size, shape, composition) will be a major focus of the *INTASENSE* project. Airborne particulate matter is the pollutant of main concern in relation to human health, with many established links between particulate exposure and chronic diseases, as well as correlations with sickness and allergic reactions.

Poor air quality is of major societal concern. It is estimated that, taken together, the pollutants responsible for poor air quality cause nearly 2.5 million premature deaths per year world-wide[[1]](#footnote-1). Significantly, around 1.5 million of these deaths are due to polluted indoor air, and it is suggested that poor indoor air quality may pose a significant health risk to more than half of the world’s population[[2]](#footnote-2). For example, particulate matter (PM) levels can be more than 10 times higher than the internationally accepted guidelines[[3]](#footnote-3) (a PM10 level < 50 g/m3) in homes where coal or wood is used for cooking and heating.

Due to their link with industrialisation, societal health problems associated with poor air quality disproportionately affect the developed and developing nations - epidemiological studies show that more than 500,000 US citizens die each year from cardiopulmonary disease linked to fine particle air pollution[[4]](#footnote-4). Similarly, it is estimated that air pollution is responsible for the premature deaths of 370,000 Europeans annually, with average life expectancy reduced by nearly nine months[[5]](#footnote-5). Significantly, in many parts of the world, the occurrence of poor health due to poor air quality is increasing as the developing nations industrialise, and as societies continue to become more urbanised.

In addition to particulate matter, the *INTASENSE* integrated sensor system will also have the capability to monitor the concentration of other pollutants such as ozone, SO2, NO2, VOCs, CO and CO2. The *INTASENSE* technology will represent an integration of new micro- and nano-sensing technologies with the advanced miniaturisation of conventional analytical systems. Key advances in micro-fluidics, air-sampling and pre-conditioning systems will also be developed

The quality of air indoors and in partially enclosed and poorly ventilated spaces is of particular concern. It is estimated that the average citizen in developed countries spends as much of 90% of their time indoors[[6]](#footnote-6). Long term exposure to poor indoor air quality represents a potential risk to health that affects over half of the world’s population – with particulate matter affecting more people than any other pollutant. Cumulative exposure to fine particles (PM10 or PM2.5) is directly linked to the risk of developing cardio-vascular and respiratory diseases and lung cancer.

Ground level ozone is formed through the photo-reaction of sunlight with other pollutants such as nitrogen oxides (NOx) and volatile organic compounds (VOCs) emitted by industrial processes and vehicles. Exposure to high levels of ozone can aggravate asthma and reduce lung capacity and continued exposure can lead to more chronic lung diseases. Ozone is currently one of the pollutants of most concern in EU states. A recent study[[7]](#footnote-7) estimates that mortality rates increase by 0.3% for each extra 10g/m3 in ozone concentration, with a similar increase in the incidence of heart disease.

Exposure to high concentrations of nitrogen dioxide (NO2) in the air has been shown to cause bronchitis in asthmatic children[[8]](#footnote-8). NO2 is also known to be the major source of nitrate particulates (PM2.5) in air. The pollutant SO2 originates from the burning of sulphur-rich fossil fuels for heating, power and in car engines, and affect the human respiratory system and cause eye irritation. When combined with water vapour, SO2 leads to the production of sulphuric acid and acid rain.

Volatile organic compounds are an important group of outdoor air pollutants, many of which are also greenhouse gases. They are also a source of concern in indoor air – particularly at places of work, where they can be an unwanted by-product of many industrial processes. Within this group of gases, the aromatic compounds benzene, toluene and xylene are potential carcinogen.

The poor health conditions arising from the continuous exposure to the various pollutants associated with poor air quality are often cumulative ones that deteriorate with time. The illnesses are often long duration chronic conditions and can be severely debilitating, contributing to a substantially reduced quality of life.

The principal outputs of the *INTASENSE* project will be:

1. Two advanced sensor modules, one for combustion gases and VOCs and one for particulates, each integrating a number of technologies to provide synergistic operation and maximum coverage. The modules will not require reagents and will have very long operating lifetimes.
2. An advanced sensor support platform containing innovative microfluidics and pre-conditioning components facilitating the integration of the three sensor modules. The platform will allow a common architecture with intelligent control, configurable for a wide range of end-use applications.
3. A demonstration unit evaluated in at least two end-use applications. Trials will include intelligent linking of *INTASENSE* sensor system to existing air handling systems to demonstrate improved air quality control.
4. Significant advances in several detection technologies, including: nano-structured-chemical sensors, photo-activated catalytic sensors and electric particulate detection.

*INTASENSE* is a 3-year collaborative project which brings together 8 organisations from 5 countries. The consortium combines academic partners and research institutes with SMEs and large industrials, and includes equipment manufacturers and end-users.

The strategic outcomes of *INTASENSE* are to:-

(i) Combine breakthroughs in micro- and nano-scale detection to deliver an air quality sensing system with advanced capabilities that can provide, at low cost, comprehensive monitoring of all key airborne pollutants linked to poor health of citizens.

(ii) Provide an easily configurable system for an extensive range of bespoke applications with different well-defined pollutant profiles, hence facilitating widespread implementation and maximum impact.

1. Develop a smart air quality sensing system that can intelligently interface with existing ventilation and air treatment systems to maximise their energy-efficiency and effectiveness, while also offering the capability for specific purification actions in response to identified pollutants.
2. Substantially improve the health, quality of life, and productivity of EU citizens by providing a comprehensive air quality monitoring system capability that will transform the implementation of air purification.
3. Generate data from a demonstration unit in real operating conditions that validates the effectiveness and durability of the developed technologies and to lay the foundations for exploitation as a smart low-cost high-performance air quality monitoring system.

Achievement of the overall strategic project objectives required developments in several complementary technical fields. The specific technical objectives are:-

1. Research and develop a particulate matter detection unit comprising the combination of a miniaturised electric particle sensor that is capable of uniquely detecting a range of particulates to better than 5 g/m3.
2. Research and develop a combustion gas and VOC sensor module comprising advanced nano-structured-chemical and photo-activated catalyst sensors that is capable of detecting a specific gaseous pollutants to better than 50ppb.
3. Develop a smart miniaturised high performance microfluidic sampling, pre-concentration and pre-conditioning sensor support platform for use with the sensing sub-systems that can substantially improve performance (response, selectivity, sensitivity) of pollutant detection and reduce background interference.
4. The complementary nature of the micro- and nano-sensing technologies will deliver continuous monitoring performance that matches or exceeds that of networked analytical systems on a single compact low-cost intelligent platform. (Milestone M5)

In this way, the implementation of *INTASENSE* sensors could have a major impact on the quality of life of EU citizens – facilitating improved public and worker health, and increasing life expectancy, as well as enabling positive improvements in building space heating efficiency.

*Please provide a description of the main S & T results/foregrounds. The length of this part cannot exceed 25 pages.*

Since the introduction of double glazing in the 1970s and the move towards greater energy efficiency in commercial and domestic buildings the concept of a ‘green building’ has become synonymous with a tightly sealed building. Tightly sealing a building to reduce air exchange rates as a means of increasing energy (and noise) efficiency inevitably also increases the impact of any indoor emissions of air pollutants to its occupants. Emissions of air pollutants from building, decorative materials and from furnishings may contribute to Sick Building Syndrome (SBS), the poorly understood phenomenon in which building occupants suffer a range of symptoms of poor health. With the increasing recognition of the need to reduce the energy use of buildings, together with the need to safeguard the health and wellbeing of occupants, ensuring the balance between energy efficiency and good indoor air quality is an important challenge to both the ventilation engineer and the analytical chemist.

The INTASENSE project approached this challenge by developing a wireless indoor air quality monitor that could provide feedback to a building’s HVAC system (Figure 1, Appendices). To achieve this there were multiple research and technical development (RTD) work packages within the INTASENSE project addressing the following topics:

WP2 – Regulation, specification and product design

WP3 – Combustion gas and VOC detection

WP4 – Particulate Matter detection

WP5 - Microfluidics, packaging and interface

WP6 – Multifunctional system integration

WP7 – Demonstration and validation

The science and technological aspects of the INTASENSE project will now be summarized under these headings.

Regulation, specification and product design

Project Partner Lancaster University (ULANC) lead the regulation, specification and product design for the INTASENSE sensor. One of the principle tasks in this work package was to agree amongst the project partners a list of representative pollutants for the development of the INTASENSE indoor air quality sensor, as well as the limit of detection for the sensors and frequencies that measurements were taken. These specifications were agreed as:

Specification (i): Identifying the target pollutants:

Within three groups of pollutants individual analytes were identified:

* Four combustion gases: NO2, CO, CO2, O3
* Four volatile organic compounds (VOCs): Benzene, toluene, formaldehyde and p-dichlorobenzene
* Two sizes of particulate matter (PM): PM2.5, PM10

Specification (ii): The INTASENSE sensor should sample at a frequency of at least:

* 10 mins for combustion gases and VOCs
* 30 mins for PM

Specification (iii): The INTASENSE sensor should be capable of detecting target pollutants with LODs of:

* ≤ 1 ppm for combustion gases and VOCs
* ≤ 5 µg m-3 for PM

ULANC ensured that the research undertaken within INTASENSE was relevant and matched to the target pollutants in multiple end-use applications. EU and international legislation were continuously reviewed throughout the project regarding the control of airborne pollutants and to oversee health and safety aspects for application within the research development task, as well as in application tests. Health Impact Assessment (HIA) activities were undertaken throughout the INTASENSE project and it has been determined that the INTASENSE system does not pose a health risk to either public or worker safety.

The gas sensors developed in the project comprised nano-scale metal oxides ‘grown’ on an electrode substrate. ULANC assessed the health and environmental risks specifically associated with the handling and use of nanomaterials in the INTASENSE project. Finding that the risk to health from nanomaterials was ‘low’, as the fabrication process involves nanostructures rather than loose nanoparticles. Specifically, the nanostructure is grown on a sensor substrate and therefore fixed to that substrate plate.

Combustion gas and VOC detection

The work within this WP, led by project partner Centro de Estudios e Investigaciones Technicas (CEIT), mainly focused on the development of conductometric type sensors and their validation for indoor air quality purposes.

Two main tasks were carried out for sensor development at CEIT. Firstly, the most suitable materials were chosen to detect each target gas. The chosen materials were three semiconductor oxides: tin oxide, zinc oxide and nickel oxide. They were manufactured as thin film (thickness of some hundred nanometers) or as nanostructured material (such as nanowires in the case of tin oxide) at the CEIT clean room facility.

Structural characterization by several microscopy advanced techniques was used to check the chemical phases, stoichiometry and grain size, among other parameters relevant to assess the performance of gas sensing materials.

Secondly, a suitable platform for the sensing material was selected, including an integrated heating element. The final choice was an alumina squared chip of 2.5 mm side with the heating element surrounding the sensing material and packaged in a TO-type package. For characterization and validation, CEIT fabricated at least 6 runs of the conductometric sensors according to the final design.

Project partner C-Tech Innovation Ltd. (CTECH), also developed photoactivated sensors working at high frequencies, using dip coating techniques. The chosen material was tungsten oxide and the characterization of the sensor performance was carried out under UV light.

After the sensor fabrication, a third important task within this work package was the integration and testing of combustion gas and VOC sensors. The approach that was implemented for the integration of the gas sensors to be developed at CEIT and CTECH was to perform the measurements of the same VOC and combustion gases at the same concentrations and under the same test conditions. This approach allowed comparison and selection of the best technology for each gas or either to perform a cross-check of the signals given by the different sensors in order to have a more reliable sensing system. After comparison of the performance of both sensing methods, the CEIT sensor out-performed the CTECH sensors and so the project progressed using the CEIT sensors in the INTASENSE platform.

The CEIT sensors were tested in the presence of target gases (carbon monoxide, benzene, formaldehyde and nitrogen dioxide), chosen in the specifications document and reviewed throughout the different meetings under the assessment of the partner ULANC. THE CEIT sensor successfully met the specifications set for target gases and the limit of detecting each gas. The three developed sensors were finally integrated in the fluidic platform developed by the Centre Suisse d’Electronique et de Microtechnique (CSEM).

Particulate Matter detection

The Technische Universistat Ilmenau (TUIL) were tasked with the development of a non-optical particulate matter detection module. The starting point of this work package was the patent DE10 2006 032 906 B4 describing particle detection by a particle-induced discharge. The assumptions of this patented particle detection is that a particle of any material entering a volume of sufficiently high field strength triggers an electrical discharge by distorting the field. This detection method will be referred to as the breakdown measurement method here. The amplitude of the discharge current is assumed to be a function of the particle size. Further, the authors of the patent promote a cleaning aspect of the device: particles are vaporized by the discharge and therefore, the particle concentration is reduced. However, the patent holders did not conduct experiments with particles in the fine dust regime in order to verify the claims. TUIL were granted use of this patent for the development of a particle detector within the scope of INTASENSE. The system sketch is depicted in Figure 2 of the Appendices.

Parallel to the work on the breakdown measurement, the feasibility of a measurement of the capacitance change was also examined. The capacitive measurement promises increased longevity because of non-invasive measurement, the particle is not destroyed by the measure (Figure 3, Appendices). This technique requires very high resolution of electrical capacitance, at high measurement frequencies. However, prototype bespoke circuits did not reach required resolution, and commercially available integrated circuits didn’t have the required frequency. It was therefore concluded that the capacity measurement was a viable approach but requires the development of a customised application-specific integrated circuit. Because this was not feasible (time and cost) within the scope of the INTASENSE project, the capacity measurement was therefore not pursued further, but archived a future opportunity.

The breakdown measurement technique became the particle detection technique, Figure 4 in the Appendices illustrates the principle of measurement. Experiments with the particle-induced breakdown detector prototypes revealed that the longevity of the detector was compromised by electrode deterioration in the microscopic scale. The energy released even with a single discharge (particle passing through) was high enough to damage the electrodes that usually have a thickness of less than 1 µm and vaporize the particle passing through.

This issue was overcome by adopting the dielectric barrier discharge mechanism. A dielectric barrier (electrical insulator that can be polarized) covering the electrodes reduces the discharge energy levels to a non-destructive limit. As a result the discharge will not vaporise particles preventing the problematic condensation of vaporised particle material on the channel walls.

A key finding of the experiments was that in order to safely trigger a discharge, the dimension of the electric field must be within the order of magnitude of the particle diameter. Detector cross sections of less than or equal to 40 µm are therefore necessary in subsequent prototypes.

It was also found that precise control of particle speed and trajectory through the detector is a key element to ensure the detector works. If particle speed is too low, charged particles – which are always present in the air stream – will follow the electric field lines and deposit on the electrodes. These particles effectively shield the electrodes, lowering the electric field in the detector. As a result, the development of a microfluidic system around a given detector geometry that enables strict control of particle velocity was undertaken. The microfluidic system had to fulfil the following requirements:

* The particle speed at the detector location must be high and thus the dwell time within the electric field low so that the trajectory of charged particles receives negligible change.
* Particles at high speeds in microfluidic systems show ballistic behaviour. Therefore, sharp turns have to be avoided to prevent particle collision with walls. Otherwise the risk of clogging due to particles adhering to the channel walls is increased.
* Implementation of a procedure to unclog the detector channels is desirable. This can be achieved without using purging fluids by reversing flow direction and/or applying an overpressure to the clogged channel.
* Realize system layout which enables robust, parallel operation of several detectors.
* The solution found is a microfluidic Venturi-injector where the detector is located in the suction inlet. A vacuum pressure at the intersection of the suction inlet and the Venturi constriction determines the flow through the detector at the suction inlet.

Figure 5 in the Appendices shows an induced-discharge particle detector integrated into Venturi-injector. The Venturi effect is the reduction in fluid pressure resulting from a constriction in the flow channel. The sketch shows the fluidic layout highlighting the Venturi constriction and detector location as well as the detector cross section. It was found that a pressure difference of 40 mBar is sufficient to direct a particle stream through the suction inlet. A non-linear relation between the suction pressure and applied overpressure at the aerosol inlet enables flow reversal and application of an overpressure (Figure 6). Parallel operation of several Venturi-injectors can be realised easily. By using a pressure-driven principle cross-influence of parallel Venturi-injectors is excluded.

The key results of the new system design are condensed into a patent application which has been submitted to the German patent office (DPMA). This patent application is quite different from the one originally investigated, as it turned out that miniaturisation requires a completely different system layout, but the basic idea is successfully confirmed. Further, continuation of the research with the prospect of commercialisation is ongoing.

Microfluidics, packaging and interface

Under this work package, a fluidic platform which drives and preconditions air-flow to the sensors, and protects and supports the sensing devices was developed by CSEM. This was intitially integrated with custom electronics from project partner Advantic Sistemas y Servicios (ADV) which drive and readout data from commercial sensors (Figure 8). This data is sent wirelessly, over a network, to a standard computer where it is displayed using a custom graphical user interface developed by ADV (Figure 9). This graphical user interface can also be used to control pump speed, select sensor types, or adjust for altitude. The final outcome of this work package was the prototype sensor support platform, tested for its performance, and ready for final integration in WP6 – Multifunctional system integration.

In the single sensor device with drying unit (Figure 8), air enters the device and passes a humidity and temperature sensor. It is then sucked up into the preconditioning unit. In the preconditioning unit the air first passes through a filter to remove particles greater than, or equal to 10 µm diameter, then through silica gel (pink, optional) and then through a second filter for particles greater than or equal to 1 µm diameter. The silica gel acts as a humidity buffer: rapid humidity fluctuations would otherwise cause the gas sensors to be inaccurate. The filters are used to remove particulates and keep the silica gel in the preconditioning unit so two must be used if the humidity needs to be stabilized. If the air should be neither filtered nor humidity controlled then the lid can be used without the base to minimize dead volumes. Upon exiting the preconditioning unit, the air passes by a second humidity and temperature sensor before entering the gas/particle sensor chamber. Next, the air passes a defined restriction and the pressure drop is measured with a differential pressure sensor. This value can be used for measuring the air flow. Finally, the air is sucked out of the device via a pump.

To confirm that the design was working correctly, computational models of gas flow through the sensor chamber were conducted prior to construction. Additionally, 25 experiments were conducted on the components for 5 devices. Based on the results of these experiments it was determined that the flow through the devices was the same, within statistical bounds.

Once the final footprint of the fluidic platform was known and commercial sensors and pumps had been selected, the electronics board and corresponding software was created. This electronics board and corresponding software is used to run and wirelessly read data from the humidity sensors, the differential pressure sensor and the gas sensor. It is also used to control the flow rate, between zero and one-hundred percent in five percent increments, and adjust the readings on the differential pressure sensor for altitude.

The microfluidic unit change in design slightly during the course of the project based on findings and results during testing within the project and to accommodate the CEIT sensor developed within INTASENSE. The flow path through the system remained the same: filter- preconditioning unit - filter – sensors. An image of the final microfluidic set up for the INTASENSE gas sensing is shown in Figure 10 within the Appendices.

Multifunctional system integration

This work package, focussed on integrating the previous research and development activities into one platform as the INTASENSE sensor system was led by Gooch and Housego (GAH). The work package involved all of the technical partners working to produce a prototype unit combining the outputs of the research and development of the gas, VOC and particle detection as well as the microfluidics platform.

Figures 11-13 in the Appendices show the culmination of this work integrating the separate components of the INTASENSE platform; the microfluidics developed by CSEM, Volatile Organic Compound (VOC) Sensors developed by CEIT, Particulate Matter Detector developed by TUIL, the module housing by GAH ( Figure 11) and the communication platform (PCB and software) developed by ADV into a working laboratory prototype. Figures 12 and 13 show this functioning laboratory prototype.

Reliability and performance tests were carried out on the prototype module to establish functionality of the system. These tests involved analysing the response of each sensor to the target gases defined in work package 2 and observing behaviours when exposed to varying levels of humidity along with analysis of the microfluidics preconditioning unit and testing of the communications platform.

The output of this work within the INTASENSE Project was a demonstration module capable of detecting the target gases at the specified levels and able to operate and communicate wirelessly in a multiple node topology. Meaning that there could be multiple INTASENSE platforms (nodes) working within a room or building.

Demonstration and validation

Project partner ADV led the demonstration and validation activities within INTASENSE. As part of this work the integration of CEIT sensors, CSEM microfluidics, GAH enclosure and ADV electronics was successfully accomplished and validated in laboratory and office conditions.

In this work package, the integrated sub-systems developed in the multifunctional system integration work package have been engineered into a robust demonstration unit for evaluation in end-use environments. During the execution of this work, the INTASENSE detection technologies have been implemented into an engineered demonstrator and validated in a smart sensor unit in real end-user applications – offices and laboratories.

The INTASENSE demonstrator has been included as part of a basic kit in order to demonstrate the following features:

1. Indoor air quality sensor performance in-situ
2. Integration of the INTASENSE unit into any Modbus network
3. Performance of wireless capabilities
4. Online data collection

The ability to remotely and in-situ configure the INTASENSE sensor array for specific end-use environments represents a significant technological advance:

1. In-situ real-time data collection and unit control software tool. Through the use of a Wireless USB dongle, user can easily access the INTASENSE unit capabilities. This is particularly useful for calibration and testing purposes:
2. Web-based online monitoring tool. The INTASENSE unit has been configured to be part of the ADV Commercial monitoring platform called “Concordia”. This integration has been possible thanks to the standard communication capabilities of the unit, being able to be installed not only in ADVANTIC platform but also in any commercial SCADA or PLC compatible with Modbus protocol.

*Please provide a description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results. The length of this part cannot exceed 10 pages.*

Impact

Direct economic impact for the project partners

The technologies and understanding gained in the INTASENSE project has acted as a spring board for the opening of new opportunities in the air quality and sensors markets for the participants. The developments have allowed the partners to generate and protect novel IP on sensor surface structuring and particle detection and the development of flexible platforms for both the electronic and air sampling systems will have a broad range of markets in the sector.

Jobs created from the development of new technology should become crystallised in the second year of the development after the end of the project when it is expected that the product development aspects will be finalised and the partners will start to commercialise the technology. To this end an agreement on further activity between the partners is in place and will be the basis for future collaboration to exploit technology. The markets addressed by the technology are wide and exploitation of individual components in key global markets looks to be a strong possibility with exports outside the EU of technology likely to be a key source of income.

Wider Economic impact

The potential healthcare costs associated with the poor health are similarly very large. It is estimated that exposure to poor air quality accounts for over 80,000 serious health admissions in the EU annually, and that there are nearly 60 million medication-use days attributable to air pollution (primarily particulates and ozone)[[9]](#footnote-9).

The protection against poor air quality exposure afforded by the implementation of the multifunctional *INTASENSE* air quality sensor systems, will, through the cost savings associated with improvements in public and worker health, represent a major positive economic impact of the project. Overall levels of sick leave will be reduced, with immediate benefits to productivity and business profitability. Moreover, healthcare costs will be reduced, allowing this funding to be spent elsewhere – either through re-direction to other treatments, or in the wider economy.

Taken together, a conservative estimate of the combined economic benefits of increased worker productivity (due to reduced sick leave) and reduced healthcare costs (due to a healthier population) could be in excess of €100 billion annually across the EU through the widespread adoption of air-quality sensor systems linked to remedial ventilation and air purification systems[[10]](#footnote-10). Powerful regulatory drivers will be supporting these economic impacts. Public and worker health policies are being introduced which target to achieve, by 2020, approximately one third improvements in: lost life expectancy; premature deaths, and respiratory medication days.

Health

The quality of air indoors and in partially enclosed and poorly ventilated spaces is of particular concern. It is estimated that the average citizen in developed countries spends as much of 90% of their time indoors[[11]](#footnote-11). Long term exposure to poor indoor air quality represents a potential risk to health that affects over half of the world’s population – with particulate matter affecting more people than any other pollutant. Cumulative exposure to fine particles (PM10 or PM2.5) is directly linked to the risk of developing cardio-vascular and respiratory diseases and lung cancer.

Ground level ozone is formed through the photo-reaction of sunlight with other pollutants such as nitrogen oxides (NOx) and volatile organic compounds (VOCs) emitted by industrial processes and vehicles. Exposure to high levels of ozone can aggravate asthma and reduce lung capacity and continued exposure can lead to more chronic lung diseases. Ozone is currently one of the pollutants of most concern in EU states. A recent study[[12]](#footnote-12) estimates that mortality rates increase by 0.3% for each extra 10g/m3 in ozone concentration, with a similar increase in the incidence of heart disease.

Exposure to high concentrations of nitrogen dioxide (NO2) in the air has been shown to cause bronchitis in asthmatic children[[13]](#footnote-13). NO2 is also known to be the major source of nitrate particulates (PM2.5) in air. The pollutant SO2 originates from the burning of sulphur-rich fossil fuels for heating, power and in car engines, and affect the human respiratory system and cause eye irritation. When combined with water vapour, SO2 leads to the production of sulphuric acid and acid rain.

Volatile organic compounds are an important group of outdoor air pollutants, many of which are also greenhouse gases. They are also a source of concern in indoor air – particularly at places of work, where they can be an unwanted by-product of many industrial processes. Within this group of gases, the aromatic compounds benzene, toluene and xylene are potential carcinogen.

The poor health conditions arising from the continuous exposure to the various pollutants associated with poor air quality are often cumulative ones that deteriorate with time. The illnesses are often long duration chronic conditions and can be severely debilitating, contributing to a substantially reduced quality of life.

The widespread adoption of the *INTASENSE* air quality sensor system will have a substantial positive impact on public health and the quality of life of citizens in the European Union and elsewhere. The information provided by the *INTASENSE* monitoring systems will enable rapid remedial actions to be taken to mitigate the harmful effects of poor air quality. This remedial action could simply be the provision of increased ventilation or personnel evacuation, or more specific detoxification or air purification action targeted at identified key pollutants, all within the context of a minimum energy footprint.

The main pollutants associated with poor air quality give rise to different health effects, and will require different mitigation strategies to return the air quality to normal. The strength of the *INTASENSE* technology is that its comprehensive continuous monitoring capability will allow the necessary purification or detoxification to be automatically controlled to maintain good air quality.

The configurable nature of the *INTASENSE* sensor architecture will allow it to be highly effective in reducing the exposure of workers and the general public to poor air quality (and the undesirable health consequences). The performance of the air quality sensor can be tailored to meet the specific needs of the different end-user application sectors, allowing it to monitor the key air pollutants likely to be present in that environment. In many cases, the *INTASENSE* detector will be able to be quickly integrated into the existing ventilation systems, allowing implementation to immediately deliver public health improvements. One such example is its use in aircraft cabins, where the proportion of fresh air and recycled air is controllable. Another example is where the air flow through road tunnels can automatically be increased in response to a build-up of combustion particulates, NO2, SO2, CO or CO2.

The ultimate impact of the widespread implementation of *INTASENSE* air quality sensors (in conjunction with mitigation strategies) will be measured by increased mean life expectancy and a reduced number of cases of the linked illnesses in the population group protected by *INTASENSE* systems. It has been estimated[[14]](#footnote-14) that better air quality control could extend the average life expectancy of EU citizens by 3 months by 2020, and reduce premature deaths by 80,000 per annum.

More immediate quality of life benefits will be realised through the reduction in exposure to “unpleasant” rather than “chronically unhealthy” air quality. Sick building syndrome (SBS) tends to be associated with time spent in airspaces without direct access to fresh air (open windows) but where airflow is carefully controlled through building. This can have large benefits in terms of minimising energy consumption, but can lead to exposure to stale air, with higher than desirable CO2 concentrations and/or the presence of VOCs that outgas from many construction materials.

Although the societal, environmental and economic impacts of the outputs of the *INTASENSE* project are potentially enormous, there will be a number of factors that could mitigate (or enhance) the scale of impacts listed above.

Significantly, the proportion of the world’s population that is exposed to poor air quality is predicted to increase substantially as the developing nations continue to industrialise and with the increased urbanisation of society. This will increase the demand for air quality sensors and the remediation technologies linked to them. The market and demand for air quality sensors will also be related directly to population growth, also projected to increase the foreseeable future.

Exposure of populations to poor air quality is increasingly becoming a source of concern for governmental and regulatory authorities world-wide. As more scientific and epidemiological studies confirm the correlation between the various air-borne pollutants and many illnesses and chronic health conditions, there is growing public pressure on authorities to commit to policies that will improve air quality for citizens. Consequently, powerful regulatory drivers, in the form of health and safety laws and regulations (vehicle exhaust emission limits, industrial pollution controls, ambient air quality legislation etc) will force improvements in air quality and reduce public exposure. This increased and accelerated introduction of regulation would reduce the timescale over which the above impacts are realised, and potentially lead to more *INTASENSE* multifunctional sensor systems being sold.

The full impact of *INTASENSE* technology will only be realised if the large market need for low-cost air quality sensors can be met. This will require mass manufacture of a product based on a number of emerging and innovative sensor and integration technologies, and will require a skilled workforce to produce the system components. A shortage in this skill-base would lead to a correspondingly slow growth in the air quality sensor supply market and, consequently, lengthen the timescale over which the *INTASENSE* impacts are achieved. Nevertheless, even if a slower timescale is realised, the impacts will still be large enough to support the development.

The low-cost multifunctional sensor system developed in *INTASENSE* will represent the state-of-the-art in integrated sensing systems for the monitoring of air quality in many end-use application sectors. However, there is always the possibility that a rival technology will emerge that could potentially represent a commercial competitor in this field – reducing the commercial impacts of *INTASENSE*. The presence of competing products could accelerate the realisation of the combined societal, developmental and environmental benefits. It is believed, however, that the high quality of the science invested in the *INTASENSE* sub-systems will give it advantages in efficiency, reliability and ease of operation that will secure a strong position in the marketplace. Furthermore, the relevant commercial experience in the *INTASENSE* consortium means that it is strategically well positioned to exploit this position.

Please provide the public website address (if applicable), as well as relevant contact details.

[www.intasense.eu](http://www.intasense.eu)

1. *Estimated deaths and DALYs attributable to selected environmental risk factors, by WHO member state*, WHO 2002 (http://www.who.int/entity/quantifying\_ehimpacts/countryprofilesebd.xls) [↑](#footnote-ref-1)
2. *ibid*, WHO 2002. [↑](#footnote-ref-2)
3. *The 2005 WHO Air Quality Guidelines*, World Health Organisation, 2005. [↑](#footnote-ref-3)
4. C. Arden Pope III, *Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution*, Jornal of the American Medical Association*,* **287** pp1132-1141, 2002. [↑](#footnote-ref-4)
5. *The Clean Air For Europe (CAFÉ) Programme*, EU Thematic Strategy, September 2005. [↑](#footnote-ref-5)
6. US National Safety Council, 2002 [↑](#footnote-ref-6)
7. ##  Zanobetti, A. and  Schwartz, J**.,** Mortality Displacement in the Association of Ozone with Mortality, American Journal of Respiratory and Critical Care Medicine Vol 177. pp. 184-189, (2008)

 [↑](#footnote-ref-7)
8. ##  Pershagen, P. et al, Air Pollution Involving **Nitrogen Dioxide** Exposure and Wheezing**Bronchitis**in**Children, I**nt. J. Epidemiol. 24(6), pp1147-53, 1995.

 [↑](#footnote-ref-8)
9. Clean Air for Europe (CAFÉ) Steering group, http://ec.europa.eu/environment/air/index\_en.htm [↑](#footnote-ref-9)
10. World Health Organisation press release April 2005. [↑](#footnote-ref-10)
11. US National Safety Council, 2002 [↑](#footnote-ref-11)
12. ##  Zanobetti, A. and  Schwartz, J**.,** Mortality Displacement in the Association of Ozone with Mortality, American Journal of Respiratory and Critical Care Medicine Vol 177. pp. 184-189, (2008)

 [↑](#footnote-ref-12)
13. ##  Pershagen, P. et al, Air Pollution Involving **Nitrogen Dioxide** Exposure and Wheezing**Bronchitis**in**Children, I**nt. J. Epidemiol. 24(6), pp1147-53, 1995.

 [↑](#footnote-ref-13)
14. Clean Air for Europe (CAFÉ) Steering group, <http://ec.europa.eu/environment/air/index_en.htm> [↑](#footnote-ref-14)