LIFEINDEXAIR

Manual for the management tool utilization

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ABBREVIATIONS

AI	Alveolar – Interstitial region
As	Arsenic
BB	Bronchial region
Bb	Bronchiolar region
BoD	Burden of Disease
Cd	Cadmium
DALY	Disability-Adjusted Life Year
DD	Deposited dose
DDR	Deposited dose rate
EMEP	European Monitoring and Evaluation Programme
ET1	Extrathoracic region (1)
ET2	Extrathoracic region (2)
EU	European Union
NH_3	Ammonia
Ni	Nickel
NO_x	Nitrogen oxides
Pb	Lead
PM	Particulate matter
PM_{10}	Airborne particles with diameters up to 10 μm
$PM_{2.5}$	Airborne particles with diameters up to 2.5 μm
$PM_{2.5-10}$	Airborne particles with diameters between 2.5 and 10 μm
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
VOC	Volatile organic compounds
WHO	World Health Organization
WRF-CAMx	Weather Research Forecast - Comprehensive Air Quality Model with Extensions
YLD	Years Lost due to Disability
YLL	Years of Life Lost

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1. INTRODUCTION

Particulate matter (PM) pollution remains a major environmental problem in many European urban centres. While PM concentration levels and related health impacts have been extensively documented, developing effective control measures for PM pollution is still rather challenging, due to the complex nature of this pollutant and its multiple primary and secondary sources. On the other hand, epidemiological studies and air quality management policies are based on ambient concentration levels, even though urban populations spend the majority of their time in indoor microenvironments.

The LIFE Index-Air management tool was developed in the framework of the LIFE Index-Air project (LIFE15 ENV/PT/000674), aiming to cover the gap between ambient air quality management and real-life exposure of urban populations and related health risks. It aspires to provide policy makers with the means to assess citizens' exposure to PM and related health effects, as well as to evaluate the effectiveness of selected air pollution mitigation measures with respect to ambient air quality, population exposure and the protection of public health. The tool also aims to enhance the knowledge of the general public on PM pollution, its sources, means of exposure and health effects and to raise awareness regarding the adoption of sustainable and environmentally friendly practices in our everyday lives.

The LIFE Index-Air tool is based on an integrated exposure-dose-burden of disease assessment. It incorporates data on major source emissions, PM concentrations and characteristic time-activity patterns of different population subgroups, as well as a number of specialised models, and provides:

(1) Mapping (in approximately 1 km x 1 km) of ambient concentrations of PM_{10}, $PM_{2.5}$ and selected heavy metals in PM_{10} (Ni, As, Cd, and Pb);

(2) Exposure modelling, for different population subgroups, as well as for the total city population;

(3) Dosimetry modelling to quantify the dose of PM_{10}, $PM_{2.5}$ and $PM_{2.5\text{-}10}$ deposited in the respiratory system, during exposure in different microenvironments and under the specific anatomical and physiological conditions determined by a subject's age and activity;

(4) Estimation of DALY (Disability-Adjusted Life Year), YLL (Years of Life Lost), YLD (Years Lost due to Disability) and number of Deaths, due to exposure to $PM_{2.5}$, based on Burden of Disease (BoD) methodology.

All the above calculations are performed based on current ambient air quality data (base case), but also on modified scenarios, determined by the user in order to test different exposure mitigation measures. The tool calculates the impact of these measures on Ambient concentrations, Exposure, Dose and BoD; it provides, thus, a quantitative evaluation of the effectiveness of already implemented or future policies, either targeting directly ambient air pollution or aiming at reducing citizens' exposure through the adoption of alternative, less impacted by air pollution, everyday schedules (Figure 1).

The LIFE Index-Air tool is available online, free of charge. Currently the tool is applied for 5 cities: Athens (Greece), Kuopio (Finland), Lisbon and Porto (Portugal), and Treviso (Italy); nevertheless, its design allows the inclusion of other cities in the future. If you are interested in including your city in the LIFE Index-Air Tool, please contact life-index-air@ctn.tecnico.ulisboa.pt.

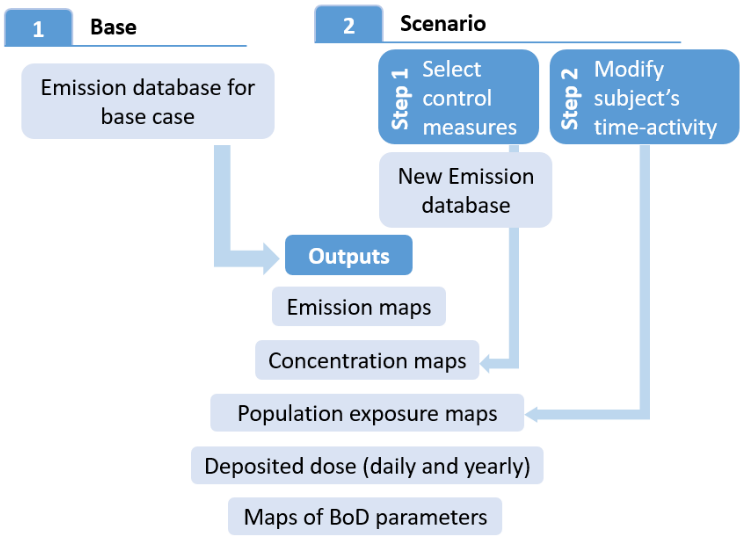


Figure 1. Graphical representation of the LIFE Index-Air tool.

2. GETTING STARTED

The LIFE Index-Air management tool is accessible through the following website:

http://194.219.150.53:5050/The user is requested to sign up/log in in order to have full access to the tool capabilities.

The following tabs are available once the user logs in (Figure 2):

- Home
- Data Analysis
- About
- Contacts

All calculations and data presentation are performed through the Data Analysis tab, which will be presented in detail in the following chapters. In addition, the user has access to a short description of the LIFE Index-Air project and management tool, the project consortium and contact information, as well as the detailed Manual and Informative video on the use of the tool.

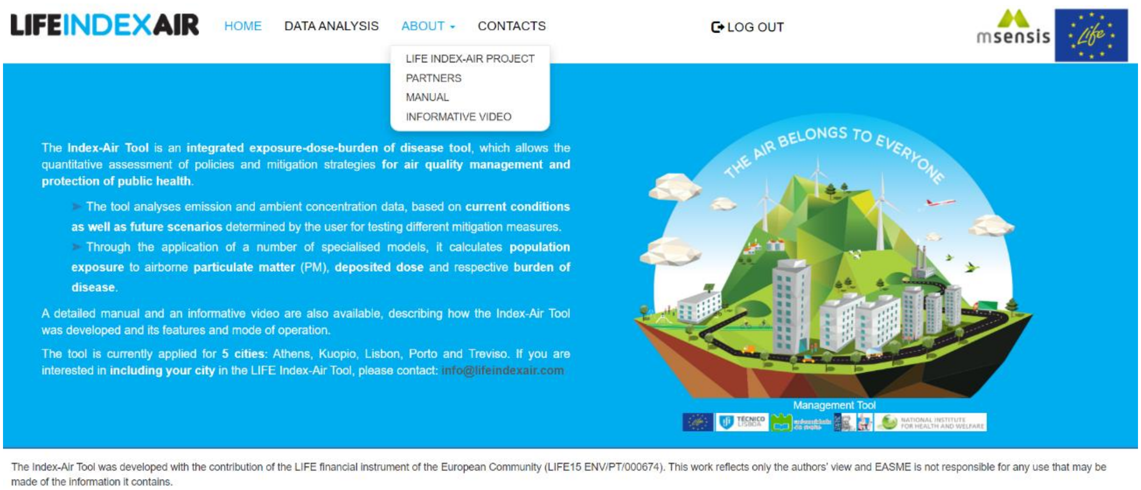


Figure 2. Screen shot from the home page of the LIFE Index-Air tool.

3. BASE CASE

3.1. INTRODUCTION

The base case allows the user to assess air quality and citizens' exposure to airborne particulate matter based on current conditions. The base year for which all calculations are performed is 2015. To begin using the tool, the user must select the study city, from the drop-down menu. Presently the following cities are available: Athens, Kuopio, Lisbon, Porto and Treviso (Figure 3). After pressing "GO", the following tabs are available:

- Emissions
- Ambient concentrations
- PM_{10} exceedances
- Population group maps
- Population exposure
- Deposited dose
- Burden of disease

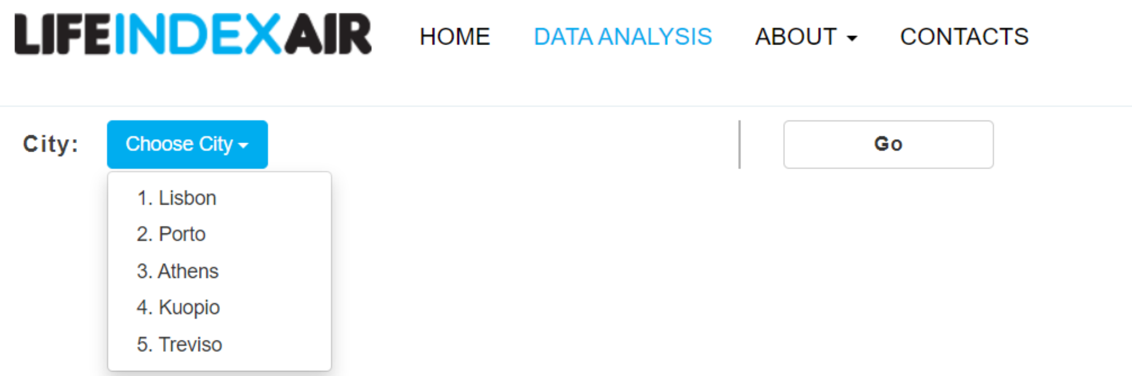


Figure 3. Screen shot from the initial page of the "Data Analysis" tab.

3.2. EMISSIONS

The "Emissions" screen provides the spatial distribution (1 km x 1 km) of annual emissions for each atmospheric pollutant (gaseous or particulate) and emission source, as well as the total amount emitted across the study area, along with the minimum and maximum values of annual gridded emissions (Figure 4). These results are given for the central Municipality of each city (e.g. Lisbon municipality) and for the remaining Municipalities included in the urban agglomeration (e.g. Other municipalities of the metropolitan area of Lisbon). The emission mapping is done using a 5-colour scale. The gridded emission values may be also viewed by moving the cursor on the map, across the different grid cells. In addition, the relative contribution of all emission sources to the selected pollutant, as an average for the whole city, is shown on a pie chart. All emission data are given in Gg/year.

The user may examine this data by choosing from a drop-down menu the Pollutant and the Source, and then pressing "Get Data". The list of pollutants and emission sources is provided in Tables 1 and 2, respectively.

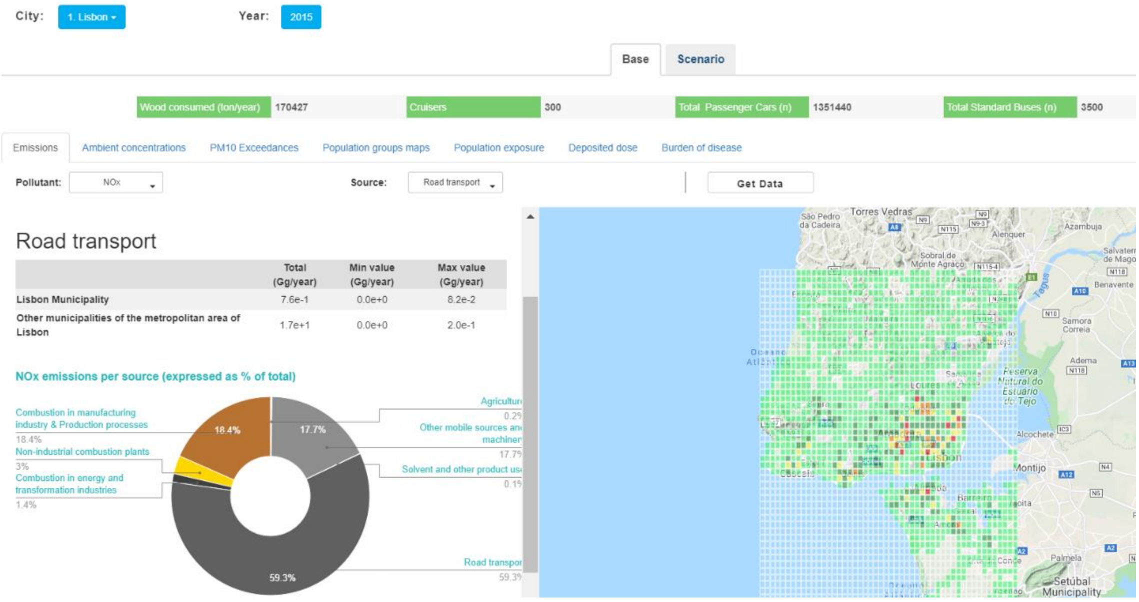


Figure 4. Screen shot from the "Emissions" tab, presenting the NO_x emissions from Road transport for Lisbon.

Table 1. List of atmospheric pollutants.

	Pollutant
Gaseous pollutants	Ammonia (NH_3)
	Nitrogen oxides (NO_x)
	Sulphur dioxide (SO_2)
	Volatile organic compounds (VOC)
Particulate pollutants	Particles with diameters up to 10 µm (PM10)
	Particles with diameters up to 2.5 µm (PM2.5)
	Arsenic in PM_{10} (As)
	Cadmium in PM_{10} (Cd)
	Nickel in PM_{10} (Ni)
	Lead in PM_{10} (Pb)

Table 2. List of emission sources.

SNAP code	Emission source
1	Combustion in energy and transformation industries
2	Non-industrial combustion plants
3 & 4	Combustion in manufacturing industry & Production processes
5	Extraction and distribution of fossil fuels and geothermal energy
6	Solvent and other product use
7	Road transport
8	Other mobile sources and machinery
9	Waste treatment and disposal
10	Agriculture

The selected particulate pollutants are among the pollutants-criteria for the assessment of air quality, according to the European legislation (Directives 2008/50/EC and 2004/107/EC). Regarding the gaseous pollutants, they are of interest with respect to particulate pollution, since they may serve as precursors for the secondary formation of atmospheric particles. The classification of emission sources follows the SNAP (Selected Nomenclature for Air Pollution) categories. All anthropogenic emissions included in the tool were obtained from the most recent European emission inventory (EMEP, European Monitoring and Evaluation Programme) based on Member States submissions for the year 2015. The EMEP inventory has a horizontal resolution of 0.1 degrees (approximately 10 km), and was disaggregated to the case study modelling domains. More details are provided in Ferreira et al. (2020).

3.3. AMBIENT CONCENTRATIONS

The “Ambient concentrations” screen provides the spatial distribution (at approximately 1 km x 1 km) of ambient concentrations of the studied particulate pollutants, as well as the average, minimum and maximum values found across the city (Figure 5). These values may correspond to two different metrics (Average or 90th Percentile of 24h concentration values) and are also provided for different time intervals (i.e. for the whole year or by season). The results are again given for the central Municipality of each city (e.g. Lisbon municipality) and for the remaining Municipalities included in the urban agglomeration (e.g. Other municipalities of the metropolitan area of Lisbon). The concentrations mapping is done using a 5-colour scale. The gridded concentration values may be also viewed by moving the cursor on the map, across the different grid cells. Concentrations are presented in μg/m^3 for PM_{10} and $PM_{2.5}$ and in ng/m^3 for heavy metals (As, Cd, Ni and Pb). The gridded concentration values included in the tool have been obtained by the application of the WRF-CAMx (Weather Research Forecast - Comprehensive Air Quality Model with Extensions) air quality modelling system. The modelled data were validated with data acquired in monitoring stations operating at the studied cities on a regular basis. More details are provided in Ferreira et al. (2020) and Korhonen et al. (2021).

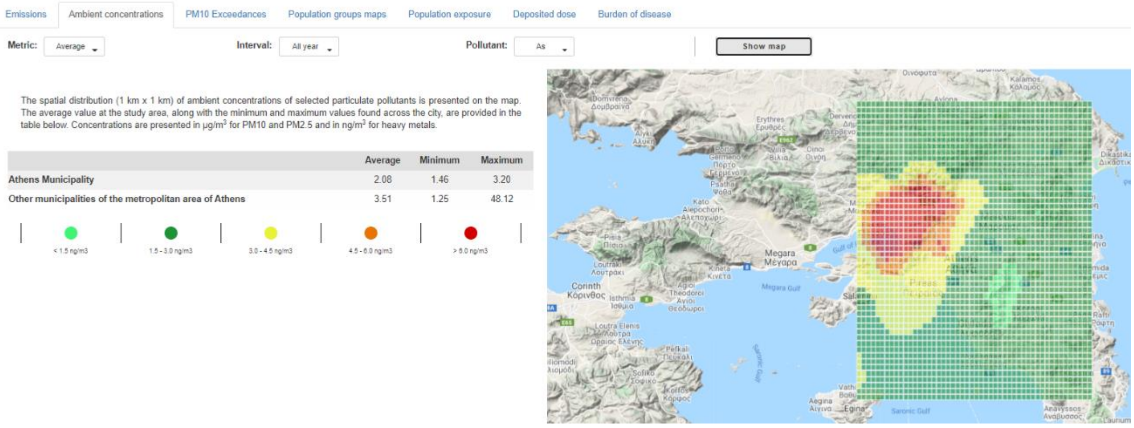


Figure 5. Screen shot from the “Ambient concentrations” tab, presenting the annual mean concentrations of As in PM_{10}, in Athens.

The user may examine this data by choosing from a drop-down menu the Metric, Interval and Pollutant, and then pressing “Show map”. The two metrics available to the user are selected to cover the reference periods used in the European Union (EU) limit values for particulate pollutants, as described in Directives 2008/50/EC and 2004/107/EC (Table 3). EU has set annual limit values for the ambient concentrations of PM_{10}, $PM_{2.5}$, and As, Ni, Cd and Pb in PM_{10}; additionally, a 24h limit value is defined for PM_{10}, allowing 35 days of exceedance per calendar year. The 90th percentile may be used as an indicator of compliance with the 24h limit value for PM_{10}, since it provides the concentration below which the maximum 10% (or approximately 35 out of 365 days) of 24h concentration values fall.

Table 3. EU limit values for ambient concentrations of particulate pollutants.

Pollutant	Annual limit value	24h limit value
PM_{10}	40 µg/m^3	50 µg/m^3 not to be exceeded more than 35 times during a calendar year
$PM_{2.5}$	25 µg/m^3	-
As	6 ng/m^3	-
Cd	5 ng/m^3	-
Ni	20 ng/m^3	-
Pb	500 ng/m^3	-

3.4. PM_{10} EXCEEDANCES

The "PM_{10} exceedances" screen provides for each grid cell of the city map the number of days throughout the year that the 24h ambient concentration of PM_{10} exceeded the respective EU limit value of 50 µg/m^3 (Figure 6). The mapping is done using a 5-colour scale. The gridded values may be viewed by moving the cursor on the map, across the different grid cells. The minimum and maximum number of exceedances throughout the city is also provided for the study year. The results are again given for the central Municipality of each city (e.g. Lisbon municipality) and for the remaining Municipalities included in the urban agglomeration (e.g. Other municipalities of the metropolitan area of Lisbon).

Note that for a site to be in compliance with EU legislation, no more than 35 exceedances should be observed.

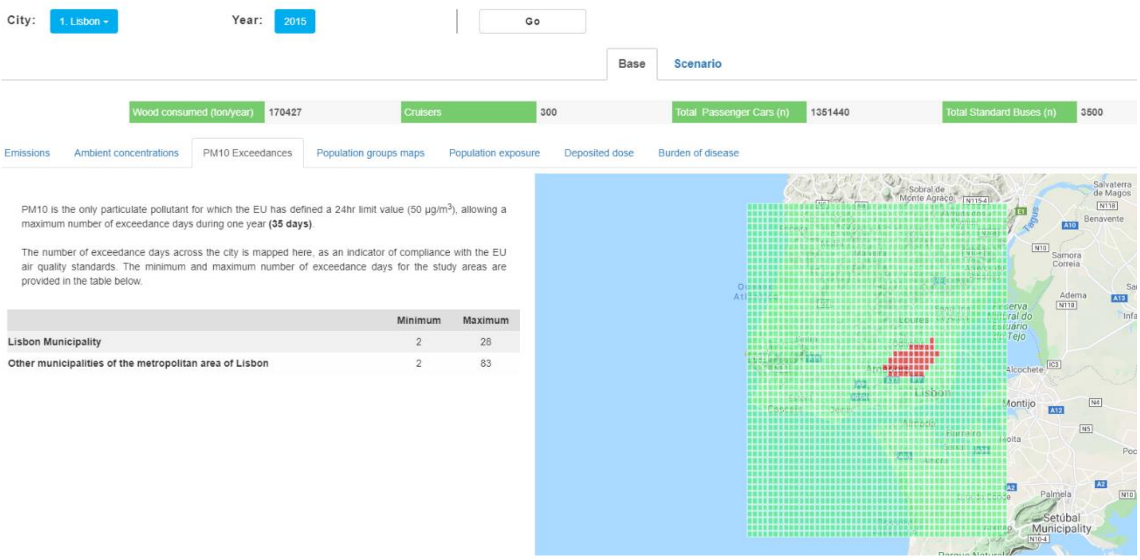


Figure 6. Screen shot from the “PM_{10} exceedances” tab, presenting the number of exceedance days for ambient PM_{10} concentrations in Lisbon.

3.5. POPULATION GROUPS MAPS

The “Population groups maps” screen provides the spatial distribution (at approximately 1 km x 1 km) of population, as well as the average, minimum and maximum population densities (number of people / km^2) found across the city (Figure 7). The results are again given for the central Municipality of each city (e.g. Lisbon municipality) and for the remaining Municipalities included in the urban agglomeration (e.g. Other municipalities of the metropolitan area of Lisbon). The population mapping is done using a 5-colour scale. The gridded values may be also viewed by moving the cursor on the map, across the different grid cells. The population statistics were obtained from the most recent census in each city. The population mapping is provided for the total population, as well as for 5 distinct subgroups:

1.	Pre-school children:	Up to 5-year old
2.	Elementary school children:	5 to 10-year old
3.	Students:	10 to 25-year old
4.	Working adults:	25 to 65-year old
5.	Elderly:	Over 65-year old

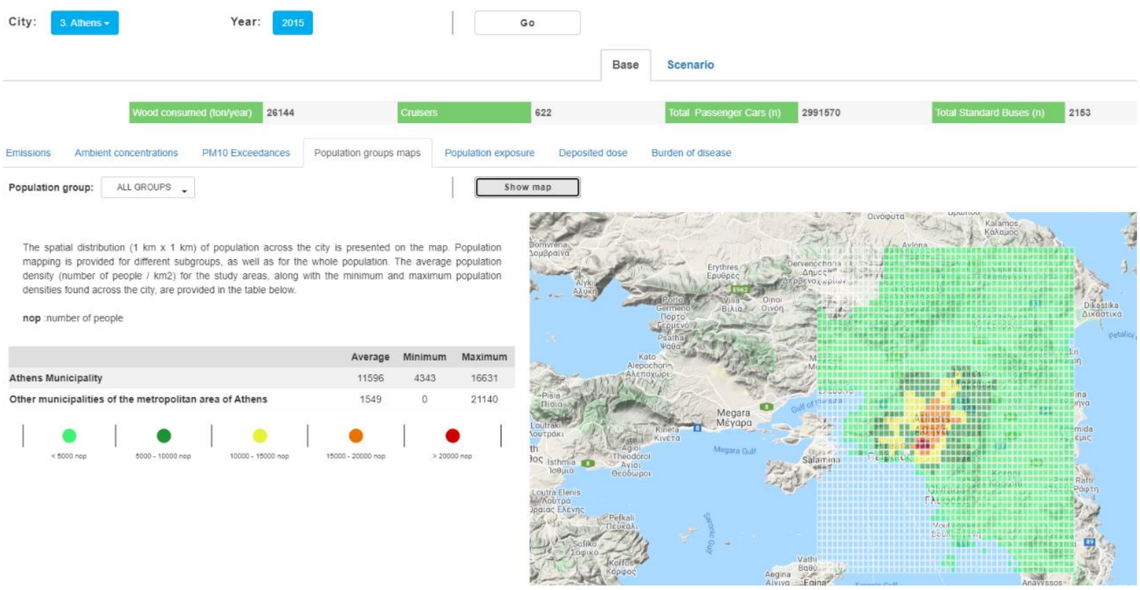


Figure 7. Screen shot from the “Population groups maps” tab, presenting the spatial distribution of total population in the city of Athens.

The user may examine this data by choosing from a drop-down menu the Population group, and then pressing “Show map”.

3.6. POPULATION EXPOSURE

The "Population exposure" screen provides the spatial distribution (1 km x 1 km) of population exposure to the studied particulate pollutants, as well as the average, minimum and maximum values found across the city (Figure 8). The results are again given for the central Municipality of each city (e.g. Lisbon municipality) and for the remaining Municipalities included in the urban agglomeration (e.g. Other municipalities of the metropolitan area of Lisbon). The exposure mapping is done using a 5-colour scale. The gridded exposure values may be also viewed by moving the cursor on the map, across the different grid cells. Exposures are presented in $\mu g/m^3 \cdot$ number of people for PM_{10} and $PM_{2.5}$ and in $ng/m^3 \cdot$ number of people for heavy metals (As, Cd, Ni and Pb). Exposures are calculated for the whole population, as well as for the 5 distinct population subgroups. The user may examine this data by choosing from a drop-down menu the Population group and Pollutant, and then pressing "Show map".

The population exposure provided for each grid cell is calculated based on the average 24h exposure (E) of a subject (population subgroup) to the selected pollutant, multiplied by the number of people pertaining to the specific subgroup. Exposure for the whole population is calculated as the sum of exposures of the five distinct population subgroups

The subject's exposure is calculated based on the microenvironmental approach, as shown in the equation below:

$$E = \frac{1}{T} \cdot \sum_{i=1}^{48} C_i \cdot dt_i \qquad (1)$$

where E is the exposure of a subject / population subgroup (in $\mu g/m^3$ or ng/m^3), T is the averaging period (24 hours), C_i is the concentration in the microenvironment where the subject (population subgroup) under study is during the time interval i, and dt_i is time interval (30 minutes).

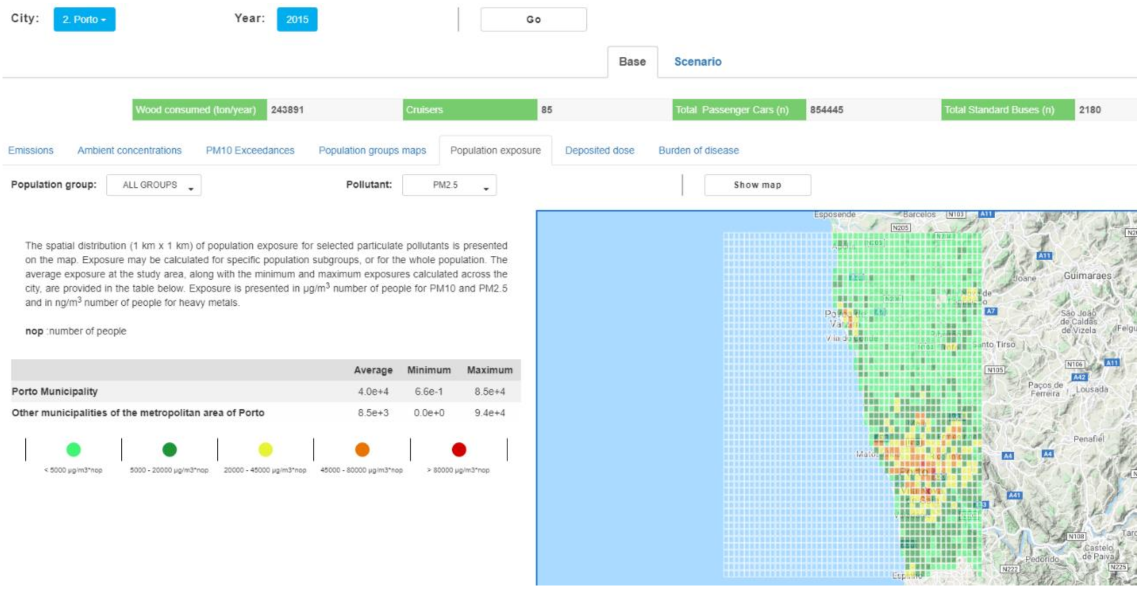


Figure 8. Screen shot from the "Population exposure" tab, presenting the average exposure to $PM_{2.5}$ of the Porto population.

The time spent in each microenvironment is defined for each population subgroup based on typical time-activity patterns derived by time-activity surveys conducted in Lisbon, Athens and Finland (Faria et al., 2020; Statistics Finland, 2020; Laskari, 2019). Regarding the time spent in transport, an average transport microenvironment was created based on the use of the different transport modes reported in the time-activity surveys. Two typical city-specific time activity patterns are included in the tool for each population subgroup, one for weekdays and one for weekends / holidays. The time interval used is 30 min.

The concentration in indoor microenvironments (C_{indoor}) is calculated by the tool based on the steady-state mass balance equation describing the indoor concentration of PM as a function of outdoor and indoor-generated particles (Diapouli et al., 2013):

$$C_{indoor} = F_{inf} \cdot C_{out} + C_{ig} \qquad (2)$$

where F_{inf} is the infiltration factor and corresponds to the fraction of outdoor particles that enter an indoor microenvironment and remain suspended, C_{out} is the ambient concentration and C_{ig} is the concentration of indoor generated particles.

The microenvironments included in the calculation of exposure are shown below:

- Home (representative of residential spaces, such as living rooms or bedrooms)
- School-IN (representative of nursery, school or university rooms)
- School-OUT (representative of outdoor activities during school hours)
- Work (representative of office rooms)
- OUT (representative of the ambient atmosphere)
- Recreation-IN (representative of indoor microenvironments characterised by high occupancy, such as restaurants, movie theatres, shops, etc.)
- Physical activity-IN (representative of gyms)
- Physical activity-OUT (including also walking or cycling)
- Transport (representative of a typical transport microenvironment, as described above)
- Private vehicle
- Bus
- Train
- Metro
- Motorcycle

The values for the Infiltration factor (F_{inf}) and Indoor-generated concentrations (C_{ig}) used for the calculations in the tool were selected to be characteristic of the pollutant (PM_{10}, $PM_{2.5}$, As, Cd, Ni or Pb), specific microenvironment and city and were based on indoor-outdoor relationships measured in similar types of microenvironments (Faria et al., 2020; Geels et al., 2015; Hänninen et al., 2015; Diapouli et al., 2011; Diapouli et al., 2010; Diapouli, 2008; Diapouli et al., 2008; Hänninen et al., 2004).

3.7. DEPOSITED DOSE

The “Deposited dose” screen provides the dose of particles deposited in different regions of the respiratory tract (ET1, ET2, BB, bb, AI, as well as total deposited dose in all regions), due to inhalation through the nose of airborne particulate matter, and specifically regarding three size fractions: PM_{10}, $PM_{2.5}$ and $PM_{2.5\text{-}10}$ (corresponding to particles with diameters between 2.5

and 10 μm). The different regions of the respiratory tract considered are shown in Figure 9). The results are provided in terms of mean daily deposited dose (in μg) during weekdays and weekends and cumulative yearly dose (in μg), for the five studied population subgroups (Figure 10). In addition, the diurnal variability of the deposited dose (in μg) and of the deposited dose rate (in μg/h) is also provided, separately for weekdays and weekends. In the respective graphs, the deposited dose rate (DDR) and deposited dose (DD) are shown in the left y-axis and the corresponding microenvironment in which exposure is occurring is shown in the right y-axis (Figure 11). These graphs may assist the user to identify the microenvironment/s which are responsible for the highest dose of particles in our respiratory tract and are thus mostly linked to the adverse health effects displayed due to exposure to PM.

The user may examine this data by choosing from a drop-down menu the Population group and Pollutant, and then pressing "Show results".

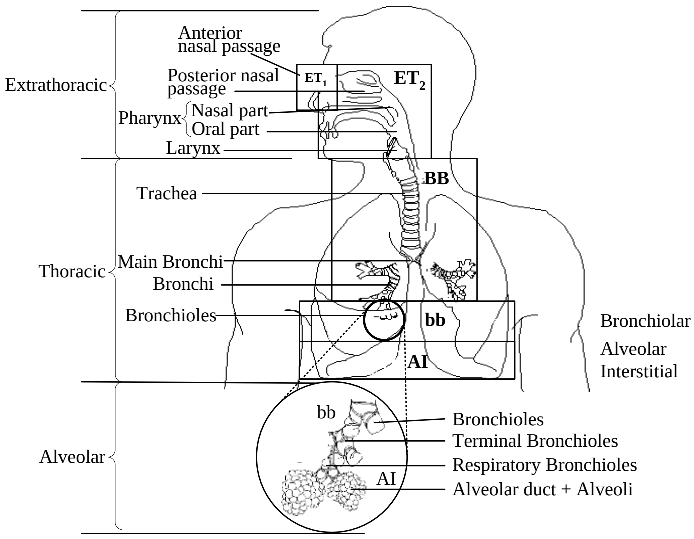
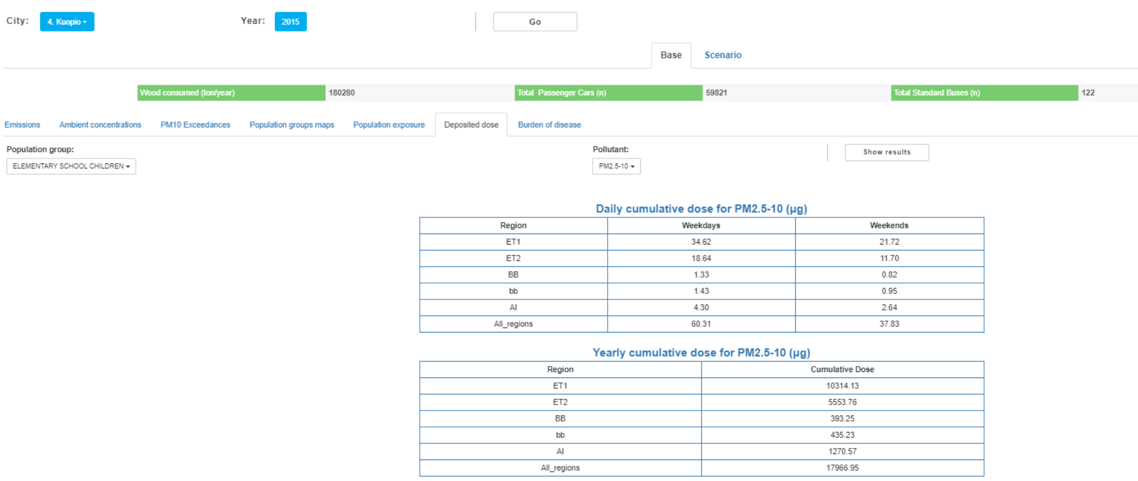


Figure 9. The human respiratory tract and the regions considered in the estimation of the deposited dose of particles due to inhalation through the nose of airborne particulate matter.



Daily cumulative dose for PM2.5-10 (μg)

Region	Weekdays	Weekends
ET1	34.62	21.72
ET2	18.64	11.70
BB	1.33	0.82
bb	1.43	0.95
AI	4.30	2.64
All_regions	60.31	37.83

Yearly cumulative dose for PM2.5-10 (μg)

Region	Cumulative Dose
ET1	10314.13
ET2	5553.76
BB	393.25
bb	435.23
AI	1270.57
All_regions	17966.95

Figure 10. Screen shot from the "Deposited dose" tab, presenting the mean daily deposited dose (in μg) during weekdays and weekends and the cumulative yearly dose (in μg) of $_{PM2.5-10}$ in different regions of the respiratory trach of elementary school children (Kuopio).

The deposited dose is calculated based on the ExDoM2 respiratory tract deposition model (Chalvatzaki & Lazaridis, 2015), and on the mean exposure to PM_{10} calculated for each one of the five studied population subgroups. Typical size distributions of indoor and outdoor PM are used in order to estimate the deposited dose of the three size fractions (PM_{10}, $PM_{2.5}$ and $PM_{2.5-10}$) (Chalvatzaki et al, 2020; Chalvatzaki et al., 2018). The model is applied for inhalation through the nose, and for the specific anatomical and physiological conditions determined by the age and activity of each population subgroup. Three activity levels (sleeping, sitting/resting and light exercise) are considered, each displaying different inhalation parameters, in relation also to the age group. The activity levels are defined based on the 30-min time-activity patterns during weekdays and weekends. A specific activity level is assigned to each microenvironment, as shown in Table 4. City-specific wind speed data were also included in the calculation since wind speed influences the inhalability of particles when the subject is outdoors. Wind speeds were obtained from the WRF meteorological model simulations and corrected to correspond to a height of 2 m, representative of the subject's exposure.

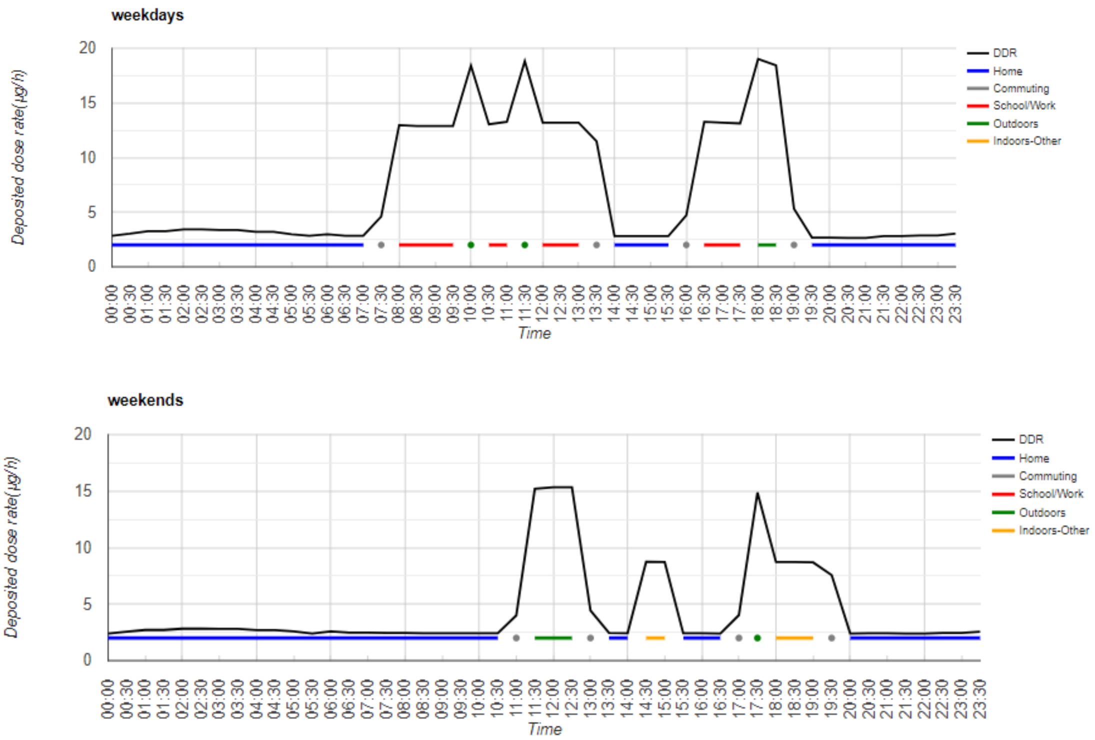


Figure 11. Results from the "Deposited dose" tab, presenting the diurnal variability of deposited dose rate during weekdays and weekends (example for deposition of PM_{10} to all regions of the respiratory tract of elementary school children, in Athens).

Table 4. Activity levels assigned to the different microenvironments for the calculation of the deposited dose of PM in the respiratory tract.

Microenvironment	Time period	Activity level
Home	00:00-7:00 & 23:00-00:00	Sleeping
Home	7:30 & 22:30	Sitting resting
School-IN	00:00 – 23:30	
Work		
Recreation-IN		
Transport	00:00 - 23:30	
Private vehicle	00:00 - 23:30	
Bus	00:00 - 23:30	
Train	00:00 – 23:30	
Metro	00:00 – 23:30	
Motorcycle	00:00 – 23:30	
OUT	00:00 - 23:30	Light exercise
School-OUT	00:00 - 23:30	
Physical activity-IN	00:00 - 23:30	
Physical activity-OUT	00:00 - 23:30	

3.8. BURDEN OF DISEASE

The "Burden of disease" screen provides an assessment of the health impacts due to exposure to $PM_{2.5}$. Burden of disease (BoD) is a comparable metric to measure health losses, including both premature mortality and morbidity. BoD is measured in disability adjusted life years (DALY), which is calculated as the sum of years of life lost due to premature mortality (YLL) and disability weighted years lived with disabilities (YLD), and may be expressed in YLL, YLD, DALY, or in number of Deaths. BoD is quantified based on Upper Respiratory Infections in the case of children (up to 10 years old) and on Natural Mortality in the case of adults over 25 years old. This method is not applicable to ages 10-25 years old. In addition, the tool provides estimates for sick days and school absenteeism for elementary school children.

BoD parameters are presented as a total for each city, as well as spatially distributed (at approximately 1 km x 1 km) across the city (Figure 12); they are calculated for the four relevant population subgroups (pre-school children, elementary school children, working adults and elderly), as well as a total for all four groups. The BoD mapping is done using a 5-colour scale and the corresponding gridded values may be viewed by moving the cursor on the map, across the different grid cells. The user may examine this data by choosing from a drop-down menu the Population group, and then pressing "Show results".

The health impact assessment is based on population attributable fraction and disease burden methods (Hänninen et al., 2011, method 1A). Population exposure is related to $PM_{2.5}$ ambient concentrations. The use of ambient concentrations, instead of exposure values, is due to the fact that the concentration-response functions available in the literature from the numerous epidemiological studies performed over the years are always based on ambient concentration data. Background disease burden data for 2015 are also included into the tool, and were obtained by World Health Organization (WHO, 2018).

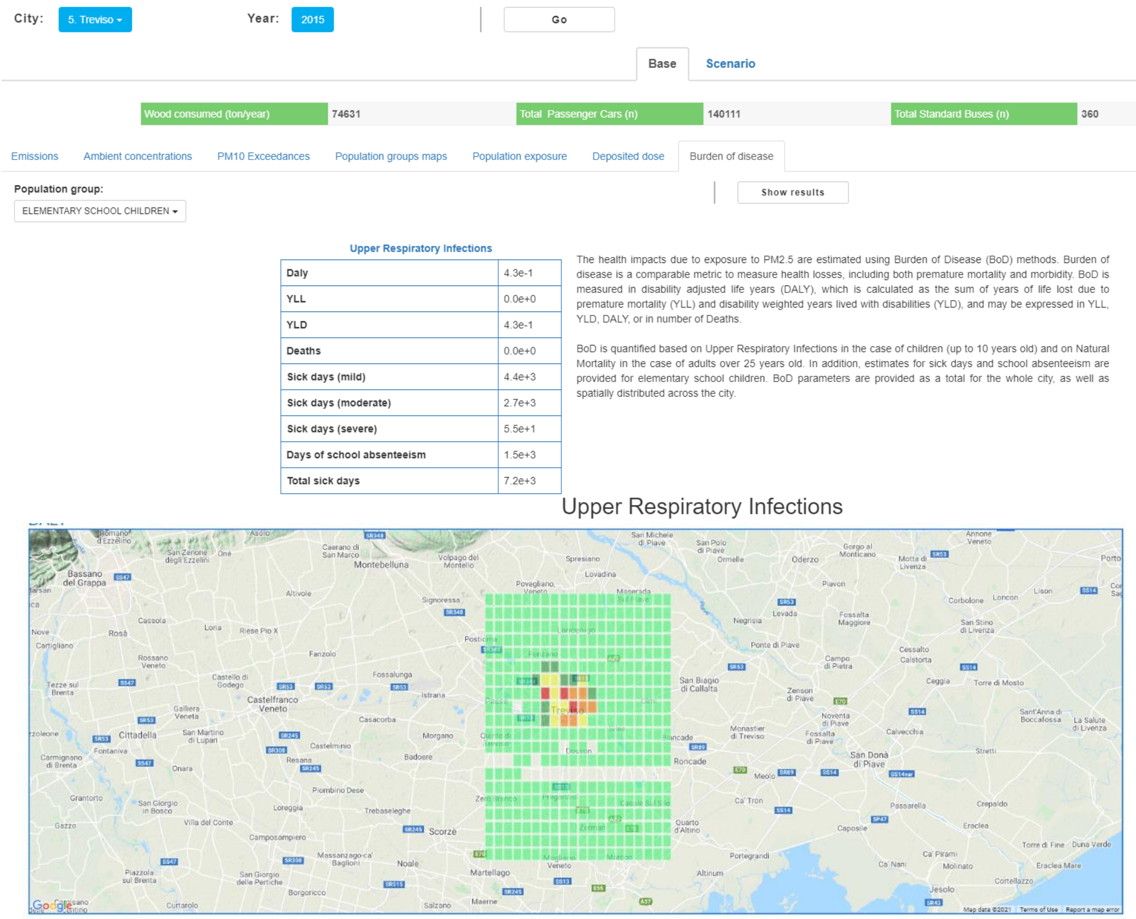


Figure 12. Screen shot from the "Burden of disease" tab, presenting the BoD parameters for elementary school children, as well as the spatial distribution for the respective values of DALY, for the city of Treviso.

4. SCENARIOS

4.1. INTRODUCTION

The “Scenario” tab allows the user to test emission scenarios related to vehicular Traffic, Residential heating and Cruise shipping and assess their impact on ambient air quality, population exposure and related health effects. Based on the selected scenario, the tool calculates a new database of modified, in relation to the base case, emissions. It then estimates the modified PM_{10} and $PM_{2.5}$ ambient concentrations, using a simplified prediction model, based on Artificial Neural Networks (ANN), and developed specifically for each city More details about the methodology used to train the ANN can be found in Relvas et al. (2017) and Relvas & Miranda (2018). The modified ambient concentrations are used in order to calculate population exposure, deposited dose and burden of disease.

In order to run the emission scenarios, the user must go to the “Scenario” tab and select from a drop-down menu the Improvement measure. A new screen appears, which allows the user to enter the specifics of the new emission scenario (Figure 13). Once all data are inserted, the user must press “Save”, in order for the new emission data to be generated, based on the modifications that are made by the new scenario.

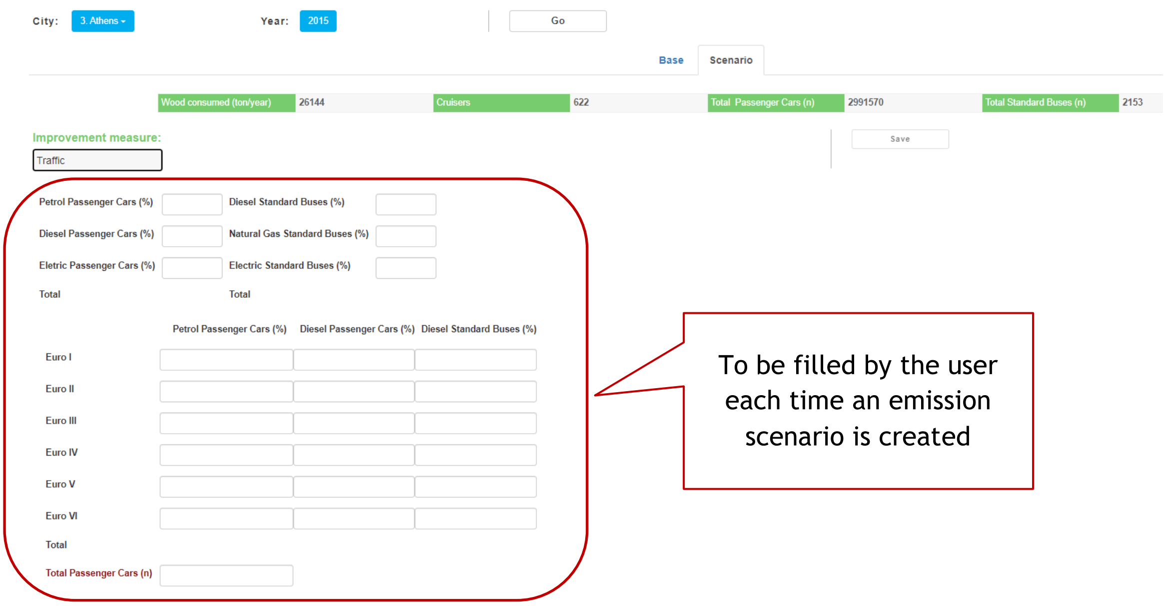


Figure 13. Screen shot from the “Scenario” tab for the “Traffic” improvement measure (example for Athens).

<u>Note that all the boxes should be filled in in each scenario screen (Figure 13).</u> The user may view the base case data for each emission source (Traffic, Residential heating and Cruise shipping) in Annex 1. Key quantities for each source (i.e. tons of wood consumed per year, number of cruises, number of passenger vehicles and number of standard buses) are also provided in the scenario screen. The user should fill each one the relevant boxes in the scenario screen, either by putting the base case value or a modified value, according to the mitigation measure to be tested.

The assessment of the various emission scenarios / mitigation measures may be performed by comparing the modified outputs for air quality, population exposure and health effects with the respective outputs for the base case. **For each type of mitigation measure (Traffic, Residential heating and Cruise shipping), it is recommended to run initially the scenario with the base case data and use this output as reference for all modified scenario comparisons.** This will decrease the uncertainty due to the different models used to estimate ambient concentrations in the base case (WRF-CAMx air quality model) and in the scenarios (ANN simplified model).

Once the tool completes all calculations for a modified scenario, the following tabs are available (Figure 14):

- Ambient concentrations
- PM10 exceedances
- Population exposure
- Deposited dose
- Burden of disease

The user may then examine all available results similarly to the "Base" tab (see Chapter 3). A new scenario may be run by pressing "New scenario?" (Figure 14). A detailed description of the use of scenarios, for each type of mitigation measure, is provided below.

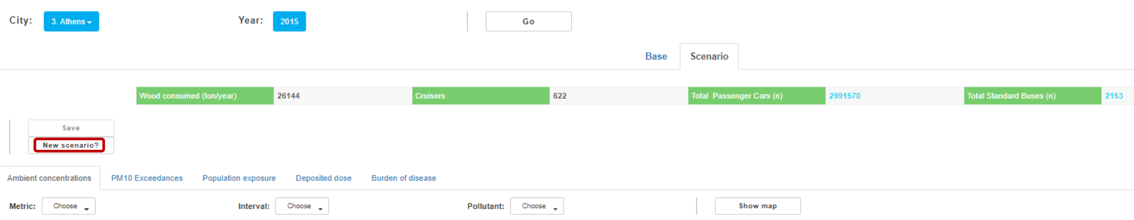


Figure 14. Available outputs after a new emission scenario is created.

In addition to selected emission scenarios / mitigation measures, the user may modify the time-activity pattern of each population subgroup (Figure 15), in order to assess the impact of citizens' everyday schedule to their exposure to $PM_{2.5}$ and PM_{10} and to the deposited dose of particles. This is available through the "Population exposure" and "Deposited dose" tabs, as is presented in detail below.

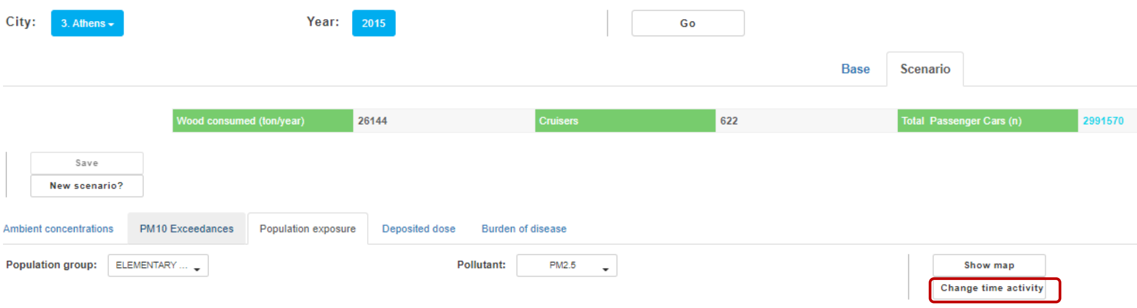


Figure 15. Screen shot from the "Scenario - Population exposure" tab, where, when selecting a specific population subgroup, a modified time-activity pattern may be created.

4.2. TRAFFIC

Emission scenarios related to vehicular traffic may be tested by selecting "Traffic" from the drop-down menu of Improvement measure. A new screen, displaying the factors that may be modified, appears (Figure 13). These parameters, that may be used in order to create a new scenario for traffic emissions, are:

- Apportionment (%) of total passenger cars per fuel type (petrol, diesel or electric);
- Apportionment (%) of petrol passenger cars per age (Euro I to Euro IV);
- Apportionment (%) of diesel passenger cars per age (Euro I to Euro IV);
- Apportionment (%) of standard buses per fuel type (diesel, natural gas or electric);
- Apportionment (%) of diesel standard buses per age (Euro I to Euro IV);
- Total number of passenger cars;
- Total number of standard buses.

The user should fill in all the relevant boxes (Figure 16), by selecting either the base case value (included in Annex 1) or a modified value, based on the emission scenario he/she is testing. The base case value for the total number of passenger cars and the total number of standard buses are also provided in the screen, at the upper right-hang side (Figure 13). Once the user fills in the relevant boxes, the new values for the total number of passenger cars and the total number of standard buses are displayed and the font colour of these values changes from black to blue, in order to denote that these values are selected by the user (Figure 16).

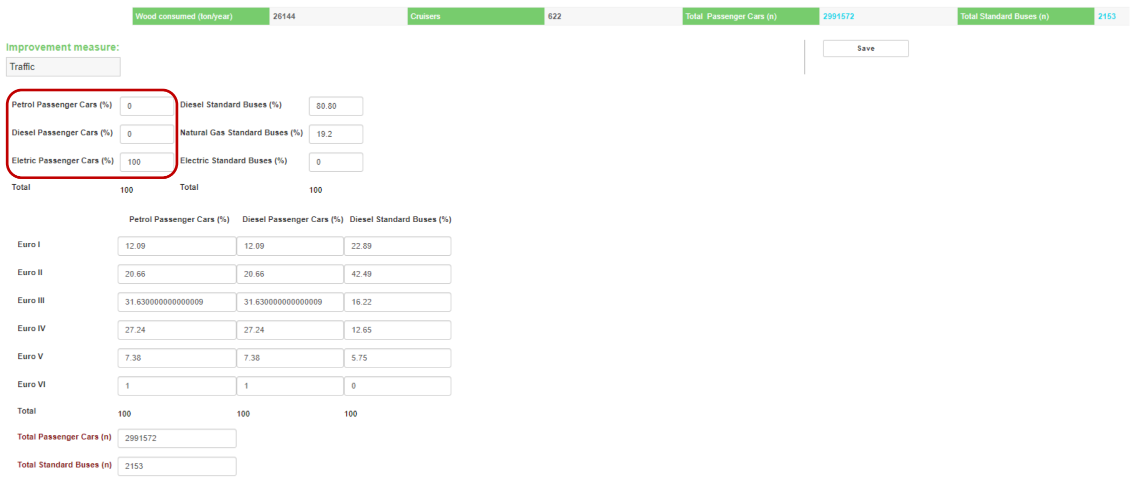


Figure 16. Screen shot from the "Scenario" tab for the "Traffic" improvement measure. An emission scenario is created, where all passenger cars are considered electric.

Once all the boxes are filled in, the user should press "Save" and wait until the tool completes all calculations in order to produce the new dataset of emissions and ambient concentrations of PM10 and PM2.5. When the new data are processed, the output tabs appear, where the user may examine the Ambient concentrations, Population exposure, Deposited dose and Burden of disease, relating to the new emission scenario.

4.3. RESIDENTIAL HEATING

Emission scenarios related to residential heating focus on the use of wood burning, since it has been shown that the last decade urban populations are turning towards this type of fuel, with significant implication for particulate air pollution in the European cities (Diapouli et al., 2017). The residential heating scenarios may be tested by selecting “Residential heating” from the drop-down menu of Improvement measure. A new screen, displaying the factors that may be modified, appears (Figure 17). These parameters, that may be used in order to create a new scenario for residential heating emissions, are:

- Apportionment (%) of wood burning devices per type
- Quantity of wood consumed (in tons/year).

The user should fill in all the relevant boxes (Figure 17), by selecting either the base case value (included in Annex 1) or a modified value, based on the emission scenario he/she is testing. The base case value for the wood consumed is also provided in the screen, at the upper left-hang side (Figure 13). Once the user fills in the relevant box, the new value for the wood consumed is displayed and the font colour of this value changes from black to blue, in order to denote that this value is selected by the user (Figure 17).

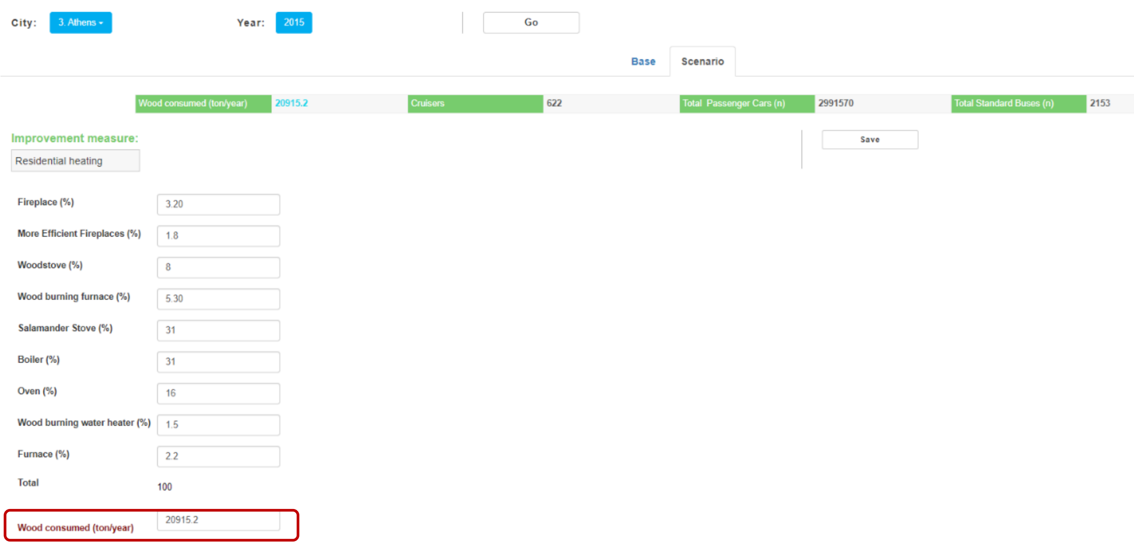


Figure 17. Screen shot from the “Scenario” tab for the “Residential heating” improvement measure. An emission scenario is created, where the wood consumed is reduced by 20%.

Once all the boxes are filled in, the user should press “Save” and wait until the tool completes all calculations in order to produce the new dataset of emissions and ambient concentrations of PM_{10} and $PM_{2.5}$. When the new data are processed, the output tabs appear, where the user may examine the Ambient concentrations, Population exposure, Deposited dose and Burden of disease, relating to the new emission scenario.

4.4. CRUISE SHIPPING

Emission scenarios related to cruise shipping may be tested by selecting “Cruise ships” from the drop-down menu of Improvement measure. For this type of mitigation measure, only one parameter may be changed, i.e. the number of cruisers (Figure 18). From the available five cities included in the tool presently, this measure applies only for Athens, Lisbon and Porto. The other two cities are not expected to be significantly affected by cruise shipping emissions.

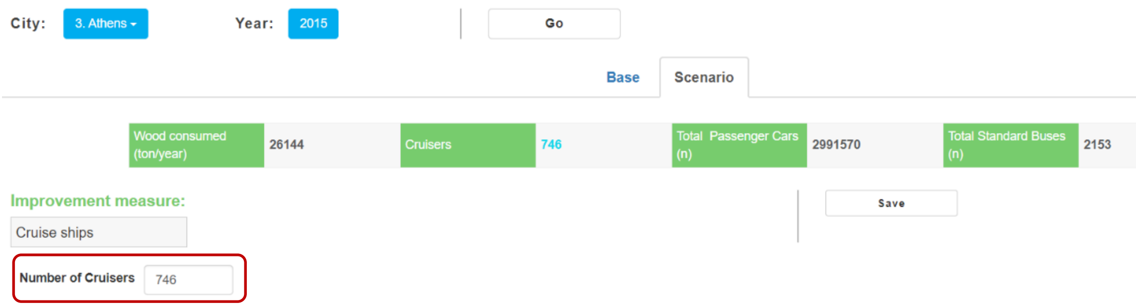


Figure 18. Screen shot from the "Scenario" tab for the "Cruise ships" improvement measure. An emission scenario is created, where the number of ships is increased by 20%.

The user should fill in the relevant box (Figure 18), by selecting either the base case value (included in Annex 1) or a modified value, based on the emission scenario he/she is testing. The base case value for the number of cruise ships is also provided in the screen, at the upper left-hang side (Figure 13). Once the user fills in the relevant box, the new value for the number of cruise ships is displayed and the font colour of this value changes from black to blue, in order to denote that this value is selected by the user (Figure 18). The user should then press "Save" and wait until the tool completes all calculations in order to produce the new dataset of emissions and ambient concentrations of PM_{10} and $PM_{2.5}$. When the new data are processed, the output tabs appear, where the user may examine the Ambient concentrations, Population exposure, Deposited dose and Burden of disease, relating to the new emission scenario.

4.5. MODIFY TIME-ACTIVITY PATTERNS

The LIFE Index-Air tool provides also the means to quantitatively assess the impact of citizens' everyday schedule to their exposure to $PM_{2.5}$ and PM_{10} and to the deposited dose of particles in their respiratory tract. This function is available through the "Scenario" tab, and specifically the "Population exposure" and "Deposited dose" tabs. The user should first run an emission scenario, selecting from the drop-down menu of Improvement measure (Traffic, Residential heating, or Cruise ships). The emission scenario may be run with the base case values or with modified values, as described in the previous sections.

Once all calculations for the emission scenarios are complete, the user may go to the "Population exposure" or "Deposited dose" tab and select a specific population subgroup from the Population group drop-down menu. Once a specific subgroup is selected, the function "Change time activity" appears (Figure 15). By pressing "Change time activity", a box appears allowing the user to define, for each half hour of the day, the microenvironment where the under-study subject (population subgroup) is. The base case time-activity patterns for weekdays and weekends are provided on the screen, and changes to microenvironments may be made through drop-down menus (Figure 19). After the modified time-activity pattern is created, the user should press "Close".

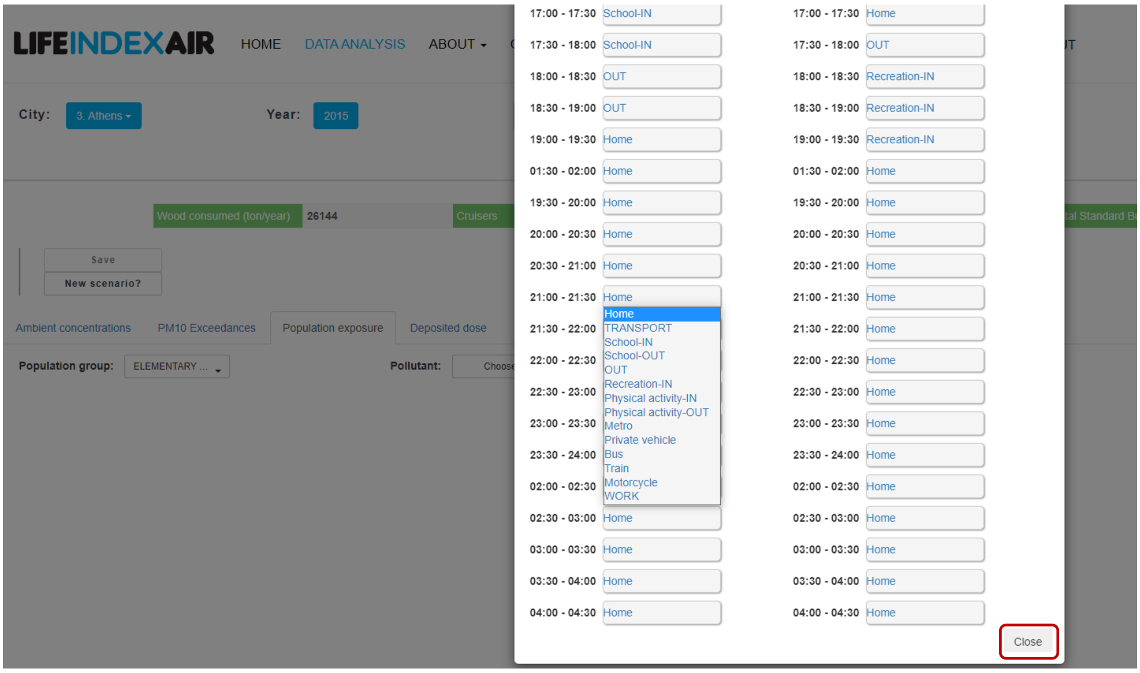


Figure 19. Screen shot from the “Scenario-Population exposure” tab, where a modified time-activity is created for the subgroup of Elementary school children.

Once the modified time-activity pattern is created in the “Population exposure” or “Deposited dose” tab, the user may examine all the relevant outputs, as described in detail in Chapter 3.

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ANNEX 1 - INPUT EMISSION DATA FOR BASE CASE

The following tables provide the input data needed in the application of the “Scenario” tab for the assessment of selected emission scenarios / mitigation measures. The values provided here for each city correspond to the base case.

Table A1a. ATHENS: Base case input data for Traffic.

Total number of passenger cars	2991572	**Total number of standard buses**	2153
Petrol Passenger Cars (%)	92.40	Diesel Standard Buses (%)	80.80
Diesel Passenger Cars (%)	7.20	Natural Gas Standard Buses (%)	19.20
Electric Passenger Cars (%)	0.40	Electric Standard Buses (%)	0.00

	Petrol Passenger Cars	**Diesel Passenger Cars**	**Diesel Standard Buses**
Euro I (%)	12.09	12.09	22.89
Euro II (%)	20.66	20.66	42.49
Euro III (%)	31.63	31.63	16.22
Euro IV (%)	27.24	27.24	12.65
Euro V (%)	7.38	7.38	5.75
Euro VI (%)	1.00	1.00	0.00

Table A1b. Kuopio: Base case input data for Traffic.

Total number of passenger cars	59821	**Total number of standard buses**	122
Petrol Passenger Cars (%)	74.24	Diesel Standard Buses (%)	100
Diesel Passenger Cars (%)	25.74	Natural Gas Standard Buses (%)	0
Electric Passenger Cars (%)	0.02	Electric Standard Buses (%)	0

	Petrol Passenger Cars	**Diesel Passenger Cars**	**Diesel Standard Buses**
Euro I (%)	4.65	4.65	22.89
Euro II (%)	14.51	14.51	42.49
Euro III (%)	18.90	18.90	16.22
Euro IV (%)	35.34	35.34	12.65
Euro V (%)	25.60	25.60	5.75
Euro VI (%)	1.00	1.00	0.00

Table A1c. Lisbon: Base case input data for Traffic.

Total number of passenger cars	1244216	**Total number of standard buses**	3500
Petrol Passenger Cars (%)	37.61	Diesel Standard Buses (%)	93.30
Diesel Passenger Cars (%)	62.07	Natural Gas Standard Buses (%)	6.70
Electric Passenger Cars (%)	0.32	Electric Standard Buses (%)	0.00

	Petrol Passenger Cars	**Diesel Passenger Cars**	**Diesel Standard Buses**
Euro I (%)	9.42	9.42	0.00
Euro II (%)	21.19	21.19	12.33
Euro III (%)	31.03	31.03	66.01
Euro IV (%)	25.64	25.64	3.33
Euro V (%)	11.72	11.72	18.33
Euro VI (%)	1.00	1.00	0.00

Table A1d. Porto: Base case input data for Traffic.

Total number of passenger cars	854445	**Total number of standard buses**	2180
Petrol Passenger Cars (%)	37.61	Diesel Standard Buses (%)	88.16
Diesel Passenger Cars (%)	62.07	Natural Gas Standard Buses (%)	11.57
Electric Passenger Cars (%)	0.32	Electric Standard Buses (%)	0.27

	Petrol Passenger Cars	**Diesel Passenger Cars**	**Diesel Standard Buses**
Euro I (%)	9.42	9.42	0.00
Euro II (%)	21.19	21.19	12.33
Euro III (%)	31.03	31.03	66.01
Euro IV (%)	25.64	25.64	3.33
Euro V (%)	11.72	11.72	18.33
Euro VI (%)	1.00	1.00	0.00

Table A1e. Treviso: Base case input data for Traffic.

Total number of passenger cars	140111	**Total number of standard buses**	360
Petrol Passenger Cars (%)	51.35	Diesel Standard Buses (%)	100
Diesel Passenger Cars (%)	48.65	Natural Gas Standard Buses (%)	0
Electric Passenger Cars (%)	0.00	Electric Standard Buses (%)	0

	Petrol Passenger Cars	**Diesel Passenger Cars**	**Diesel Standard Buses**
Euro I (%)	16.12	2.78	20.71
Euro II (%)	19.70	7.43	16.16
Euro III (%)	14.94	22.57	25.64
Euro IV (%)	31.72	34.58	19.96
Euro V (%)	14.62	30.48	16.62
Euro VI (%)	2.90	2.16	0.91

Table A2a. ATHENS: Base case input data for Residential heating.

Type of device	**Contribution (%)**
Fireplace	3.20
More Efficient Fireplaces	1.80
Woodstove	8.00
Wood burning furnace	5.30
Salamander Stove	31.00
Boiler	31.00
Oven	16.00
Wood burning water heater	1.50
Furnace	2.20
Quantity of wood consumed (tons/year)	26144

Table A2b. Kuopio: Base case input data for Residential heating.

Type of device	Contribution (%)
Fireplace	7.80
More Efficient Fireplaces	16.20
Woodstove	38.00
Wood burning furnace	11.80
Salamander Stove	6.00
Boiler	2.20
Oven	3.00
Wood burning water heater	3.20
Furnace	11.80
Quantity of wood consumed (tons/year)	180280

Table A2c. Lisbon: Base case input data for Residential heating.

Type of device	Contribution (%)
Fireplace	33.39
More Efficient Fireplaces	15.36
Woodstove	20.00
Wood burning furnace	11.00
Salamander Stove	7.80
Boiler	7.20
Oven	4.30
Wood burning water heater	0.57
Furnace	0.38
Quantity of wood consumed (tons/year)	170427

Table A2d. Porto: Base case input data for Residential heating.

Type of device	Contribution (%)
Fireplace	33.39
More Efficient Fireplaces	15.36
Woodstove	20.00
Wood burning furnace	11.00
Salamander Stove	7.80
Boiler	7.20
Oven	4.30
Wood burning water heater	0.57
Furnace	0.38
Quantity of wood consumed (tons/year)	243891

Table A2e. Treviso: Base case input data for Residential heating.

Type of device	Contribution (%)
Fireplace	13.70
More Efficient Fireplaces	13.69
Woodstove	36.26
Wood burning furnace	0.00
Salamander Stove	20.79
Boiler	3.23
Oven	7.61
Wood burning water heater	4.72
Furnace	0.00
Quantity of wood consumed (tons/year)	74631

Table A3. Base case input data for Cruise ships.

City	Number of cruise ships
Athens	622
Lisbon	300
Porto	85

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