

## **Horizon 2020**

### **Societal Challenge: Improving the air quality and reducing the carbon footprint of European cities**



#### **Project: 690105 – ICARUS**

Full project title:

**Integrated Climate forcing and Air pollution Reduction in Urban Systems**

#### **D8.9: Second report on outcomes of project events targeted at the scientific community and key stakeholders**

**WP8 Dissemination, communication and involvement of stakeholders**

Lead beneficiary: MESAEP

Date: 12/2018

Nature: Report

Dissemination level: Public

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	WP8: Dissemination, communication and involvement of stakeholders	Security:	Public
	Author(s): N. Barouki, D. Sarigiannis, A. Gotti	Version: Final	2/18

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### Document Information

Grant Agreement Number	690105	Acronym	ICARUS
Full title	Integrated Climate forcing and Air pollution Reduction in Urban Systems		
Project URL	<a href="http://icarus2020.eu/">http://icarus2020.eu/</a>		
Project Officer	Mirjam Witschke - <a href="mailto:Mirjam.WITSCHKE@ec.europa.eu">Mirjam.WITSCHKE@ec.europa.eu</a>		

Delivery date	Contractual	October 2018	Actual	December 2018
Status	Draft <input type="checkbox"/>		Final <input checked="" type="checkbox"/>	
Nature	Demonstrator <input type="checkbox"/>	Report <input checked="" type="checkbox"/>	Prototype <input type="checkbox"/>	Other <input type="checkbox"/>
Dissemination level	Confidential <input type="checkbox"/> Public <input checked="" type="checkbox"/>			

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### Document History

Name (Institution)	Date	Version
MESAEP	October 2018	First draft
AUTH, EUCENTRE	November 2018	First draft revised
MESAEP	December 2018	Final

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## 1 Executive summary

The ICARUS consortium has adopted a very aggressive large-scale scientific dissemination strategy with the organization of a special session dedicated on climate change and air pollution management at the 19<sup>th</sup> international symposium of the Mediterranean Scientific Association for Environmental Protection (MESAEP), which was organized in Rome at the HQs of the National Research Council of Italy in October 2017; this event was accompanied by the proactive participation of the ICARUS team members in 37 international scientific events across the world. In all of these, the ICARUS partners presented the preliminary findings of the project with regard to methodological advances, identification of the current burden of air pollution in several EU cities and assessment of co-benefits and win-win solutions in combatting urban air pollution and climate change. In all of these encounters with the scientific community at large the integrated approach of ICARUS has been received very positively and key stakeholders such as public authorities responsible for environmental management and urban planning have asked to stay close to the project in order to benefit directly from the final outcomes. The outcomes identified so far comprise the following:

- Transport policy assessment – evaluation of co-benefits in terms of air quality improvements and consequent public health benefits from policy interventions in the transport sector targeting climate change
  - Identification of hot spots for targeted interventions in the participating cities
  - Determination of integrated sectorial measures with the maximum benefit in terms of combatting climate change and urban air pollution
  - Assessment of technological measures in terms of their efficiency and effectiveness in combatting climate change and urban air pollution
  - Identification of win-win solutions tackling greenhouse gas and air pollutant emission reduction in different EU cities participating in ICARUS
  - Elucidation of the role that socio-economic factors have in determining population exposure to air pollutants in European cities
  - Delineation of the comprehensive and novel ICARUS methodology for refined exposure and health impact assessment related to air pollution
  - Articulation of an innovative method for high spatial resolution data fusion in order to reduce the residual uncertainty in the impact assessment of air pollution abatement and climate change mitigation measures
  - Development of an agent-based modeling platform for refined exposure assessment
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## 2 Events related to stakeholders interaction and related outcomes

### 2.1 Mediterranean Scientific Association of Environmental Protection (MESAEP) 2017 symposium

A special session entitled “Climate change mitigation and air pollution abatement – towards win-win solutions” was organized by ICARUS in the frame of the 18th MESAEP International Symposium held at Rome, Italy from 4 to 8 October 2017. The session was chaired by Prof. R. Friedrich and Dr. E. Scoccimarro and it was introduced by a keynote lecture given by Dr. Simone Cresti project officer at the University of Siena who provided an overview of the Partnership on Research and Innovation in the Mediterranean Area (PRIMA) foundation initiative.

Abstract	Title	Authors	Presenter	Time
 <span style="float: right;">Page   14 <span style="margin-left: 100px;">Oral presentations</span></span>				
Keynote lecture – Sala Convegni				9:00-
Simone Cresti – PRIMA Foundation				9:45
COFFEE BREAK				9:45-
Climate change mitigation and air pollution abatement – towards win-win solutions				10:15
Morning session – October 5 <sup>th</sup> Oral presentations – Sala Convegni				
Chair: Rainer Friedrich – Enrico Scoccimarro				
373	An integrated approach to combat atmospheric pollution in smart cities through policy interventions and behavioural change – The ICARUS paradigm	Dimosthenis Sarigiannis	Dimosthenis Sarigiannis	10:15
103	Possible ways of mitigating the effects of climate change using efficient urban planning and landscape design principles in Turkey	Süleyman Toy, Neslihan Demircan, Metin Demir	Süleyman Toy	10:30
248	Conflicts between climate change mitigation and air pollution abatement	Rainer Friedrich	Rainer Friedrich	10:45
118	Characteristics of air pollution in the city of Erzurum	Metin Demir	Metin Demir	11:00
129	“The Evaluation Of The Urban Agriculture As Urban Ecosystem Services About The Mitigating Effects At Climate Changes”	Neslihan Demircan	Neslihan Demircan	11:15
137	A study of determining environmental quality in lake Urmia in north-western Iran	Naiyer Gheshlagh Sofla, Hasan Yilmaz	Hasan Yilmaz	11:30
228	Enlarging road surfaces and urban climatic conditions in the sample of a middle – sized Turkish city, Erzurum, Turkey	Muhammed Yasin Çodur, Süleyman Toy, Ahmet Ünal	Muhammed Yasin Çodur	11:45
254	Dynamic Monitoring of Land Cover Change: A Recent Study for Istanbul Metropolitan Area	Wasim Shoman, Merve Korkutan, Uğur Algancı, Hande Demirel	Wasim Shoman	12:00
356	Extreme events of perceived temperature over Europe: a projected northward extension of dangerous area	Enrico Scoccimarro, Pier Giuseppe Fogli, Silvio Gualdi	Enrico Scoccimarro	12:15
384	A meteorological monitoring network to investigate climate change in towns: six Mediterranean urban case studies	Cristina Lavecchia, Samantha Pilati, Pamela Turchiarulo, Cinzia Ferrari, Luca Avellis, Laura Mancini	Cristina Lavecchia	12:30
289	Investigation of the Effect of Traffic on Environmental Pollution	Muhammed Yasin Çodur, Ahmet Ünal	Muhammed Yasin Çodur	12:45

**Figure 1. The program of the ICARUS related Session in the 18th MESAEP International Symposium**

The oral session was complemented by a poster session which included three poster presentations.

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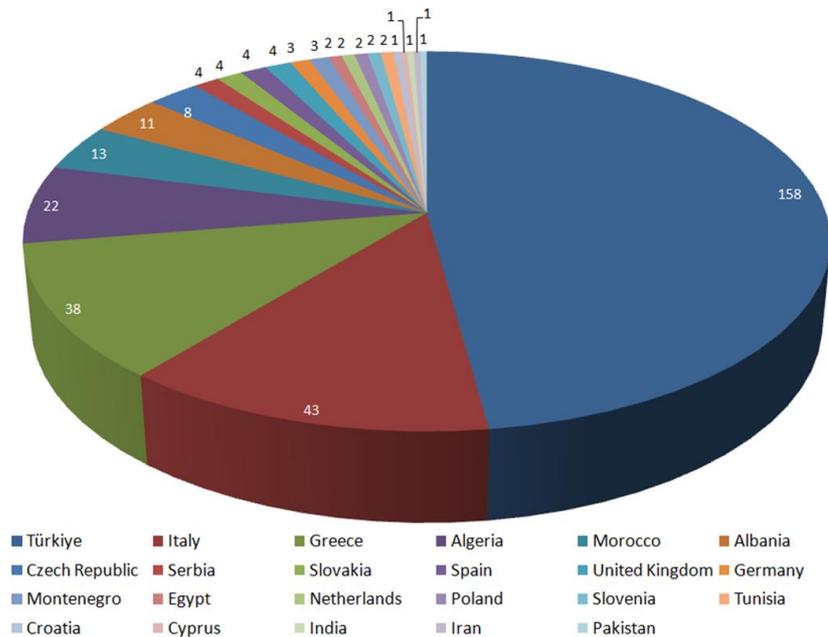
Climate change mitigation and air pollution abatement – towards win-win solutions				
Morning session at Coffee Break – October 5 <sup>th</sup> Posters				
Abstract	Title	Authors	Presenter	Time
67	Impacts of Climate Change on the Extremes of Temperature and Precipitation	Evren Ozgur, Kasim Kocak	Evren Ozgur	
173	Decadal Variations of Snow Seasons for Maritime and Continental Parts of Turkey	Evren Ozgur, Kasim Kocak	Evren Ozgur	
308	Informational parameters and synthetic multivariate indices for a smart monitoring network: the case study of hydro-meteorological data measured in Basilicata from 2000 to 2015.	Maria Ragosta, Giuseppina Anna Giorgio, Vito Telesca	Maria Ragosta	

**Figure 2: Scientific poster program of the ICARUS scientific session**

The quality of the submitted papers was high and several colleagues expressed their interest in publishing their work presented in the symposium into this special session. After a thorough peer review process, where each manuscript was evaluated by two independent reviewers, eleven high quality manuscripts were finally selected for an oral presentation. Three out of the eleven presentations were provided by the ICARUS consortium (Prof. D. Sarigiannis, Prof. R. Friedrich and Dr. E. Scoccimarro) who provided an overview of the ICARUS project, the methods and tools developed and the main results obtained. The remaining three presentations focused on other current initiatives and research projects in European countries in the field of air quality and climate change.

The MEASEP conference was an ideal opportunity for the ICARUS consortium to show to an audience of around 300 delegates from 23 different countries the ICARUS project methods, tools and results. Indeed, the audience encompassed a wide range of stakeholders including key representatives of the Italian Public Health Service (ISS), the National research Council (CNR) as well as well-known scientists from several European Universities and Research Centres specialized on the different aspects of monitoring and assessment of air quality and climate change.

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**Figure 3. Geographical distribution of MESEAP delegates**

This event contributed to greatly enhance the ICARUS visibility and to lay the groundwork for a closer cooperation in air quality and climate change management and to institute a dialogue in the scientific community and gave us the opportunity to establish strategic connections with other European initiative such as PRIMA foundation and to learn from other research groups what is the state of the art in this research field in the Mediterranean area.

## 2.2 Other events

From the beginning of the project, ICARUS organised or participated in a significant number of events that attracted the interest of stakeholders and scientific community.

1. The ICARUS project launch event & scientific workshop were held on 1-3 June 2016 at the Research Dissemination Centre of the Aristotle University of Thessaloniki (AUTH). The ICARUS kick-off scientific workshop was part of the Green Week 2016, the biggest annual occasion to debate and discuss European environment policy. A press release was given by the project Coordinator Prof. Sarigiannis as side event during the Kick-Off.
2. AUTH presented an overview of the ICARUS project, methods and tools at the workshop on supporting joint actions towards a sustainable green economy in Europe and beyond in Horizon 2020 societal challenge 5 "climate action, environment, resource efficiency and raw materials" on June 6, 2016 and at 11<sup>th</sup> meeting of the programme committee for the specific programme implementing Horizon 2020, on June 7, 2016 in Bruxelles (Belgium).

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3. The AUTH team gave an oral presentation at the 10<sup>th</sup> International Symposium on Sanitary and Environmental Engineering (SIDISA 2016) held in Rome (Italy) on 20-22 June 2016 entitled “The ICARUS paradigm for air pollution exposure management in cities.
  4. The use of Agent Based Modelling (ABM) in exposure assessment was thoroughly discussed in a dedicated session at the Annual Conference of the International Society of Exposure Science (ISES) that took place from 9-13 October 2016 in Utrecht, the Netherlands. Advances that were attained during year 1 of the project will also be discussed at the corresponding session at the forthcoming 27<sup>th</sup> annual conference of ISES that will take place at Raleigh, NC, USA (co-organised by the US EPA and NIEHS) on October 15-19, 2017. ICARUS and AUTH are invited to present the ICARUS advances in this matter.
  5. The ICARUS project was invited at the Workshop “Improving air-quality and carbon footprint in cities: Enhancing synergies among EU-funded R&I projects” which was organized by DG Research & Innovation in collaboration with the Executive Agency for Small and Medium-Sized Enterprises (EASME), on 11 October 2016 in Brussels, as a side event of the European Week of Regions and Cities (10-13 October 2016). The workshop aimed to enhance cooperation among the three sister projects (ICARUS, CLAIr-CITY, iSCAPE), co-funded by Horizon 2020, and to create synergies and links with other relevant initiatives such as the Partnership on Air Quality (PAQ) of the Urban Agenda of the EU. Nearly 50 stakeholders from several Member States & City Authorities representatives, members of the Covenant of Mayors and officials from various General Directorates of the European Commission (DG REGIO, DG ENV, DG JRC, DG GROWTH) attended the event. During the morning session, Dr. Gotti (AUTH) on behalf of the ICARUS team, presented the ICARUS project, illustrating its main objective, the methodological framework and tools to be applied in order to identify and assess appropriate abatement strategies for improving the air quality and reducing the carbon footprint in nine European Cities.
  6. The ICARUS methodological framework and early research results in the context of the evaluation of the health risk posed by biomass combustion in Greece were presented at the 28<sup>th</sup> Conference of the international society for environmental epidemiology (ISEE) organized on September 1-4, 2016 in Roma (Italy) The meeting provided the opportunity to discuss and gather feedbacks on the ICARUS methodological framework.
  7. On 3 November 2016 AUTH in collaboration with ADDMA, EUC and Resilient Athens organized the 1<sup>st</sup> Stakeholder Event which took place at the Europe Direct Hall of the city of Athens. The event which sees the participation of all the ICARUS partner representatives and more than 50 key stakeholders aimed at exchanging views and expertise with stakeholders and the community, initiating win-win strategies, designing policy solutions and promoting research activity that will contribute to reduce air pollution and mitigate climate change in urban systems. More details are given in Task 8.3 Engagement of city partners and main polluters.
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8. The ICARUS methodology and concepts were presented by NCSR D at the 3<sup>rd</sup> VDI expert forum on atmospheric chemistry which took place in Frankfurt on 5-6 December 2016. The presentation was entitled “An Insight to ICARUS project: “Integrated Climate forcing and Air pollution Reduction in Urban Systems”
  9. ARTEMIS participated to the HellasGIS 9<sup>th</sup> Symposium held on December 8, 2016 in Athens where the main objectives and the methodological framework of ICARUS have been presented.
  10. Masaryk University presented the ICARUS project at the 13<sup>th</sup> Czech- Slovak conference on air quality on April 10-12, 2017 in Brno (Czech Republic). The presentation entitled “Integrated climate forcing and air pollution reduction in urban systems (ICARUS): Project overview and objectives” has been published in the Conference Proceedings ISBN: 978-80-210-8544-2.
  11. CMCC presented a poster entitled “The extreme events of perceived temperature over Europe: a projected northward extension of dangerous area” at the European Geosciences Union General Assembly on April 23-28, 2017 in Vienna, Austria. The abstract was submitted to Geophysical Research Abstracts Vol. 19, EGU2017-4417-1, 2017.
  12. SWISSTPH is active in the preparation of an interactive Swiss TPH booth at the Basel “Umwelt Tag” (i.e. environment day) taking place on June 10<sup>th</sup>, where ICARUS will also be promoted.
  13. An abstract entitled “Conceptualizing Stakeholder Engagement in the realm of tackling Air Pollution & Nurturing Environment - conscious Citizens, for Smart, Sustainable & Resilient Cities” has been submitted by AUTH and presented as oral presentation at the 27<sup>th</sup> Annual Meeting of SETAC Europe 2017, held in Brussels from 7 to 11 May 2017.
  14. Two further abstracts were submitted and accepted as oral presentations at the 6<sup>th</sup> International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE) and SECOTOX conference organized in Thessaloniki from June 25 to June 30, 2017. Both presentations will present the ICARUS project focusing on specific scientific aspects of the project. The first one is entitled “Can Agent Based Modelling, coupled with sensors data, be used for personal exposure assessment?” and the second one “A holistic approach in support of air quality for future green and resilient cities”.
  15. ICARUS participated to the 6<sup>th</sup> Environmental Conference of Association of Greek Chemists, in Thessaloniki (Greece) in May 2017 with an oral presentation entitled “Integrated Approach to Addressing Air Pollution in Smart Cities through Political Interventions & Changes in Behaviour
  16. ICARUS participated to the 27<sup>th</sup> Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC) in Brussels (Belgium) in May 2017, giving oral presentation entitled
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“Conceptualizing Stakeholder Engagement in the realm of tackling Air Pollution & Nurturing Environment - conscious Citizens, for Smart, Sustainable & Resilient Cities”

17. ICARUS participated to the 11<sup>th</sup> Panhellenic Scientific Conference of Chemical Engineering held in Thessaloniki in May 2017 with an oral presentation entitled “Emerging methodologies for the evaluation of personal exposure to environmental pollutants”
  18. ICARUS participated to the 6<sup>th</sup> International Conference on Environmental Management, Engineering, Planning & Economics (CEMEPE) and SECOTOX held in Thessaloniki (Greece) in June 2017, giving two oral presentations entitled “Can Agent Based Modelling, coupled with sensors data, be used for personal exposure assessment?” and “A holistic approach in support of air quality for future green and resilient cities”
  19. Earth’s Climate Change Science and Impacts Symposium organized in Belgrade (Serbia) in October 2017 where the ICARUS team presented the work “Extreme events of perceived temperature over Europe in the future: the humidity role”
  20. ICARUS attended the joint exploitation workshop “Collective Awareness Platform for Data Needs, Citizens' Participation and Regulatory Society Challenges” organized by the European Executive Agency for Small and Medium-sized Enterprises (EASME) in November 2017 in Brussels. The event was be a key opportunity to discuss goals and aims of other EU-funded projects dealing with climate change and air quality, and the solutions emerging from the new technologies to tackle those issues. Beside ICARUS other projects which joined the event were iSCAPE hackAIR, ClairCity CITI-SENSE, and nanoMONITOR.
  21. Clean Air Forum, Paris, November 2017. The ICARUS Coordinator Prof. D. Sarigiannis represented the project consortium at the Clean Air Forum. The forum served as the platform for experts and politicians to put forth innovative ideas, solutions, to share, learn and implement the results to reduce the health risk posed by the air pollution. Over 300 participants from government, industry, and NGOs as well as citizens shared their views at the Forum.
  22. ICARUS participated to the 21<sup>st</sup> European Eco-innovation Forum, Eco Innovation for Air quality, jointly organised by the European Commission and the Ministry of Environment and Water of the Republic of Bulgaria, under the auspices of the Bulgarian Presidency of the Council of the European Union in Sofia (Bulgaria) in February 2018 with an oral presentation entitled “Assessment of public health co-benefits from traffic related emission policies in Thessaloniki”. ICARUS was invited to take part to an interactive session showcasing companies, municipalities, and public and private sector initiatives that have succeeded in developing and deploying effective new technologies, or innovative business and governance models for reducing air pollution originating from transport
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23. ICARUS team was present at the EU Green Week, 21 – 25<sup>th</sup> May 2018 in Brussel. A joint stand was hosted in the main exhibition hall of the event. The stand had several visitors: policy makers, MEPs assistants, ministries' and municipalities' representatives as well as researchers that were interested in the different methodologies and citizen's engagement approaches. The session consisted of short project presentations, a panel discussion and live demonstration of low cost sensors. The ICARUS team presented the use of different sensor devices, data collection methods and data interpretation and validation.
24. Prof. Dimosthenis Sarigiannis and Dr. Alberto Gotti attended the 2nd annual meeting of the EU projects iSCAPE and Clair-City as representatives of the respective Project Advisory Boards. During the meetings Prof. Sarigiannis provided an overview of the ICARUS projects and first results through an oral presentation entitled "Integrated assessment of policies and measures tackling population exposure and health impact of air pollution and climate change in urban environments - the ICARUS paradigm".
25. ICARUS participated to the ISEAC40 Environmental & Food Monitoring Conference, in June 2018 in Santiago de Compostela (Spain) with an oral presentation entitled "The Organic Carbon (OC) And Elemental Carbon (EC) In 5 European Cities. The Icarus Experience" where the analytical results of the OC+EC levels measured in the 6 ICARUS cities and their comparison were presented.
26. ICARUS participated to the 36<sup>th</sup> Congress of Spanish Society of Epidemiology held in September 2018 in Lisbon with an oral presentation entitled: ICARUS project: Integrated Climate Forcing and Air Pollution Reduction in Urban System
27. At the 6<sup>th</sup> International City Health Conference held in September 2017 in Basel (Switzerland) ICARUS was present with a poster entitled "Integrated Climate forcing and Air pollution Reduction in Urban Systems!
28. ICARUS attended the Eurocities Environmental Forum, respectively organized at Essen (Germany) in October 2017 and at Tampere (Finland) in October 2018. The forum aims to improve understanding of the links between air pollution, climate change, and public health, exploring different scenarios for the designing of integrated policies delivering co-benefits. By focusing on examples from the energy, constructions and transport sectors, participants will discuss the opportunities to achieve the Paris Agreement while creating immediate local benefits for people and health. The ICARUS project was presented in various round tables focused on win-win solutions for air pollution exposure management in cities.
29. ICARUS participated to the Climate change 2018 international conference in the mediterranean & middle east challenges & solutions in May 2018 in Nicosia (Cyprus) with an oral presentation entitled "GHGs and AQ measurements over European cities using aerial and ground platforms as part of the ICARUS air pollution and climate change mitigation
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strategy” where the results of the measurement campaigns performed with a light aircraft flying over 3 Mediterranean cities (Athens, Thessaloniki and Ljubljana) were presented

30. We participated to International Conference Sport and Public Space organized in September 2018 in Ljubljana (Slovenia) with an oral presentation entitled “Towards an active citizenship in a modern urban environment”
  31. ICARUS attended the 5<sup>th</sup> Geological congress held in Velenje (Slovenia) in October 2018 to present the results of source apportionment campaign executed in Ljubljana. In addition, measures and policies for reduction of emissions for Ljubljana were presented in the presentation entitled “Integrated climate forcing and air pollution reduction in urban systems (ICARUS): Ljubljana case study, Velenje, Slovenia”.
  32. ICARUS participated to the 11<sup>th</sup> International Scientific Conference on Energy and Climate Change held in Athens (Greece) in October 2018 with an oral presentation entitled “Weather clustering approaches and air quality climatic trends in urban environments”.
  33. At the 5<sup>th</sup> annual SISC (Italian Society for Climate Sciences) Conference on Climate Actions in Support of Paris Agreement held in Bologna (Italy) on October 2017 ICARUS was present with an oral presentation entitled “The role of humidity in determining Perceived Temperature extremes scenarios in Europe” where the ICARUS projections of perceived temperature at the surface under different future scenarios are investigated based on EURO-CORDEX data in a multimodel and high (12 km) resolution contest were presented.
  34. An Informative presentation of the Athens Resilience strategy was given by ICARUS at Athens City Hall in Athens (Greece) in October 2017 to participants about the environmental actions implemented by the Municipality of Athens for the protection of the environment in the frame of ICARUS.
  35. ICARUS participated to the 7<sup>th</sup> IVU Symposium on Air Quality Control and Models held in Freiburg (Germany) in May 2018. Almost 100 experts from the areas of air pollution control, planning and modelling from Germany met for lectures, exchanges of views and discussion.
  36. ICARUS was present at the LfU Symposium on Air Quality Control (Clean Air Planning - Measures and strategies against nitrogen oxides) in Augsburg in October 2018, where new findings and possible measures to improve the immission situation have been presented.
  37. ICARUS participated to the 3rd Symposium MAUI Air Quality: Management and Monitoring held in Curitiba, Brazil in April 2018 with an oral presentation of Prof Rainer Friedrich entitled “Air Pollution Control in Urban Areas in Germany” with focus on objectives of air pollution control and evaluation of policies and measures.
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### 3 Discussion on the outcomes of project events targeted at the scientific community and the implications for key stakeholders

In ICARUS, a lot of methodological advances are proposed and implemented that allow the precise evaluation of policies and measures. Towards this aim, an array of methods that describe the continuum from ambient air emissions till human health effects seem to provide very refined estimates of exposure and effects, thus, allowing the more precise estimation of expected impacts. This is of particular importance aiming at a cost-benefit analysis of the various interventions. The scientific results presented so far that rely on key methodological approaches of ICARUS and how they are used in practice with various stakeholders, are outlined below:

#### 3.1 Assessment of policies related to transportation

The public health co-benefits of GHG emission reduction policies in the city of Thessaloniki were investigated. Both local policies affecting a few municipalities (e.g. the construction of an underground railway in the municipality of Thessaloniki and Kalamaria) and national policies affecting all the municipalities in the greater metropolitan area (e.g. allowing new diesel passenger vehicles entering the cities and promotion of electric vehicles) were considered. They were ranked with respect to the reductions in mortality and morbidity, which resulted due to improved air quality. Two main policy scenarios were assessed considering (a) construction and operation of the underground rail and (b) changes in traffic composition. A combination of measurement techniques, as well as modelling tools (including transport, air quality and exposure modelling) were utilized towards this aim. From the analysis it was found that for BAU-2020 the gradual increase in vehicle numbers and simultaneously the renewal of passenger vehicles with newer end-of-pipe emission control technology improves air quality. This results in a slight reduction in DALYs to 3512 and 2720 per 105 people respectively. The slight increase in mortality compared to 2010 levels is due the 3% increase in population numbers expected from 2010 to 2020 in the Greater Thessaloniki Area. The first traffic scenario considered (MIT-1) illustrated the optimal combination of the measures considered, namely (a) the introduction of a metropolitan underground rail, which primarily influences traffic flow and velocities leading to reduced emissions in the municipalities of Thessaloniki and Kalamaria; and (b) changes in vehicle composition, the greater benefits of which will come from the large number of newly registered diesel vehicles. It should be noted that the transition of the vehicle fleet composition from gasoline-based into a diesel-fuelled fleet is of great concern in European cities and could potentially offset the benefits of policies that encourage integrated transport among some of the proposed solutions. On the other hand, the limited penetration of electric passenger vehicles will not influence air quality in Thessaloniki significantly, despite generation of zero emissions locally. Overall, simulations showed a noticeable improvement in air quality in the city centre (municipality of Thessaloniki) as the result of the reduced traffic load. Comparisons against the BAU scenario for PM10 and PM2.5 show reduction in mortality and in the corresponding DALYs.

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### 3.2 Spatial component – increasing resolution and identification of hot spots that need interventions

From the same study, it was also found that there are significant differences within the various municipalities, highlighting the importance of deriving high spatial resolution estimates; Significant differences were identified among the various municipalities, where the highest reduction in mortality cases include Kalamaria (5%), Thessaloniki (4%) and Pilaia (4%). These areas are the ones that are either more polluted (e.g. Thessaloniki center) or densely populated. But the identification of the risk maps based on high resolution health impact maps, allowed us to identify, to which areas this will be more beneficial, something that was communicated to city authorities.

### 3.3 Integrated sectorial measures

It has to be noted, that policies and measures should be investigated not only isolated, but actually as a bunch of measures; the operation of an underground rail network in the city of Thessaloniki should be part of a sustainable transport system, via the promotion of energy efficient multi-modal transport systems, clean fuels and vehicles. Towards the development of the unique opportunity to develop an integrated system, the improvement of the public transport system is essential, accompanied by technological improvements that will result in cleaner buses (e.g. buses fuelled with LPG). This type of integrated approach could also be pursued at the national, regional and local level.

### 3.4 Evaluation of technological measures

The detailed methodology for assessing the impacts of different components allowed also the precise evaluation of a purely technological scenario. The MIT-2 scenario solely simulates the drastic change in vehicle fleet in favour of electric vehicles. Reduction in mortality and morbidity attributed to PMx pollution in the municipality of Thessaloniki, is 4% for PM10 and PM2.5. For the other municipalities in the greater Thessaloniki area, the observed differences are related to the relative fleet composition. MIT-2, i.e. the promotion of 'green' transportation in the city via the widespread use of electric vehicles will bring savings resulting from the reduction in PM10 and PM2.5 exposure up to 66 and 54 million Euro respectively. Similarly, reductions in NO<sub>2</sub> and C<sub>6</sub>H<sub>6</sub> exposure will lead to savings of 41 and 1 million Euros respectively. The total savings to the public health system rise to 162 million Euros on an annual basis. From the above it appears that the introduction of electric vehicles is a very efficient measure for reducing airborne pollutants and most importantly PM and NOx. Changes in benzene emissions and reduction of benzene-attributable leukaemia is insignificant. This can be explained by the fact that diesel vehicles have negligible benzene emissions. Penetration of diesel vehicles will result in lower health and monetary benefits compared to policies that favour the use of zero emission vehicles. A combination of fiscal, technological policy scenarios and infrastructural interventions would maximise the expected benefits, as identified in a similar study carried out in China (He et al., 2016), where the combined use of bio-fuels with the increased market

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share of hybrid cars was proven as the most efficient policy. Data on the monetary cost per municipality and pollutant are given in section A10 (tables A17-A18) of the supplementary material.

The significant evidence on the co-benefits obtained by MIT-2 scenarios, indicated the importance of the transition to zero-emission vehicles (ZEVs) in terms of improving public health and well-being. These results agree well with the findings of other similar studies carried out in Europe, highlighting the importance of disruptive technological advances in the private vehicle sector. ZEVs are more effective than diesel vehicles in reducing GHG and toxic pollutants released into the urban atmosphere. Uptake of GHG emission abatement measures follows the socio-economic gradient in the urban population; it can be further limited by dire financial conditions and recession. However, these results, once more, provided additional evidence on the need for a transition from conventional vehicles (and especially diesel ones) to ZEVs.

The use of electric vehicles should be promoted via a series of benefits and fiscal incentives provided by the central government. Retail cost could be reduced via VAT and registration tax removals and series of other fiscal incentives could be put in place to make the acquisition and use of electric vehicles affordable. Although the question of fleet renewal and disposal of older vehicles, as well as the provision of financial incentives in a country facing tremendous economic difficulties seems a challenge, the health and monetary co-benefits in the long run provide the impetus for win-win solutions towards the concurrent mitigation of GHG emissions and urban air pollution.

### 3.5 GHG reduction hand in hand with air pollution reduction

One key result of our study is the comprehensive methodology we have developed that incorporates a unique data fusion algorithm that integrates efficiently environmental monitoring data and modelling. This method resolves problems of data paucity that hamper the detailed impact assessment of climate change mitigation interventions in many a city around the world. Thessaloniki is a typical case in this regard and the fact that we succeeded in obtaining spatially refined and robust results paves the way for similar applications in other urban settings worldwide. Certainly, many cities in Europe and the Americas are of similar size and face similar problems regarding data availability and intervention options. Thus, our results bear significant relevance to many cities globally.

### 3.6 Socioeconomic components of exposure

Another interesting study that used the methodological framework of ICARUS, was the study of the impact of biomass burning for space heating in public health, in the view of the continuous financial recession that characterizes the whole of Greece. From this perspective, exploring options that pave the way towards a green city is of interest, since cost effectiveness of policies that target mitigation of both GHG emissions and air pollution in cities is of importance in other parts of the world as well. In our opinion the conclusions and lessons learned from our study as well as the methodology outlined can be readily used in other mid-size cities in Southeastern Europe (our region) and the world.

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The significant repercussions of the incumbent financial crisis on the average household income, which when combined with the simultaneous increase in the price of light heating diesel due to extra-heavy taxation led a large number of Greek households to energy poverty. The associated health effects are reckoned to be disproportionately high compared to the short-term potential financial gains from increased taxation and similar austerity measures. In practice, according to the Foundation for Economic and Industrial Research, there were no actual financial benefits from the increased taxation of light diesel for space heating. On the contrary, the revenues from excise tax and VAT imposed on heating oil from the over-taxation were 187 million euro less than the previous year in Greece. This was due to the lower amount of heating oil taxed (2,629,931 kt in 2011-2012 compared to 1,335,083 kt in 2012-2013). Austerity measures resulted in a dramatic change in consumer behavior, with a consequent consumer shift to alternative fuels for space heating (such as illicit or unregulated biomass burning). This change resulted in both reduced tax revenues to the state and urban air quality deterioration, which would result in an increase of 40% in health burden costs between the winters of 2012-2013 and 2011-2012.

### 3.7 Refined exposure and health impact assessment

To better characterize the impacts of specific policies and to identify spatial differences within an urban area, an integrated mechanistic approach was developed, describing in more detail the interaction between toxicants (PAHs) adsorbed onto airborne particles and health effects on the urban population. This is clearly illustrated by comparing the relative risk between the people living in the two different sampling sites in the city of Thessaloniki. The non-mechanistic methodology that takes into account only TEQ and IUR reflects only differences in ambient air PAHs/TEQ levels. The mechanistic methodology proposed and applied herein, incorporated the effect of complex environmental, physicochemical and physiological processes. These include:

- (a) the PM size distribution emitted from biomass burning;
- (b) the PAH adsorption on the different particle size fractions;
- (c) the deposition distribution of different PM size fractions across the human respiratory tract.

The PM size distribution affects the way these are distributed across the different HRT regions. In turn, the deposition profile of PM across the HRT varies with age of the exposed individuals due to age-dependent differences in respiratory physiology. Thus, risk assessment can take into account that a higher fraction of small diameter particles (also found to be more toxic per unit of particles mass) are deposited in the middle and lower HRT. By incorporating all these parameters, the risks associated to the increased PM and PAHs due to biomass burning are further differentiated by source and age of the exposed population. Using the IUR methodology, cancer risk estimates for the population living close to the two sampling sites differ by a factor of three. This reflects only the difference of PAH levels found on PM<sub>10</sub>. With the methodology proposed in this work, the estimated cancer risk at the two sites differs by a factor of five to seven depending on the age group. Thus, the IUR method would result in significant underestimation of the actual cancer risk related to the

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particulate matter from biomass burning. These findings are particularly important when the impacts of biomass burning for space heating are evaluated among other bundle of measures related to buildings.

### 3.8 High spatial resolution of data fusion

The data fusion technology proposed by ICARUS, shows great potential for integrated air quality and health management. It brings together the state of the art in air quality monitoring and assessment, namely, state-of-the-art atmospheric models and analytical in situ measurements. It further encompasses advanced Earth observation data processing tools for optimizing the monitoring and assessment capabilities. The information fusion methodology implemented herein functionally integrates all three information sources (Earth observation, modeling, and analytical measurements) and reduces the overall error of the method to about 15 percent. This is a significant improvement over the best atmospheric models and pollutant concentration maps produced by spatial interpolation of measurements from the ground. Spatial analysis of the data, however, indicates the presence of hot spots, characteristic of heavy industry sites outside of the urban area but within the metropolitan domain of several typical European cities. In this way, all environmental information that can be available in policy makers can be readily exploited, allowing a more accurate estimation of the impact of policies.

### 3.9 Agent based modelling for exposure assessment

Agent based modelling (ABM) is a simulation technique that allows us to explore and understand phenomena, where independent entities interact together, forming an emergent whole. While the direct representation of individuals' actions is organizationally difficult, ABM simplifies this process by managing information at the level of the autonomous decision-makers, called "agents". By estimating the daily time-activity patterns of subgroups of population, we were able to estimate their personal exposure and intake dose per body weight. The identification of exposure peaks and troughs throughout the day in exposure time series leads to useful conclusions regarding capping exposure to high levels of pollution. The dynamic nature of intake dose assessment at the individual and population level allows for the derivation of guidance regarding behaviours that are linked with exposure to high levels of pollution. ABM results indicate that exposure varies between different individuals and population subgroups with different sociodemographic characteristics. ABM can indeed be used for personal exposure assessment, giving access to an unprecedented amount of "individualized exposure data", which can improve our understanding of exposure and health associations, but which are worthless without interpretation. By modelling the heterogeneous routine of human agents, our ABM can produce detailed information related to the societal system examined and can generate data that could be used to fill in the gaps that exist in traditional datasets. The establishment of an ABM approach that integrates SES indicators with the capacity for aggregation and analysis at various levels of population size, leads to an exposure assessment model especially useful for vulnerable groups of population, such as children, the elderly, low SES groups and people living in hot spot areas. This is an opportunity to capture evidence for cases where

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specific subgroups of population are disproportionately exposed to higher levels of environmental risk than other parts of the same society. This methodological tool, provides unique opportunities for evaluating the impact of measures and policies, accounting for the SES components, since it allows us to estimate the penetration of available technological options in junction with the cost of fiscal incentives, as well as non technological behavioral patterns that affect exposure related to sociodemographic characteristics. All of these are “non-linear” parameters that have to be taken into account when evaluating both technological and non technological measures.