Deliverable C.4: Report on the heat related impact and adaptation assessment

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Municipality of Reggio Emilia (Italy)

Municipality of Strovolos (Cyprus)

Municipality of Lakatamia (Cyprus)

Municipality of Peristeri (Greece)

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Executive Summary

This report presents the heat-related impacts and adaptation assessment for the four partner municipalities namely, Strovolos and Lakatamia (Cyprus), Reggio Emilia (Italy) and Peristeri (Greece). Impacts and adaptation assessment was conducted for four vulnerable sectors associated with the urban environment and population, i.e. public health, energy demand, peri-urban fire risk and ozone exceedances.

According to the methodology developed for the assessment of heat related climate change impacts on urban municipalities, the impacts are conceived as a function of the climate change hazards and the vulnerability of the exposed population

Impact assessment was conducted for the current climate (1971-2000), which was used for comparison to the future impacts for the period 2031-2060. Furthermore, impact assessment was conducted for two different climate scenarios, based on the new pathways adopted by the Intergovernmental Panel on Climate Change (IPCC) for its 5th Assessment Report (AR5), namely the Representative Concentration Pathways (RCPs), replacing the SRES scenarios used in AR4. These are the medium mitigation scenario- RCP4.5 and the non mitigation scenario-RCP8.5.

For the impact calculation several sub-indicators were used (different for each category and sector). Values of all sub-indicators were normalized in a 1-5 scale (1: low, 2: low to moderate, 3: moderate, 4: moderate to high, 5: high). The assessment of adaptive capacity was based on the implementation of adaptation measures. In particular, a review of the available adaptation measures for addressing water and heat related climate change impacts took place and a questionnaire was developed for the evaluation of the adaptation measures based on a set of criteria (Multi-Criteria Analysis, MCA).

The hazard indicators used in the framework of the current study, are the following composite climatic indicators: humidity index (number of days with Humidex>38°C- presenting high discomfort conditions), Cooling Degree Days (number of days with CDD>5-presenting excessive cooling needs), Fire Weather Index (no of days with FWI>30- presenting high fire danger) and number of days with ozone exceedances, for the sectors of public health, energy demand, peri-urban fires and ozone exceedances, respectively.

As exposure indicator, the population density was estimated for the sectors of public health, energy demand and ozone exceedances. Population density was estimated with the use of the Copernicus vector polygon Urban Atlas 2012 dataset, as well as the ancillary data on population estimates produced by the JRC and DG REGIO. As far as the peri-urban fires are concerned, slope, aspect as well as flammability of each land cover category throughout the study grid were used as exposure indicators.

Moreover, the social sensitivity indicators developed, reflecting those population segments that are considered to be more vulnerable to climate change impacts or are less able to adapt to climate change (i.e. age, educational level -illiteracy rate, poverty rate, health problems and hospital beds per inhabitant). The values were classified based on their position with respect to the national or European average values (below/above average values). Social indicators are considered to have an additive effect on physical impacts. Statistical data for the calculation of these indicators were collected from the National Statistical Authorities and Eurostat.

The results as far as public health sector is concerned, indicate that Municipality of Peristeri presents the highest future impact (under both RCPs) among the partner municipalities, about 70% of its total area is classified in the highest classes namely 4-medium to high and 5-high impact, followed by municipality of Strovolos and Lakatamia (about 40% in RCP8.5) and municipality of Reggio Emilia (about 20% in RCP8.5).

As far as energy demand is concerned, similarly to public health, municipality of Peristeri presents the highest future impact. As regards the optimistic future emission scenario (RCP4.5) almost 7% of municipality of Peristeri is classified as medium (score 3) impact while about 60% is classified higher namely medium to high (score 4) impact. Under the extreme emission scenario (RCP8.5) the classification is higher namely 4-medium to high (7%) and 5-high (60%). These results indicate the significant impact of climate change on energy demand for cooling in the municipality of Peristeri. Regarding the remaining municipalities, Municipalities of Lakatamia and Stovolos present about 45% of their areas in class 4 and about 13% in class 5 regarding RCP8.5. Also, Municipality of Reggio Emilia presents the lowest impact about 12% of its area in the medium (score 3) and 9% in medium to high (score 4) class under both climate scenarios

As far as the ozone exceedances are concerned, Municipality of Peristeri presents the higher impacts regarding future period under both RCPs. More precisely, about 40% and 21% are classified in classes 4-medium to high and 5-high impact respectively following by Municipalities of Strovolos and Lakatamia where about 27% is classified as 4 and about 14% as 5 in both RCPs. In addition, as concerns Municipality of Reggio Emilia, about 12% of its total area is scored as 3-medium impact while about 9% is scored as 4-medium to high impact under both RCPs.

Finally, regarding peri-urban fire risk, for the Cypriot municipalities, at the current climate only 3% of the total grid points shows medium impact. At the future climate, under both emission scenarios, only 4% of the grid points with low to medium impact changed to medium impact. The same is true for the medium impact grid points that reach the high impact class. The most vulnerable area on the map is the greater area of the Forest National Park of Athalassa, adjacent to Strovolos Municipality, where high impact values are found for the future climate. As far as the municipality of Peristeri is concerned, 25% of the grid points presents low to medium impact, while 9% medium impact. In the future, the majority of the grid points that fell in low to medium class (74%) move to the high impact class. Of the medium impact class in the current climate grid points, 84% will remain at the same class, while the rest 16% will climb to the next class in the future climate.

Introduction

European cities are centers of innovation and growth and the engines of European economic development. They are responsible for an ever bigger share of Europe's economic output. They are projected to grow from housing nearly 73 % of the population now to more than 80 % by 2050 (EEA, 2015).

Climate change is a systemic challenge for cities; it does not happen in isolation but is intertwined with other environmental and socio-economic factors (EEA, 2016).

Conversely, climate change will have profound impacts on a wide range of city functions, infrastructure and services (Revi et al.,2014).

In the past, cities very often started to adapt after a disaster, because they wanted to avoid such catastrophic events in the future. In recent times, cities that have not suffered such an event had started to take action too. Increasingly, they see climate change adaptation as an opportunity to create a more attractive and vital city (EEA, 2016)

Heat or hot weather can have a significant impact on society and public health, from health discomfort to a rise in mortality and morbidity (WMO and WHO, 2015). Heat waves have caused far more fatalities in Europe in recent decades than any other extreme weather event. The impacts of exposure can be related to heat directly causing heat stroke, heat fatigue and dehydration as well as heat stress, or can be the result of a worsening the already aggravated health related to respiratory and cardiovascular diseases, electrolyte disorders and kidney problems (Aström et al., 2013; Analitis et al., 2014; Breitner et al., 2014). Heat-related problems are greatest in cities. During hot weather, synergistic effects between high temperature and air pollution (particulate matter with a diameter ≤10 micrometres (PM 10) and ozone) were observed (Katsouyanni and Analitis, 2009; Burkart et al., 2013; De Sario et al., 2013).

Regarding energy demand, climate change has affected the demand for heating and cooling and will affect future energy demand more generally. The total energy demand in Europe is not expected to change substantially, but significant seasonal shifts and effects on the energy mix are expected, with large regional differences (EEA, 2017a). According to European Environment Agency (EEA, 2017a), in recent decades, the energy demand for heating has decreased, particularly in northern and north-western Europe, whereas the energy demand for cooling has increased, in particular in southern and central Europe. The absolute change is larger for heating demand, but the relative change is larger for cooling demand.

Air pollution continues to have significant impacts on the health of the European population, particularly in urban areas. It also has considerable economic impacts, cutting lives short, increasing medical costs and reducing productivity through working days lost across the economy. Europe's most serious pollutants in terms of harm to human health are PM, NO2 and ground-level ozone (O3) (EEA 2017b).

Regarding O3, which is the pollutant examined in this report, in 2014 about 13 600 premature deaths were attributed to increased O3 concentration in the EU 28 (EEA 2017b). Climate change is expected to affect future ozone concentrations due to changes in meteorological conditions, as well as due to increased emissions of specific ozone precursors (e.g. increased isoprene from vegetation under higher temperatures) and/or emissions from wildfires that can increase under periods of extensive drought (Jacob and Winner, 2009; Royal Society, 2008).

Forest fires constitute a major environmental and socioeconomic issue in the Mediterranean. According to the EEA, the largest proportion of people and residential areas vulnerable to fire are found in southern European countries. Greek cities and the greater Athens area in particular, have a high percentage (> 16 %) of residential areas that are at direct high risk of fire. Cities in northern Italy present no forest fire risk, while in Cyprus cities face medium fire risk.

Although climate change adaptation is still a novel issue, more cities have started the process over the last few years. Most cities are at early stages of the process, assessing their vulnerability and developing adaptation strategies and plans. The frontrunners have now started to implement adaptation measures and to develop first ideas for monitoring and reporting (EEA, 2016). In the framework of LIFE UrbanProof, climate change vulnerability and adaptation assessments for the partner municipalities and local adaptation strategies for each municipality will be developed.

In the framework of this study climatic, morphological, bio-physical and socio-economic indicators are used in order to assess the heat-related vulnerability of the partner municipalities to climate change. This report is structured as follows. Section 1 explains the general methodology used for the vulnerability assessment in the framework of the project. Sections 2-5 present the indicators used, the scoring and the final impact maps for the sectors of health, energy demand, ozone exceedances and peri-urban fires, respectively.

1 Impact Assessment Methodology

In the frame of the LIFE UrbanProof project, a methodology was developed for the assessment of heat and water (Del. C3) related climate change impacts on the urban environment. The impacts are assessed with respect to the current as well as the projected changes in climate for the emission scenarios RCP4.5 and RCP8.5. At this point, it is considered crucial to present the definitions of certain terms after IPCC (2014) that will be widely used in this report.

Impact: *The term impact is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system.*

Hazard: *The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.*

Exposure: *The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.*

Vulnerability: *The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.*

Adaptation: *The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.*

According to the methodology developed for the assessment of heat and water related climate change impacts on urban municipalities, the impacts are conceived as a function of the climate change hazards and the vulnerability of the exposed population. The concept is expressed through *Equations 1* and 2 presented below:

$$\boldsymbol{I = (H * V)^{1/2}} \qquad \textbf{\textit{(Eq. 1)}}$$

and

$$\boldsymbol{V = aV_s * E} \qquad \textbf{\textit{(Eq. 2)}}$$

Where ***I*** is the impact examined, ***H*** is the hazard, ***V*** is the total vulnerability of the exposed population, ***E*** is the exposure, V_S the social vulnerability and ***a*** the weight of social vulnerability. Each variable of Equations 1 and 2 is an independent indicator consisting of one or more sub-indicators. The hazard indicators are used to reflect the climate dependent information for each impact, the exposure indicators are used to reflect the exposure of population and/or infrastructure to an impact while the social vulnerability indicators are used to reflect population groups sensitive to climate change impacts and the adaptive capacity of the society and its structures. The hazard indicators were calculated with the use of climatic information for the reference period as well as for the projected changes in climate based on the emission scenarios RCP4.5 and RCP8.5.The data were provided by the National Observatory of Athens within the framework of Action C.2 entitled "Simulation of current climate and projection of future changes in climate". Exposure is estimated with the use of spatial data on population (i.e. population density) and on the critical infrastructure (where relevant) while social vulnerability is estimated with the use of relevant statistical data on sensitivity and adaptive capacity indicators. The social vulnerability indicators are combined to form the composite social vulnerability index (for more information see Section 1.1).Adaptation is considered to reduce the level of impact and therefore the following equation is applied:

$$I_{with\ adaptation} = I_{w/o\ adaptation} - A \qquad (Eq.\ 3)$$

In general, the methodology includes the stages of normalization, weighting and aggregation. In the normalization stage, the values of indicators expressed in different measurement units are adjusted to a common scale, in order to be comparable. The normalization scale for the impact indicators is set within the numerical range 0-5 with the different values expressing five different levels, from low to high as shown in Table 1. The social vulnerability indicator values were normalized based on their position with regard to the respective European average value (above/below average values). The weighting stage includes the assignment of weights to the variables in order to express the contribution and the relevant importance of each sub-indicator in a composite index. In particular, a weight of 0.4 is assigned to social vulnerability (Vs) in order to reflect its contribution to the overall impact assessment.

Table 1: Rating scale of impact indicators

Qualitative Scale	Numerical scale
None	**I=0**
Low	**$0 < I \leq 1$**
Low to medium	**$1 < I \leq 2$**
Medium	**$2 < I \leq 3$**
Medium to High	**$3 < I \leq 4$**
High	**$4 < I \leq 5$**

1.1 Social Vulnerability Assessment Methodology

In the frame of the current impact assessment, a composite social vulnerability index was built combining those social indicators considered more relevant for the assessment of the public health, energy demand and ozone exceedances vulnerability assessments. These indicators refer to population age, chronic illnesses, poverty rate, educational level and hospital beds per inhabitant. The specific indicators are selected because they are considered to reflect the sensitive groups within the population such the elderly and the very young, the low-income people, the illiterate and the people with illnesses, or, to reflect the response capacity through the adequacy of the medical infrastructure within the region (hospital beds).The sensitivity indicators are proportionally related to vulnerability, as the higher the sensitivity the higher the vulnerability, while the adaptive capacity indicators are inversely related to vulnerability, as the higher the adaptive capacity, the lower the vulnerability. The equation used for the calculation of the Social vulnerability index (V_{social}) is as follows:

$$\boldsymbol{V_{social}} = \frac{\sum_1^n \boldsymbol{S}}{\boldsymbol{n}} \qquad \textbf{(Eq. 4)}$$

Where S is the social indicator and n is the number of individual social indicators. The correlation of these indicators with social vulnerability to public health, energy demand and ozone exceedances is presented in Sections 2, 3 and 4 respectively. Additionally, in Section 5, peri-urban fires, social sensitivity indicators are not used. Below is presented the different social indicators used as well as the methodology for their calculation.

1.1.1 Age

The developed indicator refers to the percentage of people over 70 years old plus the percentage of people under 9 years old and is used to account for the increased sensitivity of these groups to the climate change impacts under study. The data are available at municipal level and are sourced from the National Statistical Services of Italy (ISTAT, 2017), Greece (ELSTAT, 2011a) and Cyprus (CYSTAT, 2012) as well as from Eurostat (2017). The percentage values for each municipality were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

1.1.2 Illiteracy

The literacy rate is included as a measure of the adaptive capacity of individuals (World Bank, 1998). Education increases the skills and knowledge to understand risks and increases the ability to protect (Katic, 2017). People with more education have better position to negotiate equitable solutions (Granados, 2012). On the other hand, it may be more difficult for people who cannot read or write to learn and claim. Illiteracy may prevent people from understanding information provided by authorities on different risks, emergency procedures or preventative/recovery actions (Kazmierczak, 2015).

The indicator created to reflect this population group is actually the percentage of people with educational level lower than primary school, such as illiterate/literate with lack of an official educational level or those who gave up school. The data are available at municipal level and are sourced from the National Statistical Services of Italy (ISTAT, 2011), Greece (ELSTAT, 2011b) and Cyprus (CYSTAT, 2011) as well as from Eurostat (2017). The percentage values for each municipality were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

1.1.3 Low-income

The indicator created to reflect the percentage of population exposed to poverty risk. This information is available from Eurostat (2016) at national level only and therefore the values assigned to each partner municipality are the respective national ones. The percentage values for each municipality were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

1.1.4 Chronic diseases

The indicator refers to the percentage of people with chronic diseases (asthma, chronic lower respiratory-excluding asthma, high blood pressure, stroke or chronic stroke disease, diabetes, chronic depression). This information is available from Eurostat (2014) at national level only and therefore the values assigned to each partner municipality are the respective national ones. The percentage values were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

1.1.5 Hospital beds

The indicator refers to the available hospital beds per capita and is available from Eurostat (2015) at regional level. Therefore the values assigned to each partner municipality are the respective regional ones. Unlike the previous indicators, this is an adaptive capacity indicator and therefore its normalization is based on an inverse scale, as the greater the number of hospital beds per capita, the lower the vulnerability. In particular, the indicator values were normalized in the scale 5-0 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

Table 2: Normalization of social indicator values

$\frac{\text{Municipal/regional/national value}}{\text{European average value}}$	Normalized scale for sensitivity indicators	Normalized scale for adaptive capacity indicators
0.0 – 0.4	1.0 – 1.1	1.5 – 1.4
0.4 – 0.8	1.1 – 1.2	1.4 – 1.3
0.8 – 1.2	1.2 – 1.3	1.3 – 1.2
1.2 – 1.6	1.3 – 1.4	1.2 – 1.1
1.6 - above	1.4 – 1.5	1.1 -1.0

The normalized values for each of the abovementioned indicators are presented below.

Social indicator	Study area A	Study area B	Study area C
Age (<9 &>70) – municipal level	2.9 (Reggio Emilia)	2.8 (Peristeri)	2 (Strovolos)/ 1.9 (Lakatamia)
Illiteracy level – municipal level	0.9 (Reggio Emilia)	1.8 (Peristeri)	0.7 (Strovolos & Lakatamia)
Poverty risk – national level	3.8 (Italy)	3.9 (Greece)	3 (Cyprus)
Chronic diseases – national level	2.8 (Italy)	2.8 (Greece)	2 (Cyprus)
Hospital beds per inhabitant– NUTS2 level	4 (Emilia-Romagna)	2 (Attica)	3.9 (Cyprus)

2 Heatwaves and health

2.1 Impact assessment

2.1.1 Hazard indicators

For the assessment of human health hazard on heat related impacts of climate change in all partner Municipalities, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex is a parameter employed to express the temperature perceived by people. It is applied in summer and generally warm periods and describes the temperature felt by an individual exposed to heat and humidity. More specifically, the Humidex parameter (in °C) is calculated by the following equation:

$$T(h) = T_{max} + 5/9 \times (e - 10)$$

where *e* is the water vapour pressure:

$$e = 6.112 \times 10^{\left(7.5 \times \frac{T\max}{273.3 + T\max}\right)} \times h/100$$

and T_{max} is the maximum 2m air temperature (°C) and h is the relative humidity (%).

Furthermore, 6 classes of Humidex ranges have been established to inform the general public for discomfort conditions:

- <29°C comfortable
- 30–34°C some discomfort
- 35–39°C discomfort; avoid intense exertion
- 40–45°C great discomfort; avoid exertion
- 46–53°C significant danger; avoid any activity
- >54°C imminent danger; heart stroke.

All calculations were performed using the MPI-RCA4 Regional Climate Model (RCM). The period 1971-2000 was used as the base period providing a reference for comparison with future projections for the period 2031-2060. Additionally, future period simulations of the model were based on RCP4.5 and RCP8.5 emission scenarios as described in Methodology chapter (more information about RCM methodology is provided in Del. C2, link)

As a more indicative indicator for the assessment of municipality inhabitants' hazard on heat related climate change impacts, the Number of days with Humidex greater than 38°C was selected. From the above classification, a day with Humidex above 38°C can cause from discomfort to significant danger (higher classes) to human health. The annual distributions of the indicator from 1970 to 2100 using both RCP scenarios are shown in Figure 1. Municipalities of Strovolos and Lakatamia show the highest number of days with Humidex above 38°C (100-110 days) while Peristeri and Reggio Emilia municipalities show lower and quite similar number of days (40-50 days) with discomfort conditions in present period in both emission scenarios. As regards future conditions, municipalities of Strovolos and Lakatamia show an increase of about 4 and 7 days/decade under RCPs 4.5 and 8.5 respectively. In addition, municipality of Peristeri shows an increase of about 3 and 7 days/decade while Reggio Emilia shows about 3 and 6 days/decade both under RCPs 4.5 and 8.5 respectively.

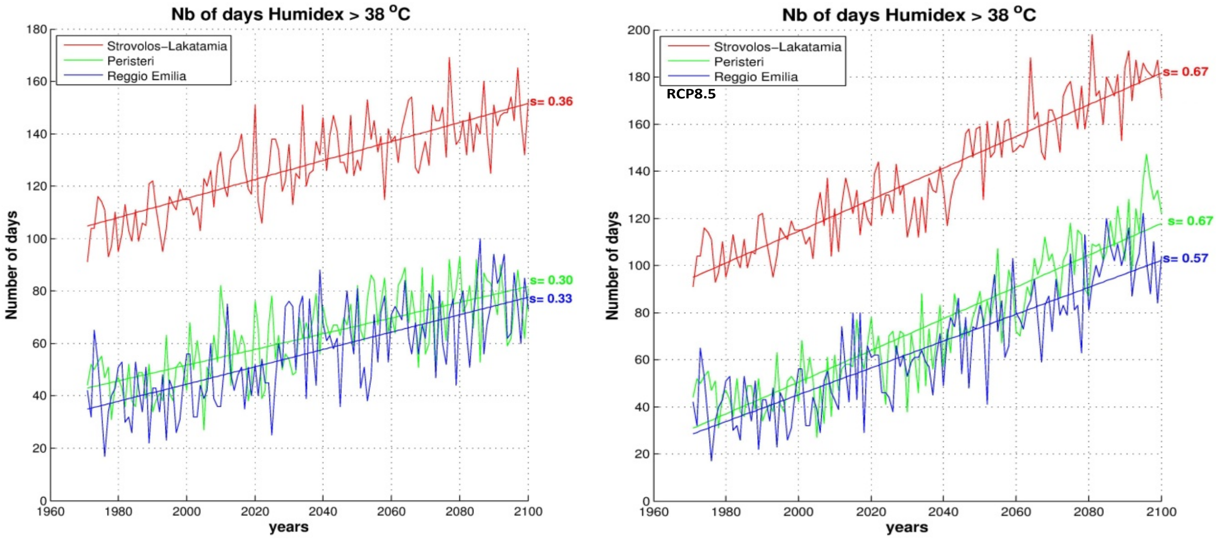


Figure 1: The annual variation (from 1970 to 2100) of the Number of days with Humidex above 38°C in all partner municipalities under the RCP 4.5 (left) and RCP8.5 (right) emission scenarios

2.1.2 Exposure indicators

- **Population density (population/km²)**

For the estimation of population density, the Copernicus vector polygon Urban Atlas 2012 dataset as well as the ancillary data on population estimates produced by the JRC and DG REGIO were used. Residential population estimates at vector polygon level were joined to the Urban Atlas vector polygon dataset in a GIS environment. In this way the two datasets were combined and enabled the population estimates for each building block in each partner municipality. The population estimates for each building block was also gave the opportunity to assess the impact, in each municipality, on a building block scale, giving better and more useful spatial results for city planners and other stakeholders.

2.1.3 Social sensitivity indicators

As described in the methodology, social sensitivity indicators were also used and assessed to estimate the vulnerability of public health to heat related climate change impacts in each partner municipality. All the separated social indicators assessed in case of public health were the following:

- **Population % under 9 and over 70 years old** - Heat exposure can increase the risk of illness and death among vulnerable population groups
- **Population % at risk of poverty** - Poor people are considered more vulnerable to extreme heat exposure (no access to air conditioning, poorly-insulated dwellings, no access to healthcare facilities etc.)
- **Illiteracy rate –** Illiteracy rate is considered as a key determinant of adaptive capacity of population. Increased illiteracy rates indicate reduced adaptive capacity namely increased exposure
- **Hospital beds per capita –** Health infrastructure and level of health services are considered an important index of adaptive capacity.
- **Health problems** - Population well-being is an important ingredient and determinant of adaptive capacity. Exposure to high temperatures may aggravate an existing health problem

2.1.4 Indicator's scoring

For the hazard and exposure indicators' scoring and classification, the following methodology was followed:

- Hazard indicator – Number of days Humidex > 38°C

As concerns classification, for each municipality the annual number of days with Humidex > 38°C was calculated for each year of the period 1971 to 2060. The annual number of days with Humidex > 38°C was derived from regional climate model outputs using both RCPs 4.5 and 8.5. The minimum and maximum value of the indicator was calculated from the whole time series (1971-2060) of both RCPs. Then the range was calculated and divided equally into five classes.

As far as scoring is concerned, the average number of days with Humidex > 38°C was calculated for the thirty-year period 1971-2000 in case of current climate and 2031-2060 in case of future climate in both time series of each emission scenario. The averages resulting from the previous procedure were classified (using the previous constructed classification) and the corresponding scores were given in each case.

- Exposure indicator – Population density

As for the population density indicator scoring, using a GIS software the population density (residents/km2) was calculated for each building block and more generally, for each different land use polygon of Urban Atlas database. Due to the high fluctuation of population density among partner municipalities and for simplicity purposes, the decimal logarithm of all population densities of each land use polygon of each municipality, was used. For comparison purposes, the same classification was used for all partner municipalities, thus the minimum and maximum value was calculated from all municipalities' population densities. Similarly to the hazard indicators, the range was divided into 5 equal classes with scores from 1 to 5, from very low population density to high.

- Social sensitivity indicators

The scoring process of each individual social indicator has already been described in Section 1.1. For the final impact assessment, the integrated final social indicator was used.

The final scores of all indicators in all partner municipalities are presented below:

2.1.4.1 *Municipalities of Lakatamia and Strovolos*

Number of days with HUMIDEX > 38°C				
Classification		Score (all polygons)		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
91-105	1			
106-119	2	2		
120-134	3		3	
135-148	4			4
149-162	5			

Population density indicator - Log10(residents/km^2)	Classification	Score (number of polygons with the same score)
0-1.117	1	552
1.118-2.233	2	184
2.234-3.350	3	654
3.351-4.466	4	503
4.467-5.583	5	67

Social impact – Sub indicators	Score (all polygons)
Age (<9 & >70)	1.95
Illiteracy level	0.7
Poverty rate	3
Health problems	2
Hospital beds per inhabitant	3.9
Integrated Final Social Indicator	**2.3**

2.1.4.2 *Municipality of Peristeri*

Number of days with HUMIDEX > 38°C				
Classification		Score (all polygons)		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
27-43	1			
44-59	2	2		
60-75	3		3	3
76-91	4			
92-107	5			

Population density indicator - Log10(residents/km^2)	Classification	Score (number of polygons with the same score)

0-1.117	1	77
1.118-2.233	2	24
2.234-3.350	3	111
3.351-4.466	4	1134
4.467-5.583	5	961

Social impact – Sub indicators	Score (all polygons)
Age (<9 & >70)	2.8
Illiteracy level	1.8
Poverty rate	3.9
Health problems	2.8
Hospital beds per inhabitant	2
Integrated Final Social Indicator	**2.66**

2.1.4.3 Municipality of Reggio Emilia

Number of days with HUMIDEX > 38°C				
Classification		Score (all polygons)		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
17-34	1			
35-51	2	2		

52-69	3		3	3
70-86	4			
87-103	5			

Population density indicator - Log10(residents/km²)	Classification	Score (number of polygons with the same score)
0-1.117	1	1963
1.118-2.233	2	455
2.234-3.350	3	1878
3.351-4.466	4	1082
4.467-5.583	5	12

Social impact – Sub indicators	**Score (all polygons)**
Age (<9 & >70)	2.9
Illiteracy level	0.9
Poverty rate	3.8
Health problems	2.8
Hospital beds per inhabitant	4
Integrated Final Social Indicator	**2.88**

2.2 Impact maps for each municipality

In the following sub-sections, impact maps for each municipality concerning public health are presented. For each municipality, impact assessment is shown for current climate (reference period: 1971-2000) as well as for future climate (future period: 2031-2060) under two emission scenarios, namely RCP4.5 and RCP8.5.

For all impact maps, the color classification (from low impact to high impact) used as well as the respective scores are shown in Table 3.

Table 3: Map color classification and the corresponding scores

Classes	Score
Low	1
Low to medium	2
Medium	3
Medium to high	4
High	5

2.2.1 Municipalities of Lakatamia and Strovolos

As far as current climate is concerned, Figure 2 depicts that about 58.3% of the two municipalities' total area is scored with 1-low impact, about 27.5% is scored with 2-low to medium impact while the remaining 14.3% of the total area is classified higher namely 3-medium impact. As for future climate under RCP4.5 scenario (Figure 3), all areas ranked previous as 1-low impact, 2-low to medium and 3-medium are now classified in a higher class i.e. 2-low to medium, 3-medium and 4-medium to high impact respectively. As regards RCP8.5 emission scenario (Figure 4) the increase is even greater than RCP4.5. All areas previously ranked (RCP4.5) as 2-low to medium, 3-medium and 4-medium to high in RCP4.5 are now (RCP8.5) ranked as 3-medium, 4-medium to high and 5-high impact respectively.

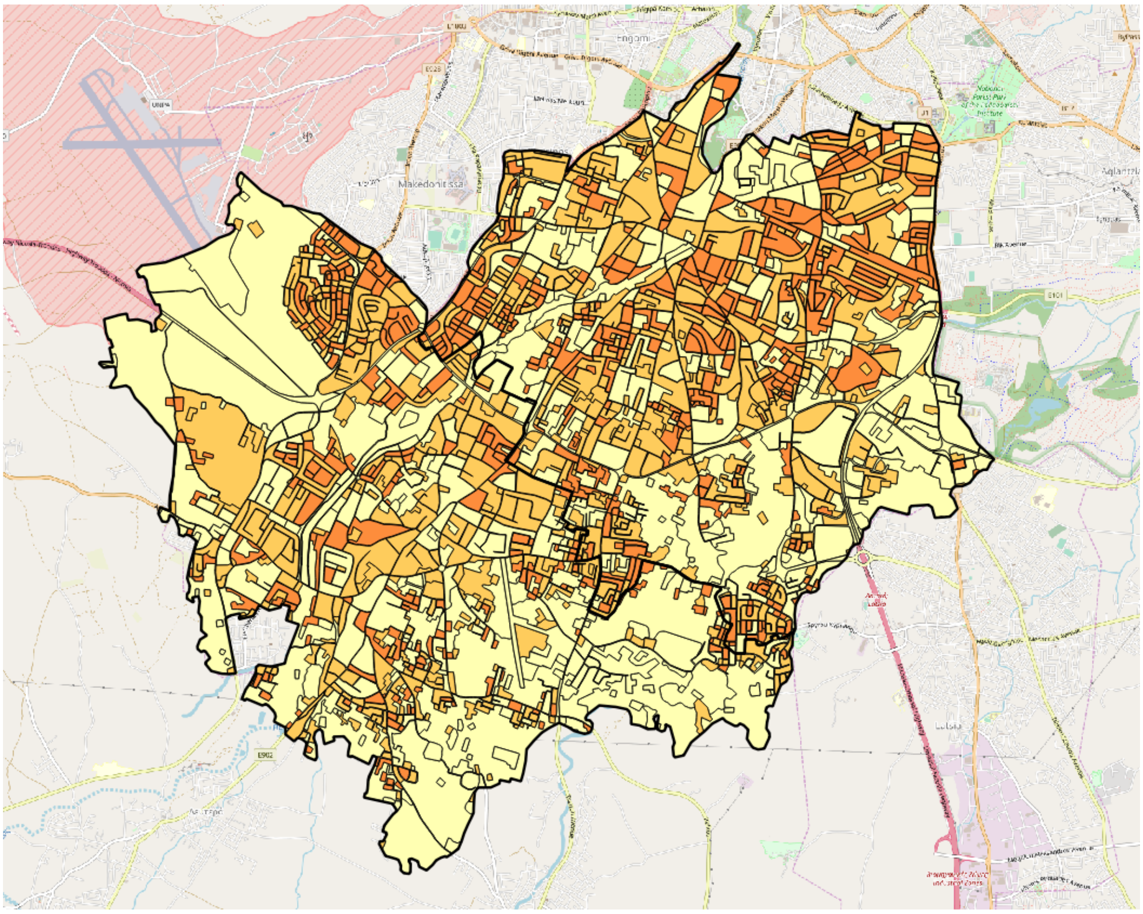


Figure 2: Impact assessment for present climate

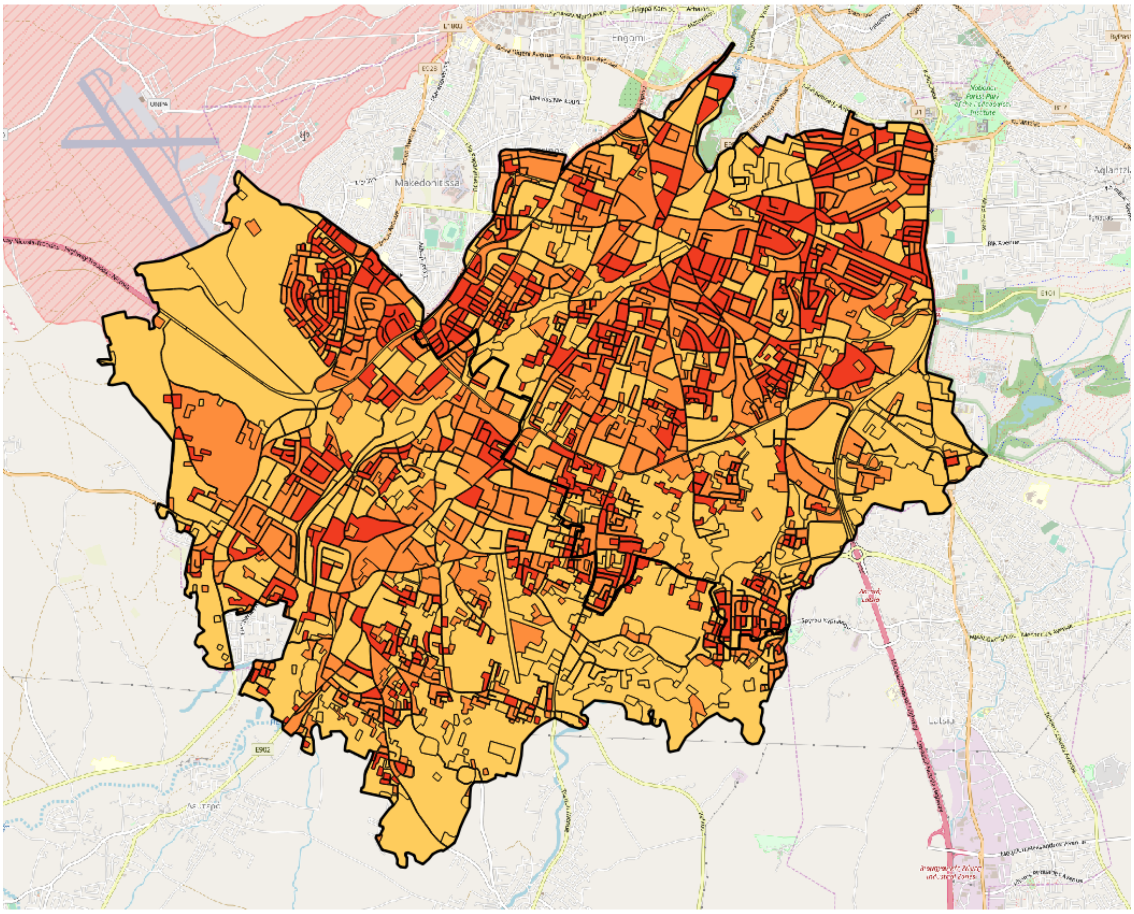


Figure 3: Impact assessment for future climate using RCP4.5 emission scenario

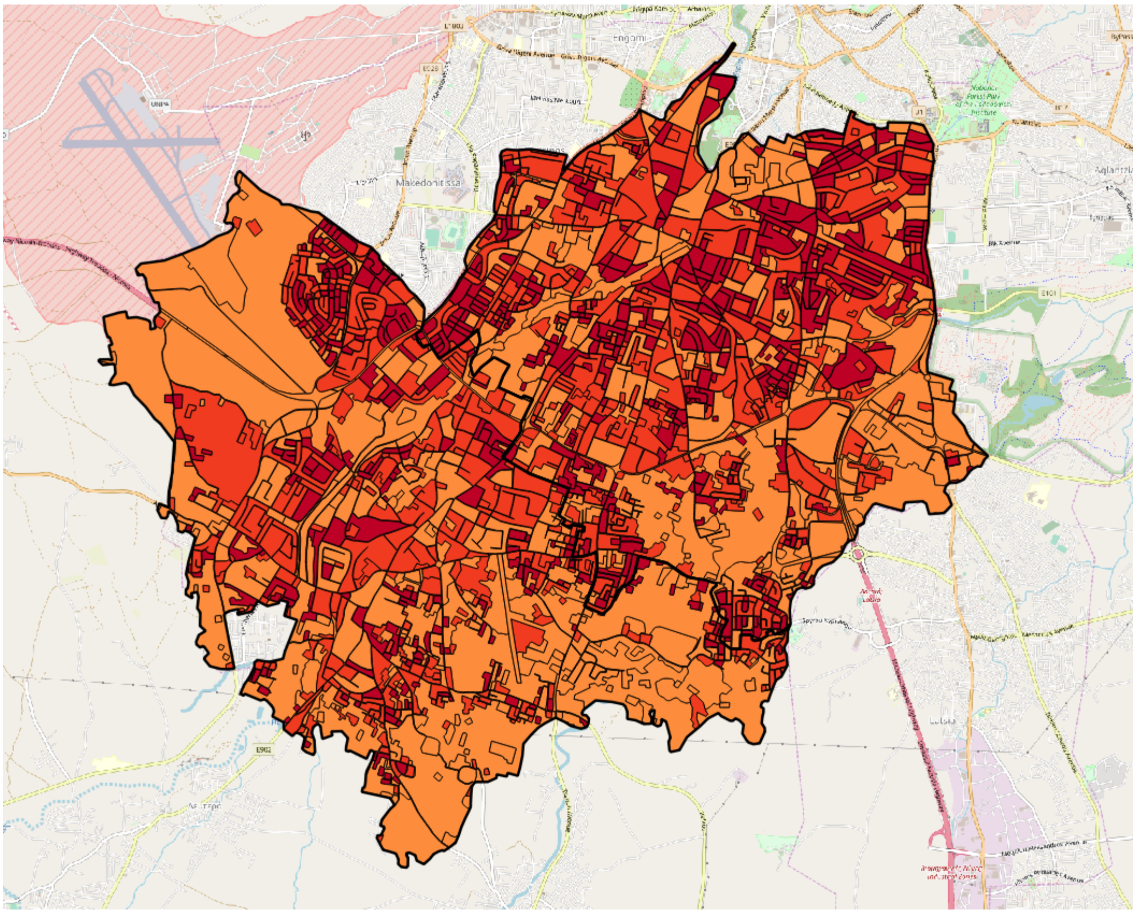


Figure 4: Impact assessment for future climate using RCP8.5 emission scenario

2.2.2 Municipality of Peristeri

Figure 5 depicts vulnerable areas within the municipality of Peristeri for the current climate. About 32% and 7% of the total area are classified in classes 1 – low impact and 2 respectively. Most areas of Peristeri, about 61%, present an increased impact since they are classified in classes 3-medium impact (40% of the total area) and 4-medium to high impact (21% of the total area). Regarding future changes, under RCP4.5 (Figure 6), about 80% of the area ranked as 1 in current climate is now ranked as 2-low to medium impact while the remaining 20% is classified even higher namely 3-medium impact. In addition, all areas previously ranked as 2, are now classified two classes higher i.e. 4-medium to high impact. Also, all areas ranked as 3 and 4 (about 61% of the municipality area) in current climate, in future period they present the highest impact since they classified as 5-high. In conclusion in RCP4.5, about 28.3% of the total municipality area is classified as 2-low to medium impact, about 3.8% as 3-medium impact, about 6.6% as 4-medium to high impact and about 61.3% as 5-high impact. The same spatial pattern and the same classification are shown under the RCP8.5 (Figure 7).

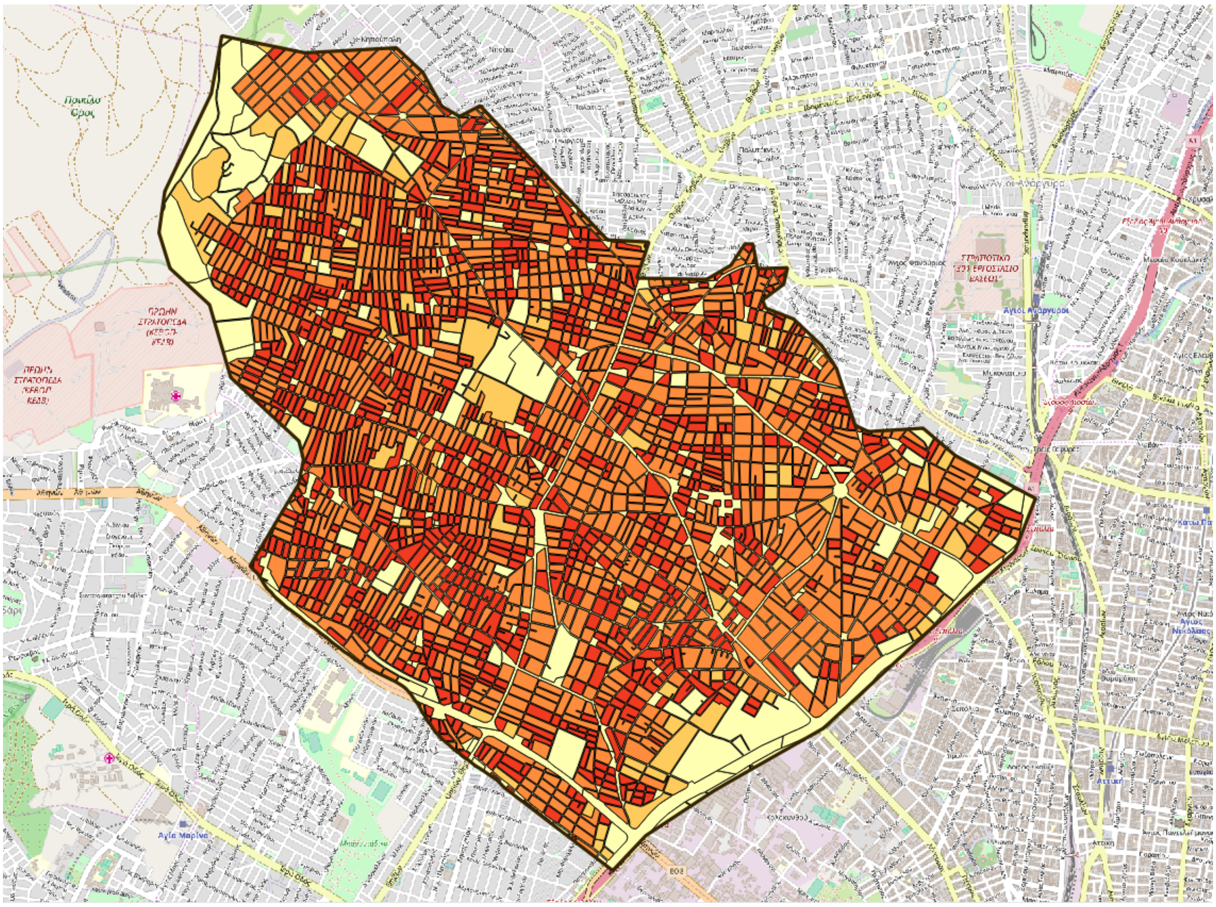


Figure 5: Impact assessment for present climate

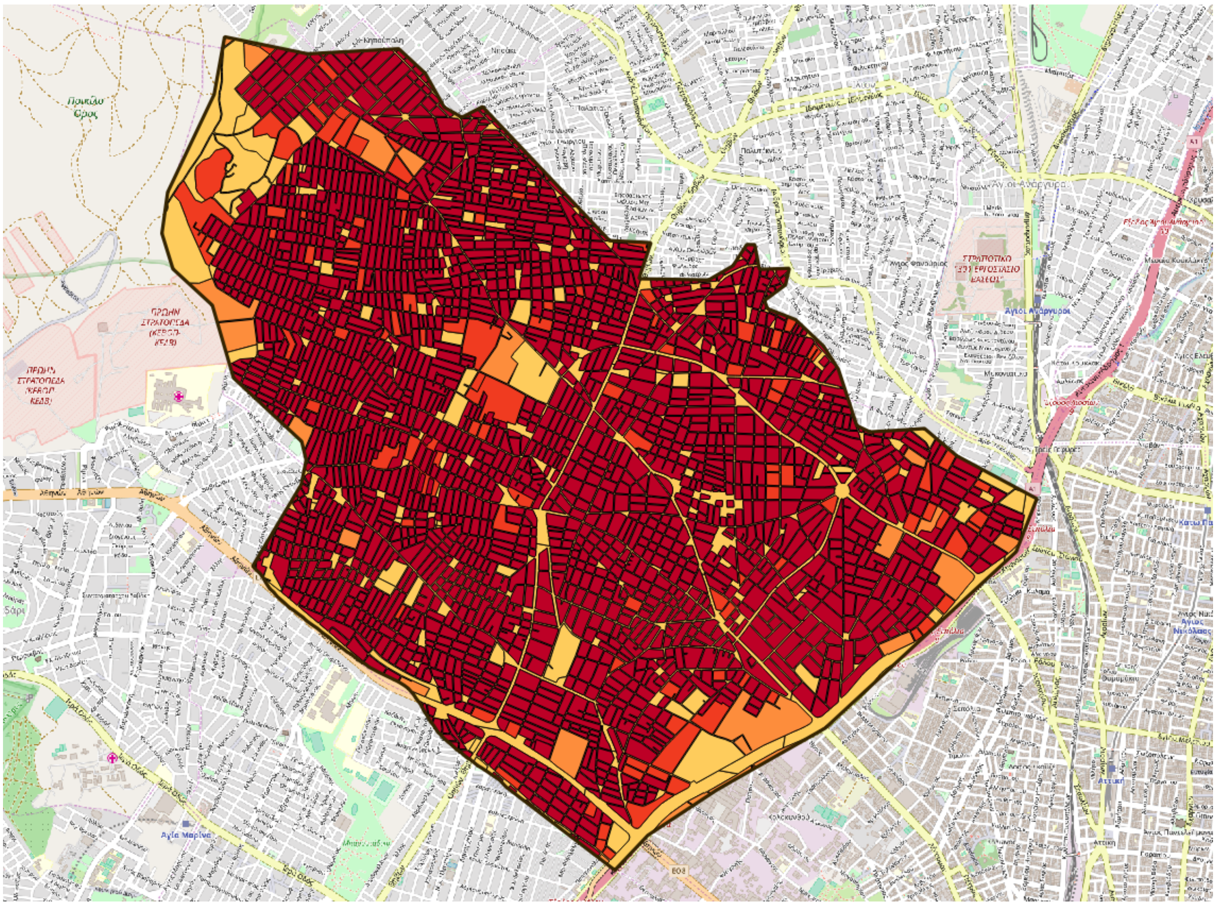


Figure 6: Impact assessment for future climate using RCP4.5 emission scenario

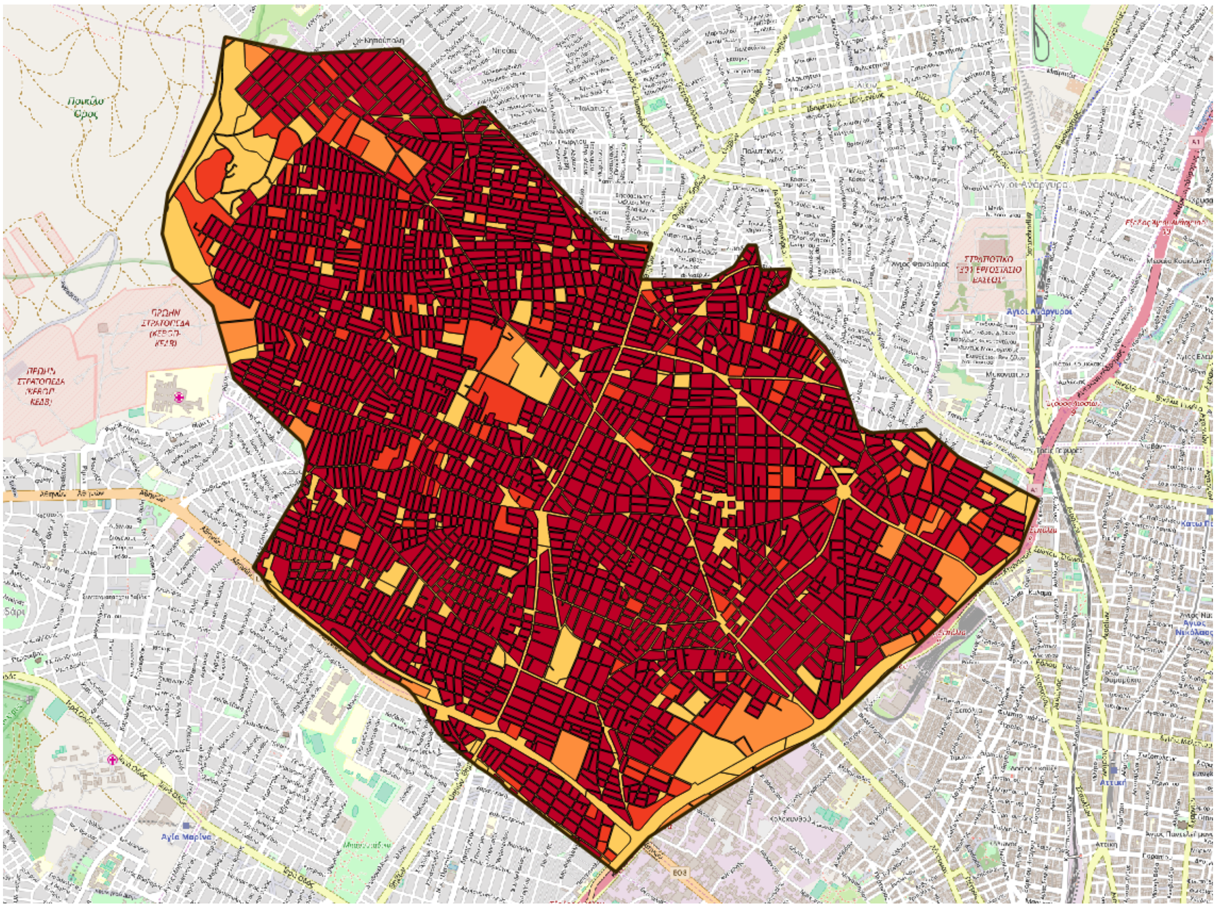


Figure 7: Impact assessment for future climate using RCP8.5 emission scenario

2.2.3 Municipality of Reggio Emilia

In Figure 8, the classification of Reggio Emilia municipality areas in terms of heat related climate change impacts on public health under the current climate is presented. About 79% of the area is classified in class 1-low impact, about 12% is classified as 2-low to medium impact while the remaining 9% is classified in class 3-medium impact. As regards future changes under RCP4.5 (Figure 9), the whole area, previous ranked 1, is now classified in higher classes namely 2-low to medium (46% of the previous area) and 3-medium impact (56% of the previous area). In addition, areas classified as 2 and 3 in current climate, are now classified as 4-medium to high and 5-high impact respectively. In total under RCP4.5, about 36.2% of the municipality of Reggio Emilia is classified as 2-low to medium impact, about 43.2% as 3-medium impact, about 12.1% as 4-medium to high impact and about 8.5 as 5-high impact. As concerns the RCP8.5 scenario, the same spatial pattern and the same classification as RCP4.5 is presented (Figure 10).

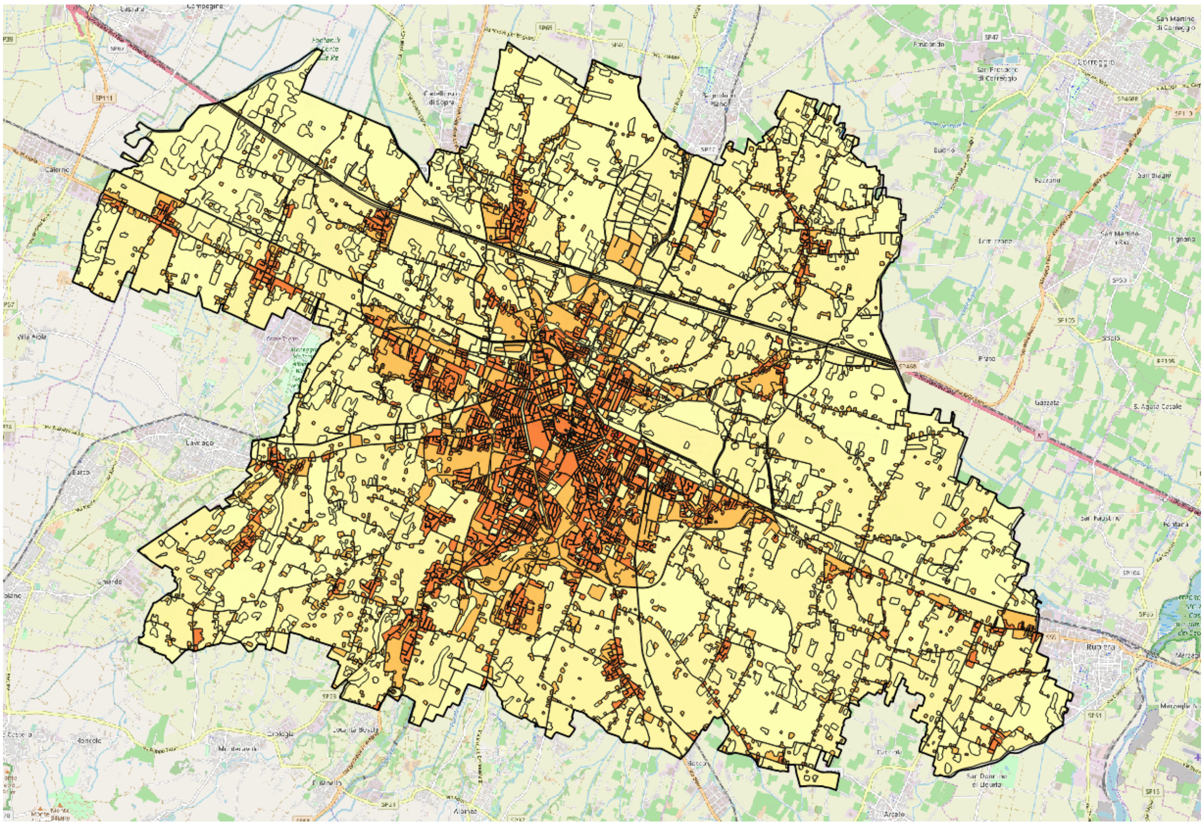


Figure 8: Impact assessment for present climate

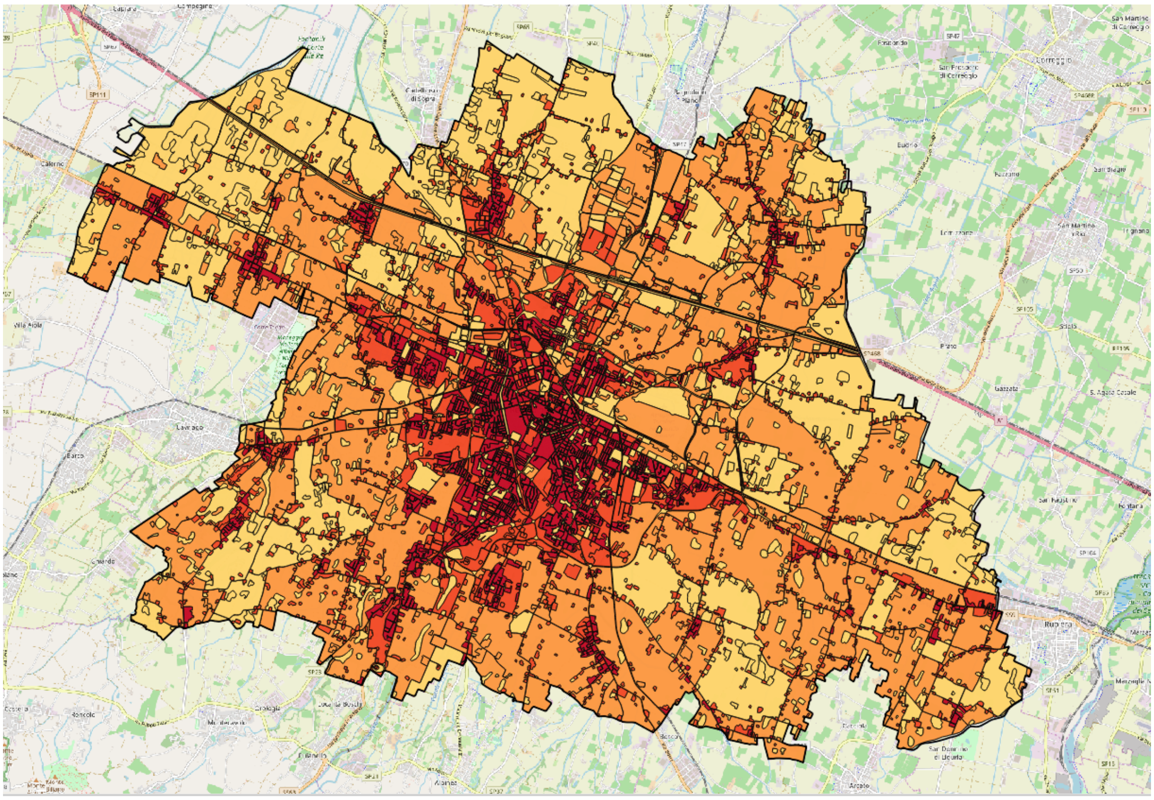


Figure 9: Impact assessment for future climate using RCP4.5 emission scenario

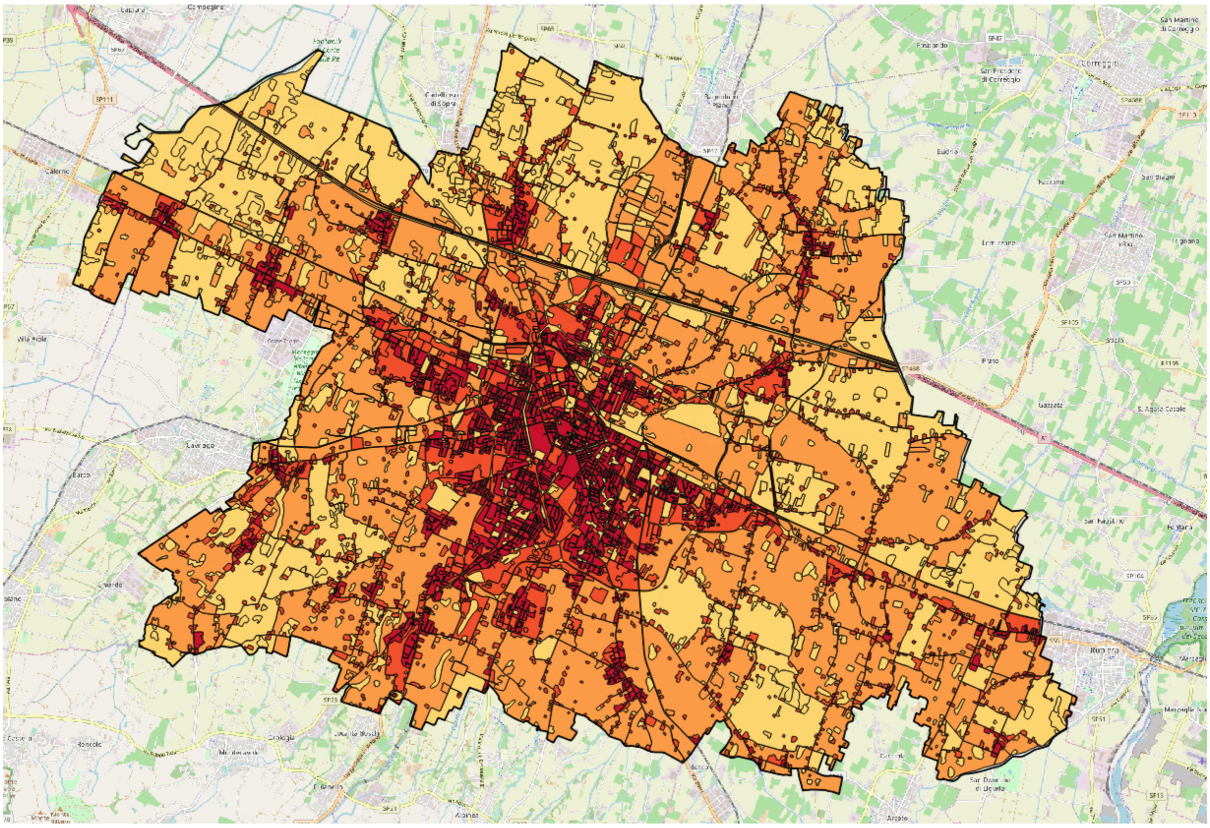


Figure 10: Impact assessment for future climate using RCP8.5 emission scenario

2.3 Proposed adaptation measures

The classification of the proposed adaptation measures is based on the mean score extracted from the four selected criteria. In Table 4, the mean score for each adaptation measure, as well as the individual scores for each evaluation criterion are also presented. More information on each adaptation measure is presented in Annex A.

Table 4: Proposed adaptation measures for public health and their evaluation

Adaptation measures	Evaluation criteria				Mean score
	Efficiency in addressing the impact	Environmental Friendliness	Economic Viability	Job growth	
Urban parks	82.86	91.67	57.62	39.05	**67.80**
Raising public awareness	81.90	80.95	68.57	31.19	**65.65**
Early warning systems	83.24	80.59	62.94	30.88	**64.41**
Water pollution monitoring	80.00	83.53	52.65	37.06	**63.31**
Pavements redesign	70.29	74.71	41.18	58.24	**61.10**
Strict controls/health inspections in food industry	71.25	64.06	57.19	40.00	**58.13**
Strategies for public buildings restoration	73.06	73.33	37.22	47.22	**57.71**
Limitation of outdoor activities	58.24	53.82	65.63	8.75	**46.61**
Air-conditioned public buildings	68.24	35.88	35.29	37.65	**44.26**

3 High temperatures and energy demand

3.1 Impact assessment

3.1.1 Hazard indicators

To assess the hazard of energy demand on heat related climate change impacts in all partner municipalities, the indicator of Degree-Day (CDD) was used. Firstly introduced by Thom (1962), Degree-Day is a measurement designed to reflect the demand for energy needed to heat or cool a building. It is defined as the difference of the mean daily outdoor temperature from the base temperature. Base temperature is the temperature above or below which a building presents no requirements for heating or cooling, respectively. In other words, base temperature is usually an indoor temperature which is adequate for human comfort. In the framework of this program, study focused on the cooling energy demands of building, for this reason the corresponding indicator, Cooling Degree-Day was used.

For the calculation of the CDD index the following equation is used:

$CDD = \max(T - T^*, 0)$

where T^* is the base temperature, in this case 25 °C (Giannakopoulos et al., 2009; 2016) and T is the mean daily temperature calculated from the daily data of the RCM for the control – reference period (1971-2000) as well as the future period (2031-2060) under two emission scenarios, namely RCP4.5 & 8.5.

Among all indicators which are widely being used and based on CDD index, the Number of days with CDD above 5 (Nb of days CDD>5) was selected as the most indicative hazard indicator. The Nb of days CDD>5 expresses the energy demand for excessive cooling of a building. The annual distributions of the indicator from 1970 to 2100 using both RCP scenarios in all partner municipalities are shown in Figure 11.

Municipality of Peristeri shows the highest number of days with CDD above 5 (≈10 days) while Strovolos and Lakatamia as well as Reggio Emilia municipalities show lower and quite similar situation (≈5 days) with high energy demand in present period. As regards future conditions, municipalities of Strovolos and Lakatamia show the highest increase of about 2 and 7 days/decade under RCPs 4.5 and 8.5 respectively. In addition, municipalities of Peristeri and Reggio Emilia show both an increase of about 2 and 5 days/decade under RCPs 4.5 and 8.5 respectively.

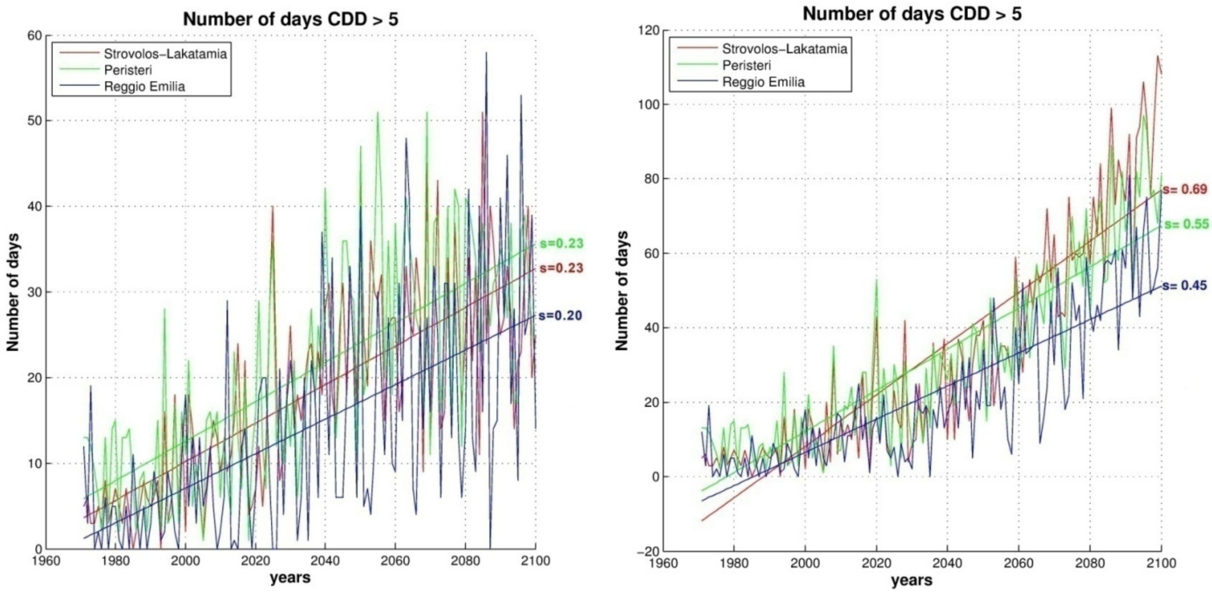


Figure 11: The annual variation (from 1970 to 2100) of the Number of days with CDD > 5 in all partner municipalities under the RCP 4.5 (left) and RCP8.5 (right) emission scenarios

3.1.2 Exposure indicators

- **Population density (population/km²)**

Similarly to health sector, population density (population/km²) was used as an exposure indicator in case of energy since it affects the spatial distribution of energy demand within the municipalities, for example densely populated areas have more increased energy demand for cooling compared to sparsely populated areas. The methodology used for population density estimation in all partner municipalities is analyzed in section 1.1.2.

3.1.3 Social Sensitivity indicators

In addition to population density, social sensitivity indicators were also used and assessed to estimate the vulnerability of energy demand on heat related climate change impacts in each partner municipality. All the separated social indicators assessed in case of public health were the following:

- **Population % under 9 and over 70 years old** – Vulnerable population groups to heat exposure have increased energy needs for cooling
- **Population % at risk of poverty** – Poor population has lack of access to modern energy services (energy poverty) increasing in this way their vulnerability to heat related climate change impacts.
- **Health problems** – Population with pre-existing health problems has more elevated energy needs for cooling during extreme heat events

3.1.4 Indicator’s scoring

For the hazard and exposure indicators’ scoring and classification, the following methodology was followed:

- Hazard indicators – Number of days CDD > 5

As concerns classification, for each municipality the annual number of days with CDD>5 was calculated for each year of the period 1971 to 2060. The annual number of days with CDD > 5 was derived from regional climate model outputs using both RCPs 4.5 and 8.5. The minimum and maximum value of the indicator was calculated from the whole time series (1971-2060) of both RCPs. Then the range was calculated and divided equally into five classes.

As far as scoring is concerned, the average number of days with CDD > 5 was calculated for the thirty-year period 1971-2000 in case of current climate and 2031-2060 in case of future climate in both time series of each emission scenario. The averages resulting from the previous procedure were classified (using the previous constructed classification) and the corresponding scores were given in each case.

- Exposure indicator – Population density

The methodology used for the population density classification is described in section 1.1.3

- Social sensitivity indicators

The scoring process of each individual social indicator has already been described in Section 1.1. For the final impact assessment, the integrated final social indicator was used.

The final scores of all indicators in all partner municipalities are presented below:

3.1.4.1 Municipalities of Lakatamia and Strovolos

Number of days with CDD > 5				
Classification		Score		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
20-36	1	1		
37-52	2			

53-67	3		3	
68-83	4			4
84-99	5			

Population density indicator - Log10(residents/km²)	Classification	Score (number of polygons with the same score)
0-1.117	1	552
1.118-2.233	2	184
2.234-3.350	3	654
3.351-4.466	4	503
4.467-5.583	5	67

Social impact – Sub indicators	Score (all polygons)
Age (<9 & >70)	1.95
Poverty rate	3
Health problems	2
Integrated Final Social Indicator	**2.3**

3.1.4.2 Municipality of Peristeri

Number of days with CDD > 5				
Classification		Score		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
3-16	1			
17-30	2	2		
31-43	3		3	
44-57	4			4
58-70	5			

Population density indicator - Log10(residents/km²)	Classification	Score (number of polygons with the same score)
0-1.117	1	77
1.118-2.233	2	24
2.234-3.350	3	111
3.351-4.466	4	1134
4.467-5.583	5	961

Social impact – Sub indicators	Score

Age (<9 & >70)	2.8
Poverty rate	3.9
Health problems	2.8
Integrated Final Social Indicator	**3.2**

3.1.4.3 *Municipality of Reggio Emilia*

Number of days with HUMIDEX>38°C				
Classification		Score		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
0-9	1	1		
10-18	2		2	2
19-28	3			
29-37	4			
38-46	5			

Population density indicator - Log10(residents/km^2)	Classification	Score (number of polygons with the same score)
0-1.117	1	1963
1.118-2.233	2	455
2.234-3.350	3	1878

3.351-4.466	4	1082
4.467-5.583	5	12

Social impact – Sub indicators	Score
Age (<9 & >70)	2.9
Poverty rate	3.8
Health problems	2.8
Integrated Final Social Indicator	**3.2**

3.2 Impact maps for each municipality

In the following sections, impact maps for each municipality concerning energy demand are presented. For each municipality, impact assessment is shown for current climate (reference period: 1971-2000) as well as for future climate (future period: 2031-2060) under two emission scenarios, namely RCP4.5 and RCP8.5.

For all impact maps, the color classification (from low impact to high impact) used as well as the respective scores are shown in Table 5.

Table 5: Map color classification and the corresponding scores

Classes	Score
Low	1
Low to medium	2
Medium	3
Medium to high	4
High	5

3.2.1 Municipalities of Lakatamia and Strovolos

As far as current climate is concerned, Figure 12 depicts that about 58% of the total municipalities' area is scored with 1-low impact, while about 41% of the area is scored higher namely 2-low to medium impact. Also, the remaining 1% is classified in class 3-medium impact. As for future climate under RCP4.5 scenario (Figure 13), all areas previously ranked as 1, are now classified as 2-low to medium (70% of the previous area) and 3-medium impact (30% of the previous area). In addition, all areas ranked as 2 in current climate, are now classified in classes 3-medium (67% of the previous area) and 4-medium to high (33% of the previous area) impact. Finally, all areas classified as 3 in current climate, are now classified in the highest class, namely 5-high impact. In total as regards RCP4.5, about 40.3% of the municipality area is classified in class 2, about 45.4% in class 3, about 13.3% in class 4 and about 1% in class 5. As for RPC8.5 emission scenario, Figure 14 depicts that Municipality areas are classified even higher compared to RCP4.5. More precisely, all areas classified in classes 2, 3 and 4 are now classified in higher classes namely 3-medium, 4-medium to high and 5-high impact respectively.

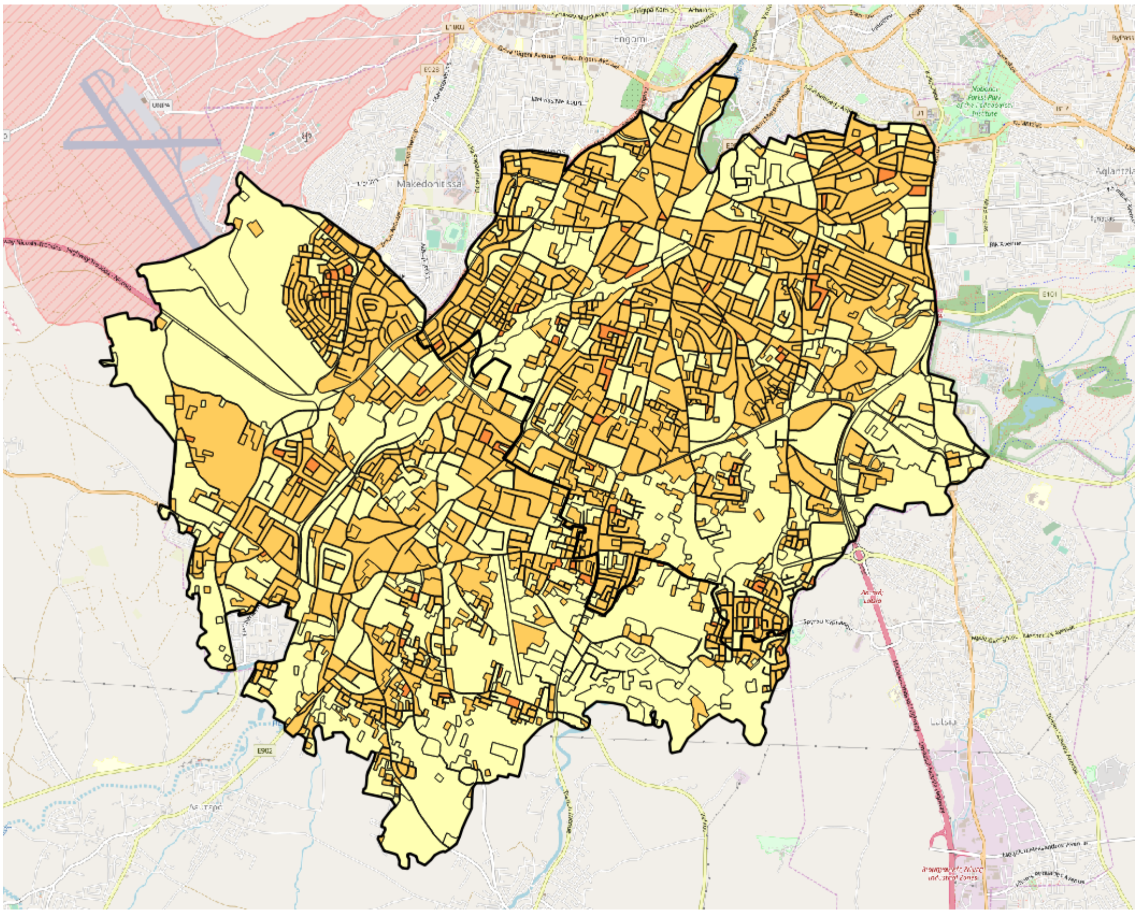


Figure 12: Impact assessment for present climate

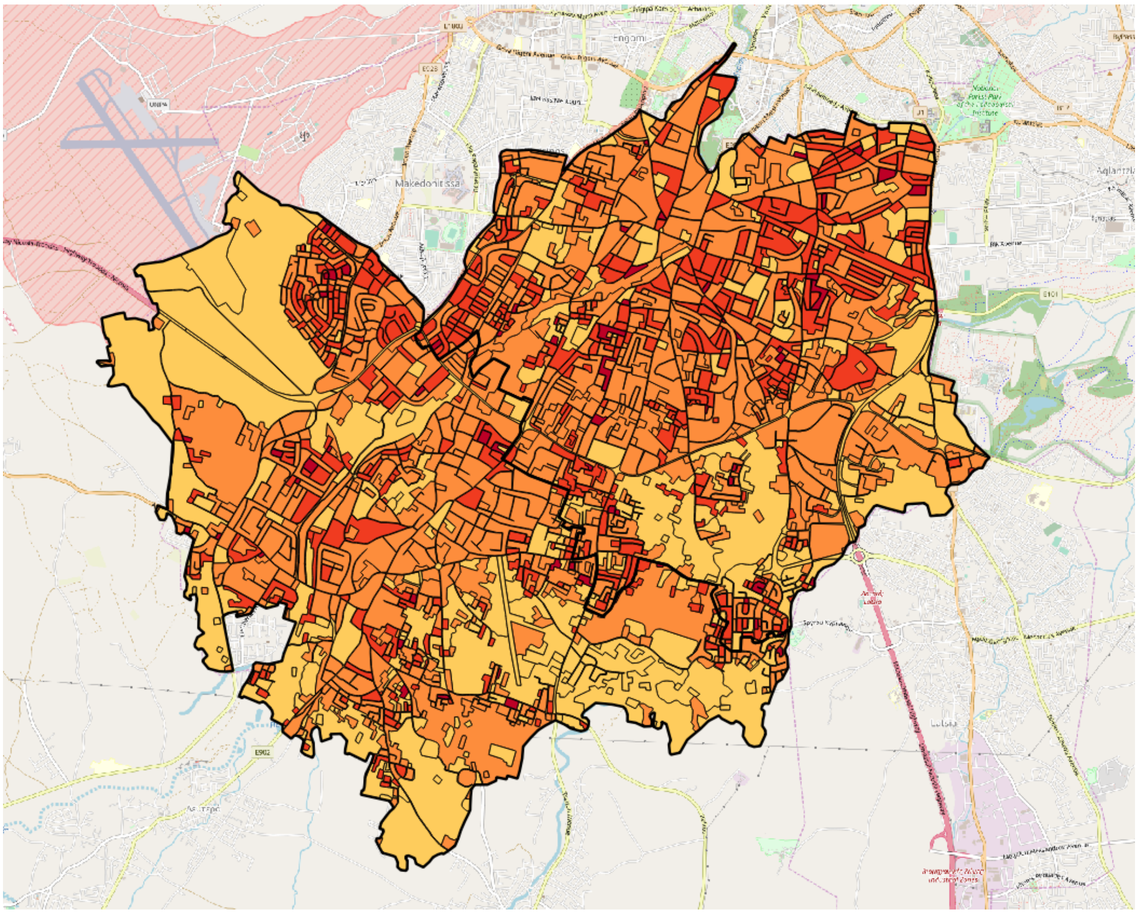


Figure 13: Impact assessment for future climate using RCP4.5 emission scenario

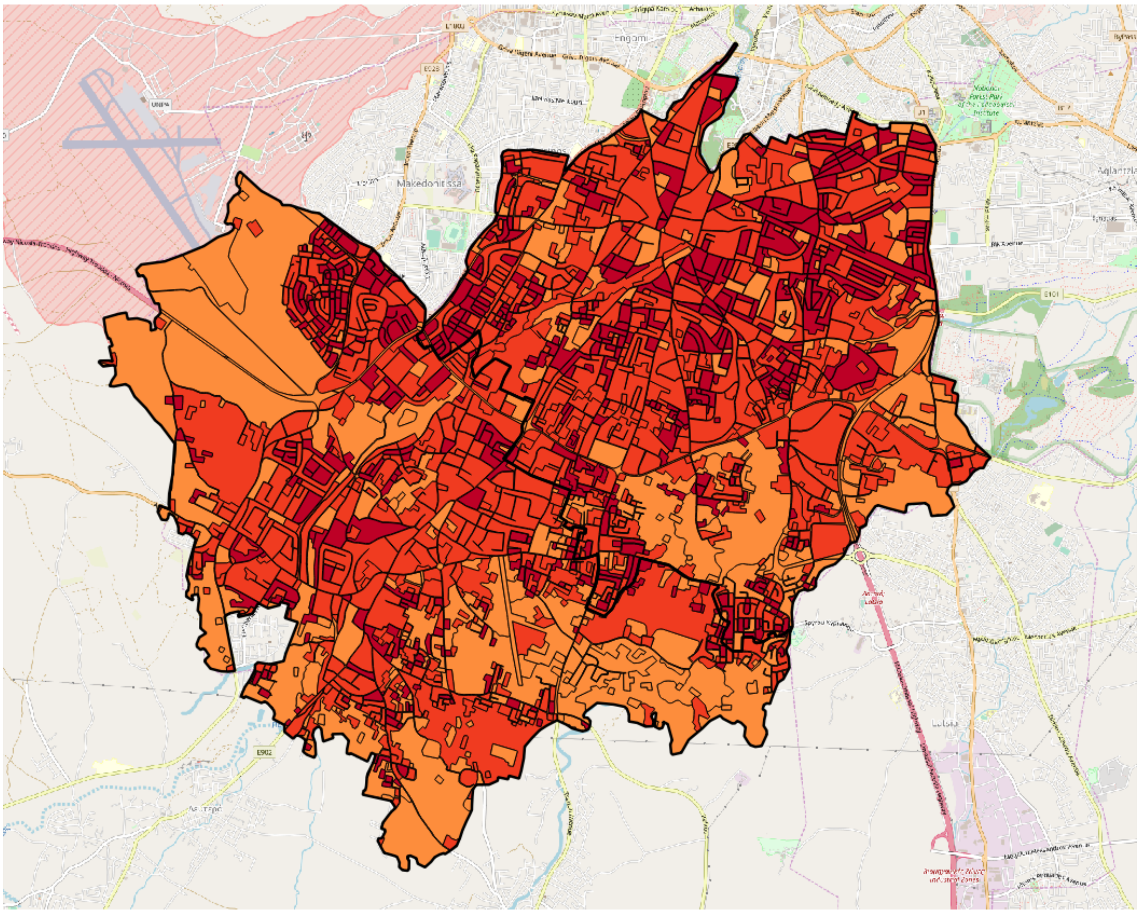


Figure 14: Impact assessment for future climate using RCP8.5 emission scenario

3.2.2 Municipality of Peristeri

Figure 15 depicts vulnerable areas within the municipality of Peristeri for the current climate regarding energy demand for cooling. About 32% of the municipality area is classified as 1-low, about 7% is classified as 2-low to medium while the remaining 61% is classified as 3-medium impact. Regarding future changes under RCP4.5 (Figure 16), all areas previous classified as 1,2 and 3 are now classified higher, namely 2-low to medium, 3-medium and 4-medium to high impact respectively. As for RCP8.5 future emission scenario, Figure 17 shows that the increase is even higher, in other words areas previously (RCP4.5) classified as 2,3 and 4 are now classified in higher classes namely 3-medium, 4-medium to high and 5-high impact respectively.

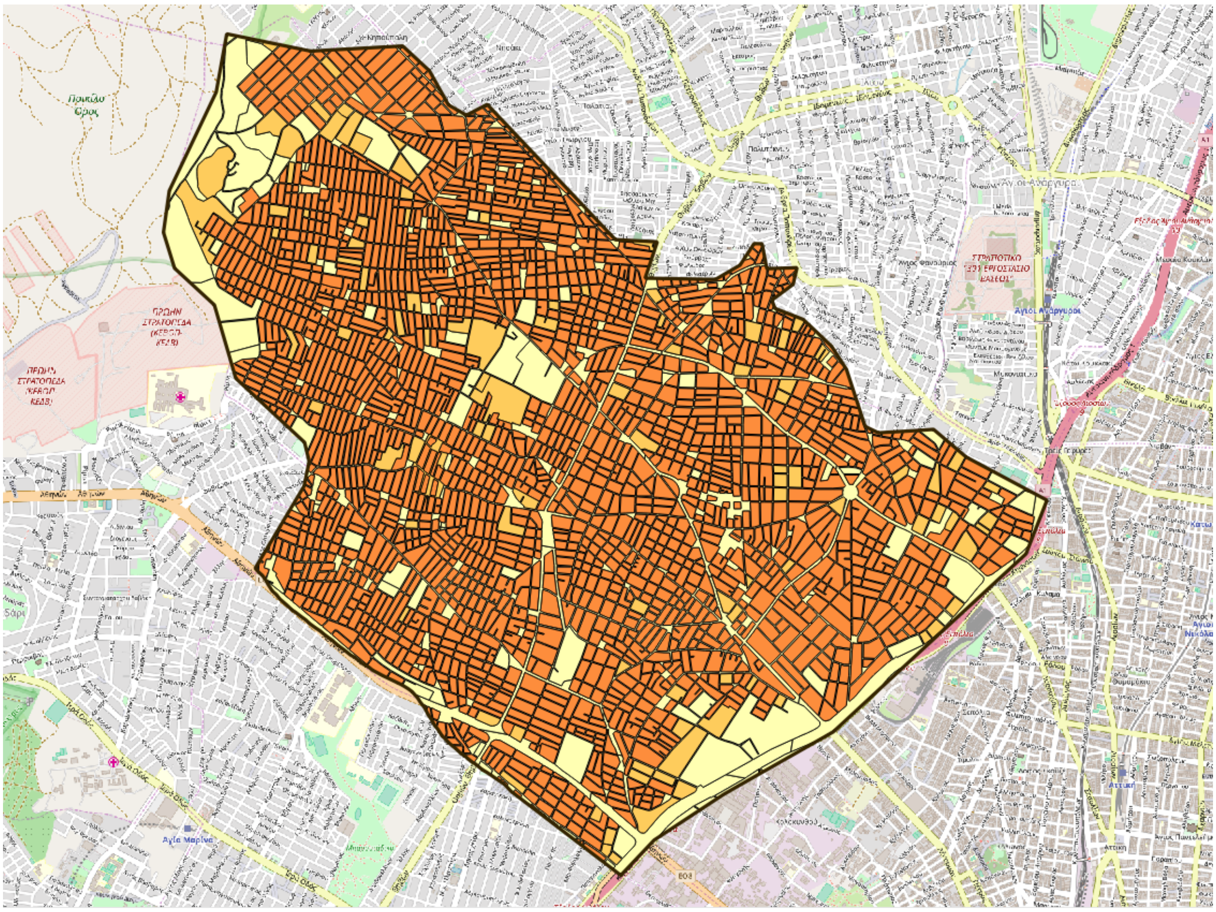


Figure 15: Impact assessment for present climate

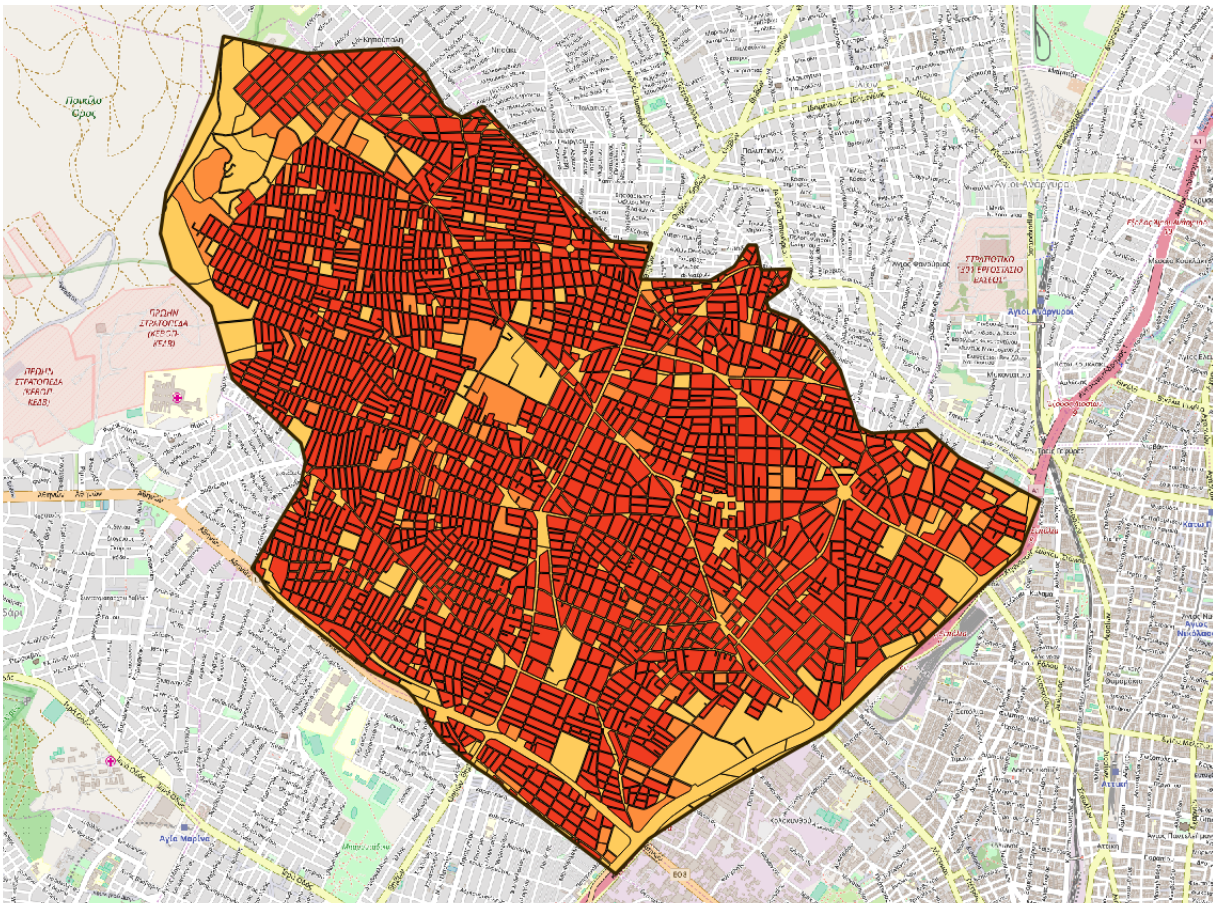


Figure 16: Impact assessment for future climate using RCP4.5 emission scenario

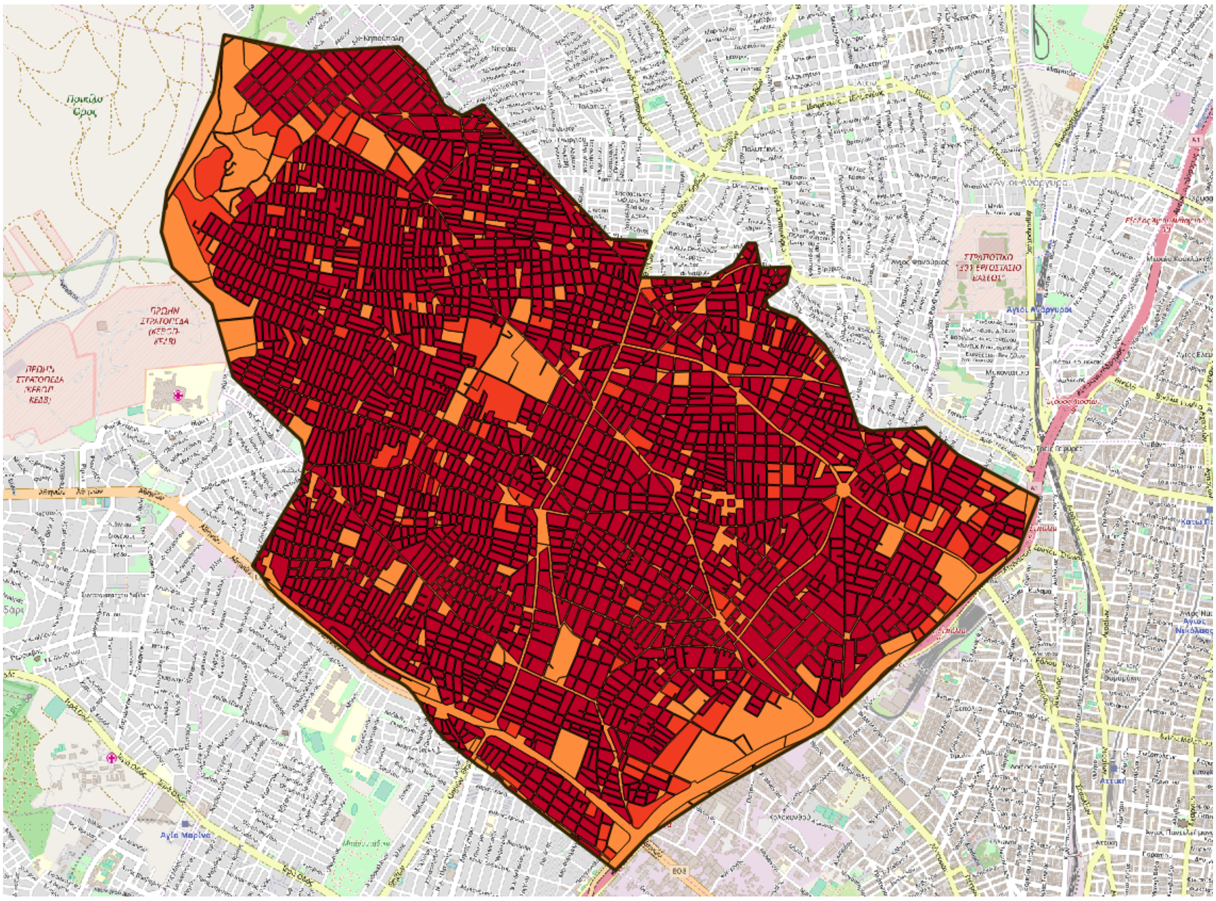


Figure 17: Impact assessment for future climate using RCP8.5 emission scenario

3.2.3 Municipality of Reggio Emilia

In Figure 18 the classification of Reggio Emilia municipality areas in terms of heat related climate change impacts on energy demand under the current climate is depicted. About 79% of the total municipality area is classified as 1-low, about 12% is classified as 2-low to medium impact while the remaining 9% is classified as 3-medium impact. As regards future changes under RCP4.5, Figure 19 shows that all areas previously ranked as 1 are now classified in a higher classes, namely 2-low to medium impact (about 46% of the previous area) and 3-medium impact (about 54% of the previous area). In addition, all areas classified as 2 and 3 in current climate, in future period they present an increase of two classes, namely 4-medium to high and 5-high impact respectively. In total, under RCP4.5, about 36.2% of the total municipality area is classified as 2, about 43.2% as 3, about 12.1% as 4 and about 8.5% as 5. As concerns the RCP8.5 scenario, the same spatial pattern and the same classification as RCP4.5 is presented (Figure 20).

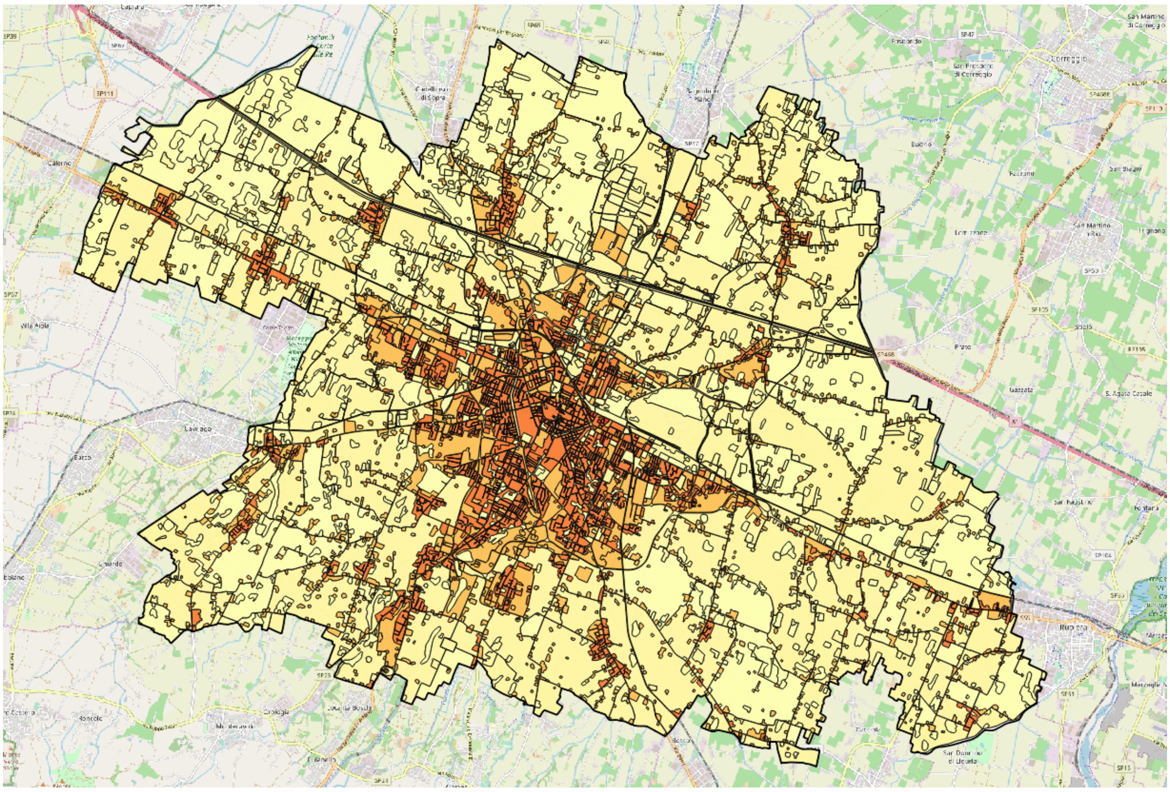


Figure 18: Impact assessment for present climate

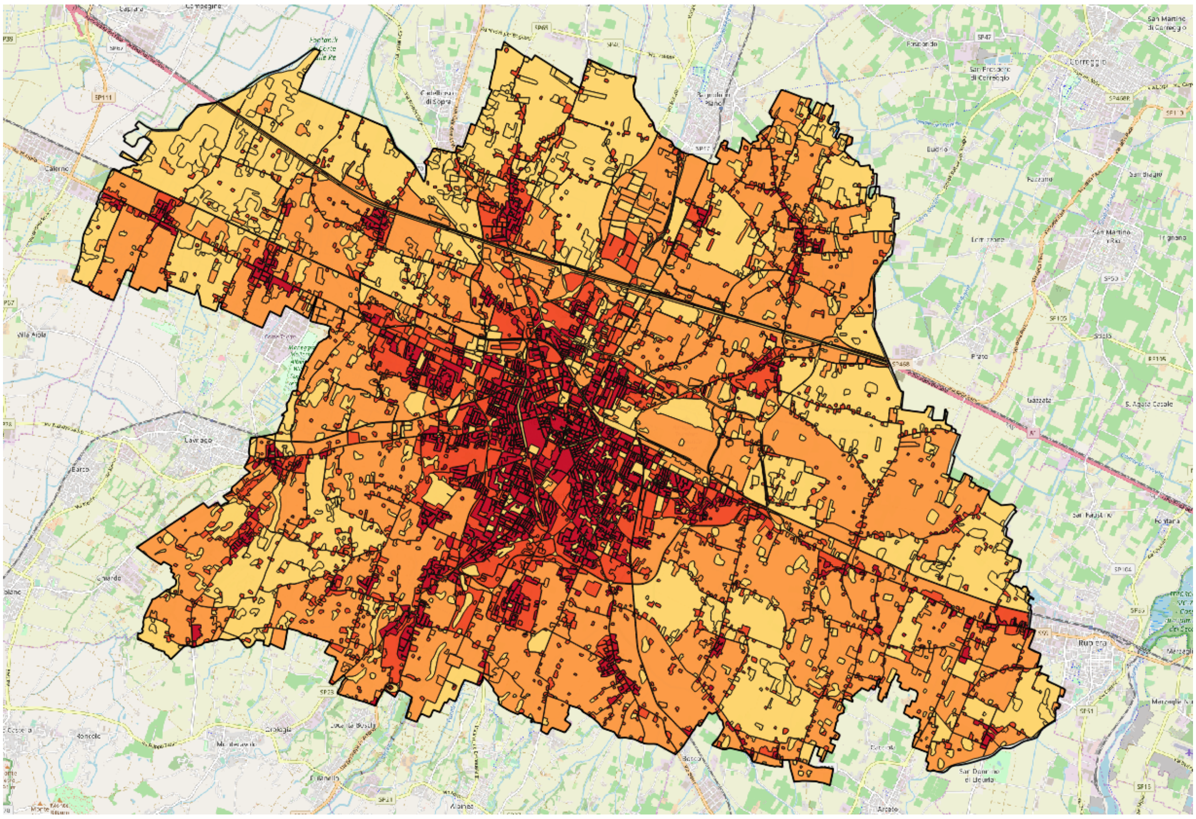


Figure 19: Impact assessment for future climate using RCP4.5 emission scenario

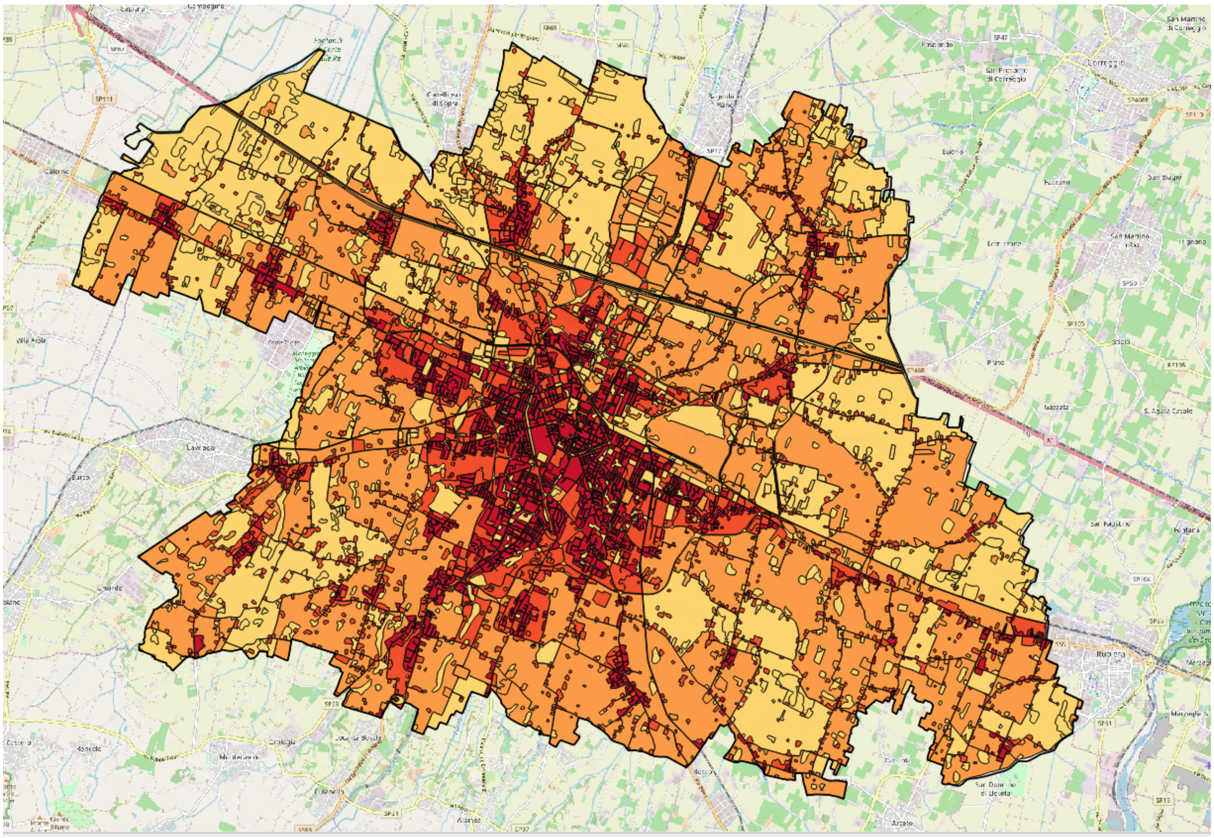


Figure 20: Impact assessment for future climate using RCP8.5 emission scenario

3.3 Proposed adaptation measures

The classification of the proposed adaptation measures is based on the mean score extracted from the four selected criteria. In Table 6, the mean score for each adaptation measure, as well as the individual scores for each evaluation criterion are also presented. More information on each adaptation measure is presented in Annex A.

Table 6: Proposed adaptation measures for energy demand and their evaluation

Adaptation measures	Evaluation criteria				Mean score
	Efficiency in addressing the impact	Environmental Friendliness	Economic Viability	Job growth	
Financial incentives for the Holistic Energy Efficient Retrofitting of Residential Buildings	78.64	83.18	43.41	65.45	**67.67**
Economic incentives for renewables and energy efficiency	81.36	84.77	37.27	62.73	**66.53**
Renovation of municipality buildings to Nearly Zero-Energy Buildings	79.78	82.17	34.78	66.09	**65.71**
Demonstration projects and educational programs	69.35	79.35	66.74	40.65	**64.02**
Urban forest	68.00	84.00	58.20	40.00	**62.55**
Cool Roofs	65.00	70.91	50.23	54.55	**60.17**
Economic incentives to reduce urban heat island	66.59	72.27	36.36	54.77	**57.50**
Green roofs	62.71	75.00	39.79	51.67	**57.29**
Cool pavements	62.50	70.00	40.23	56.36	**57.27**

4 Ozone exceedances

In order to calculate the number of ozone exceedances under climate change, the statistical methodology of Varotsos et al., 2013 is used. More specifically, we analyze the observed ozone temperature relationship in the partner municipalities which is then extrapolated to the future with the use of temperatures for the regional climate model. Consequently, the impact to ozone exceedances is assessed for each one of the partner municipalities.

4.1 Impact assessment

4.1.1 Hazard indicators

A number of meteorological variables have been found to influence ozone concentration in terms of correlation coefficients such as temperature, morning solar radiation, number of days since the last frontal passage, humidity and the frequency of summertime mid latitude cyclones as the closest associated with ozone (Ordonez et al., 2005; Wise and Comrie, 2005; Camalier et al., 2007; Leibensperger et al., 2008). However, the majority of the observational studies identify temperature as the most important meteorological factor in driving both the mean and the extreme O_3 production [e.g. Camalier et al., 2007; Pusede et al., 2015 and references therein; Otero et al., 2016 and references therein; Shen et al., 2016 and references therein]. In addition, recent regional air-quality modeling studies in Europe indicate that increased future temperatures, as projected by climate models, lead to increases in mean future ozone concentrations when anthropogenic emissions are kept constant at current levels [Langner et al., 2005; Meleux et al., 2007; Hedegaard et al., 2008; Katragkou et al., 2011; Langner et al., 2012, Varotsos et al., 2013].

In this report the historical O_3-T relationship is used as a training period for the statistical model (Varotsos et al., 2013) where with the use of regional climate projections the future ozone exceedances (defined here as days with daily maximum 8 h average ≥ 60 ppb) [EU Directive 2008/50/EC, 2008).

In Figure 21 the relationship between the daily maximum 8hour average O_3 concentrations and the daily maximum temperature for the partner municipalities are shown. The correlation coefficient and the slopes indicate strong relationship between the two variables with correlations higher than 0.7. In addition, the calculated slopes are typical for urban environments (Coates et al., 2016).

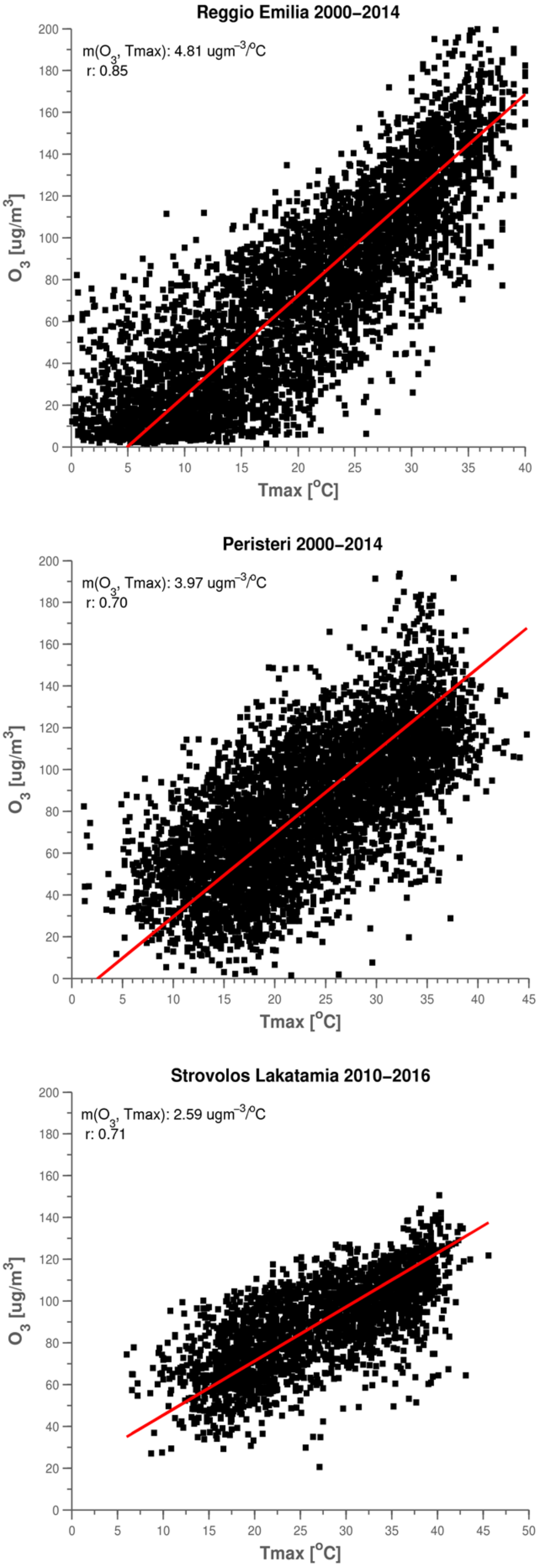
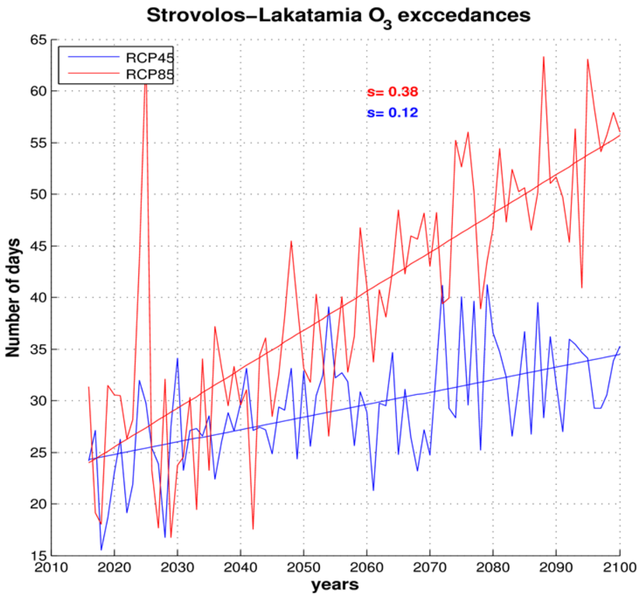
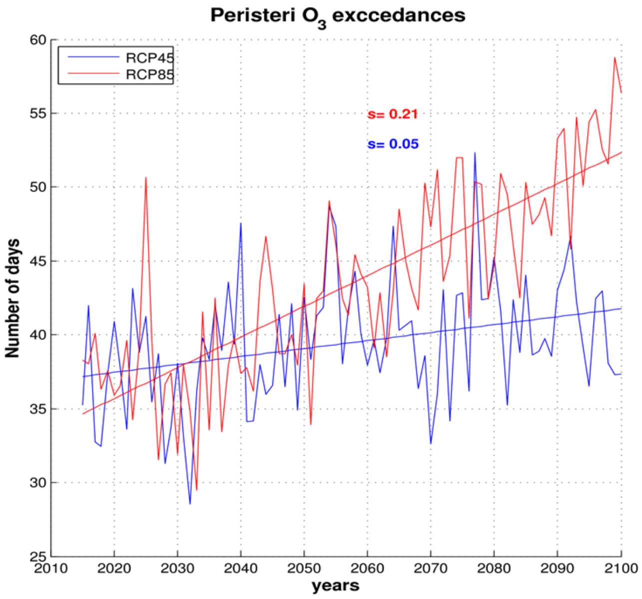


Figure 21: The relationship of the daily maximum 8hr average ozone concentrations with daily maximum temperatures (right) for the Reggio Emilia (top), Peristeri (Middle) and Strovolos-Lakatamia (bottom)

In Figure 22 the trend of the average annual number of ozone exceedance days for the partner municipalities under the RCP4.5 and RCP8.5 future emissions scenarios are shown. From the figure it is evident that the lowest and highest positive trends are calculated under the RCP4.5 the RCP8.5 scenarios respectively. More specifically, under RCP4.5 the trends calculated are 1.2 days/decade for Strovolos-Lakatamia, 0.5 days/decade for Peristeri and 1.6 days/decade for Reggio Emilia. Under RCP8.5 the slopes are higher reaching 3.8 days/decade in Strovolos-Lakatamia, 2.1 days/decade in Peristeri and 4 days/decade in Reggio Emilia.





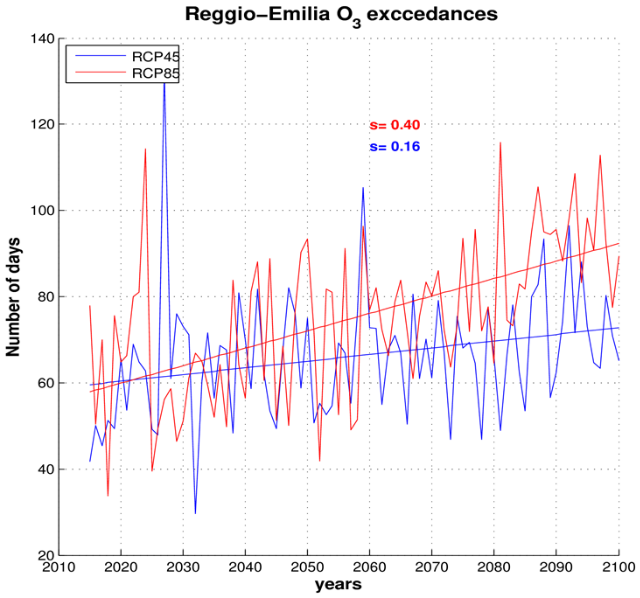


Figure 22: Trends of the average annual ozone exceedance days under RCP4.5 (blue line) and RCP8.5 (red line) for Strovolos-Lakatmia (top), Peristeri (middle) and Reggio-Emilia (bottom)

4.1.2 Exposure indicators

- **Population density (population/km²)**

Similarly to health sector, population density (population/km²) was used as an exposure indicator in case of ozone exceedances since it affects the spatial distribution of the impacts within the municipalities, for example densely populated areas are more vulnerable compared to sparsely populated areas. The methodology used for population density estimation in all partner municipalities is analyzed in section 1.1.2.

4.1.3 Social sensitivity indicators

As described in the methodology, social sensitivity indicators were also used and assessed to estimate the vulnerability of population to future heat related ozone exceedances in each partner municipality. All the separated social indicators assessed in case of ozone exceedances were the following:

- **Population % under 9 and over 70 years old** – Exposure to increased ozone concentrations (during ozone exceedances) can increase the risk of illness and death among vulnerable population groups)
- **Population % at risk of poverty** - Poor people are considered more vulnerable to ozone exceedances (poorly-insulated dwellings, no access to healthcare facilities etc.)
- **Illiteracy rate –** Illiteracy rate is considered as a key determinant of adaptive capacity of population. Increased illiteracy rates indicate reduced adaptive capacity namely increased exposure

- **Hospital beds per capita –** Health infrastructure and level of health services are considered an important index of adaptive capacity.
- **Health problems** - The healthier the population is, the more adaptive is to the impacts of climate change. In addition, exposure to increased ozone concentrations during days with ozone exceedance, may aggravate an existing health problem

4.1.4 Indicator's scoring

For the hazard and exposure indicators' scoring and classification, the following methodology was followed:

- Hazard indicators – Number of days with ozone exceedances

As concerns classification, for each municipality the annual number of days with ozone exceedances was calculated for each year of the period 2000-2060 for municipalities of Reggio Emilia and Peristeri and 2010-2060 for municipalities Strovolos-Lakatamia. The annual number of days with ozone exceedances was derived from regional climate model outputs using both RCPs 4.5 and 8.5. The minimum and maximum value of the indicator was calculated from the whole time series of both RCPs. Then the range was calculated and divided into five classes.

As far as scoring is concerned, the average number of days with ozone exceedances was calculated for the periods 2000 – 2014 (Reggio Emilia and Peristeri) and 2010-2016 (Strovolos and Lakatamia) in case of current climate and 2031-2060 in case of future climate (all municipalities) in both time series of each emission scenario. The averages resulting from the previous procedure were classified (using the previous constructed classification) and the corresponding scores were given in each case.

- Exposure indicator – Population density

The methodology used for the population density classification is described in section 1.1.3

- Social sensitivity indicator

The scoring process of each individual social indicator has already been described in Section 1.1. For the final impact assessment, the integrated final social indicator was used.

The final scores of all indicators in all partner municipalities are presented below:

4.1.4.1 Municipalities of Lakatamia and Strovolos

Number of days with Ozone Exceedances			
Classification	Score		
	Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)

1-10	1			
11-25	2	2		
26-40	3		3	3
41-60	4			
61-100	5			

Population density indicator - Log10(residents/km²)	Classification	Score (number of polygons with the same score)
0-1.117	1	552
1.118-2.233	2	184
2.234-3.350	3	654
3.351-4.466	4	503
4.467-5.583	5	67

Social impact – Sub indicators	Score (all polygons)
Age (<9 & >70)	3
Illiteracy level	2
Poverty rate	3
Health problems	1
Hospital beds per inhabitant	1

Integrated Final Social Indicator	**2**

4.1.4.2 Municipality of Peristeri

Number of days with Ozone Exceedances				
Classification		Score		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
1-10	1			
11-25	2			
26-40	3			
41-60	4	4	4	4
61-100	5			

Population density indicator - Log10(residents/km²)	Classification	Score (number of polygons with the same score)
0-1.117	1	77
1.118-2.233	2	24
2.234-3.350	3	111
3.351-4.466	4	1134
4.467-5.583	5	961

Social impact – Sub indicators	Score (all polygons)
Age (<9 & >70)	2
Illiteracy level	2
Poverty rate	4
Health problems	2
Hospital beds per inhabitant	2
Integrated Final Social Indicator	**2**

4.1.4.3 Municipality of Reggio Emilia

Number of days with Ozone Exceedances				
Classification		Score		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
1-10	1			
11-25	2			
26-40	3			
41-60	4			
61-100	5	5	5	5

Population density indicator - Log10(residents/km²)	Classification	Score (number of polygons with the same score)

0-1.117	1	1963
1.118-2.233	2	455
2.234-3.350	3	1878
3.351-4.466	4	1082
4.467-5.583	5	12

Social impact – Sub indicators	Score (all polygons)
Age (<9 & >70)	2
Illiteracy level	2
Poverty rate	4
Health problems	2
Hospital beds per inhabitant	3
Integrated Final Social Indicator	**3**

4.2 Impact maps for each municipality

In the following sections, impact maps for the partner municipalities are presented. For each municipality, impact assessment is shown for the current climate which in each municipality corresponds to a different period due to the different available observational period, as well as for the future climate (2031-2060) under two emission scenarios, namely RCP4.5 and RCP8.5. More specifically, in Strovolos-Lakatamia the observed O3 data cover the period 2010-2016 whereas in Peristeri and Reggio Emilia the data cover 2000-2014

For all impact maps, the color classification (from low impact to high impact) used as well as the respective scores are shown in Table 7.

Table 7: Map color classification and the corresponding scores

Classes	Score
Low	1
Low to medium	2
Medium	3
Medium to high	4
High	5

4.2.1 Municipalities of Lakatamia and Strovolos

As far as current climate is concerned, Figure 23 depicts that about 58.3% of the municipalities area is scored with 1-low impact, about 27.5% is scored higher namely 2-low to medium impact, about 13.2% is scored with 3-medium impact while the remaining 1% is scored even higher namely 4-medium to high impact. As for future climate under RCP4.5 scenario (Figure 24), all areas previously ranked as 1, now are classified as 2-low to medium (70% of the previous areas) and 3-medium impact (30% of the previous areas). In addition all areas classified as 2 and 3 in current climate, in future climate they present higher rankings namely 4-medium to high and 5-high impact. The same for those classified as 4 in current climate, now are classified as 5-high impact. In total, under RCP4.5, about 40.3%, 17.9%, 27.5% and 14.3% of the two municipalities' areas are classified as 2-low to medium, 3-medium, 4-medium to high and 5-high respectively. Concerning RPC8.5 emission scenario (Figure 25), the same spatial distribution as RCP4.5 is found.

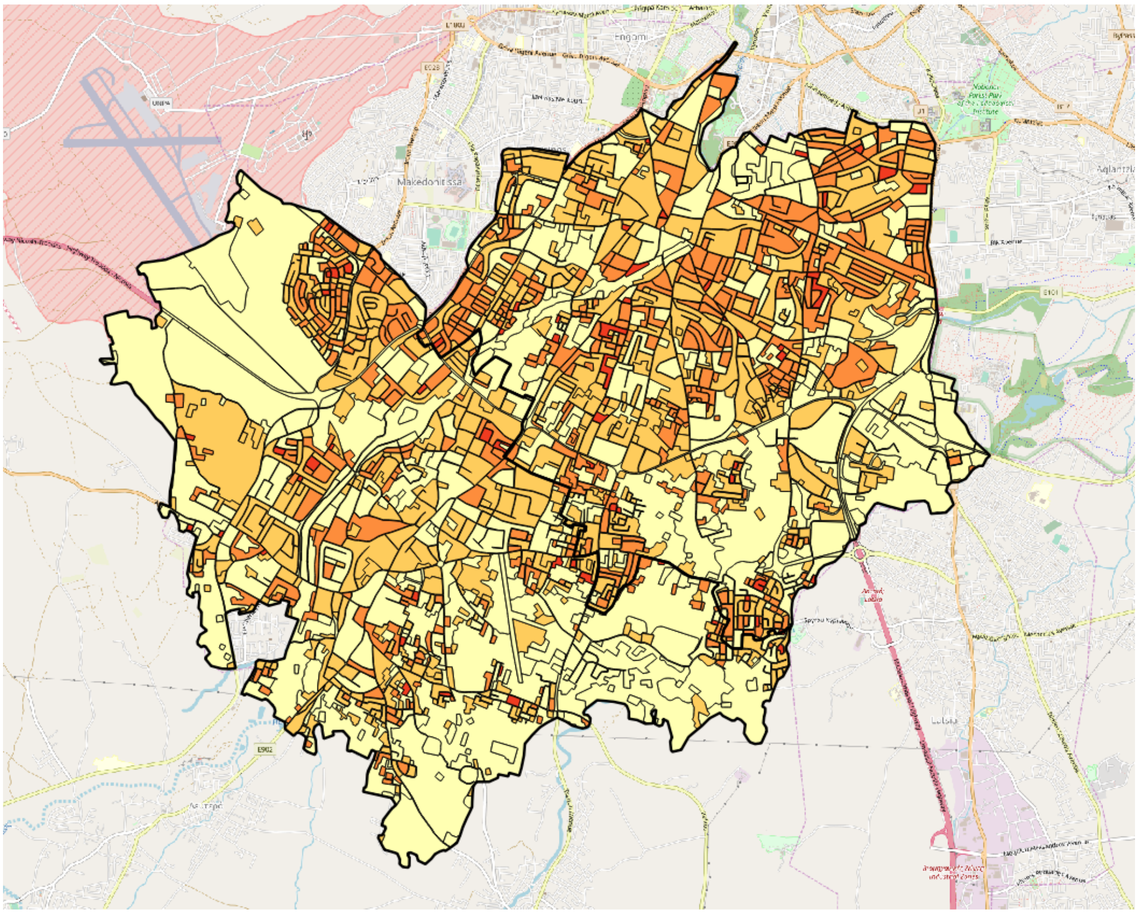


Figure 23: Impact assessment for present climate

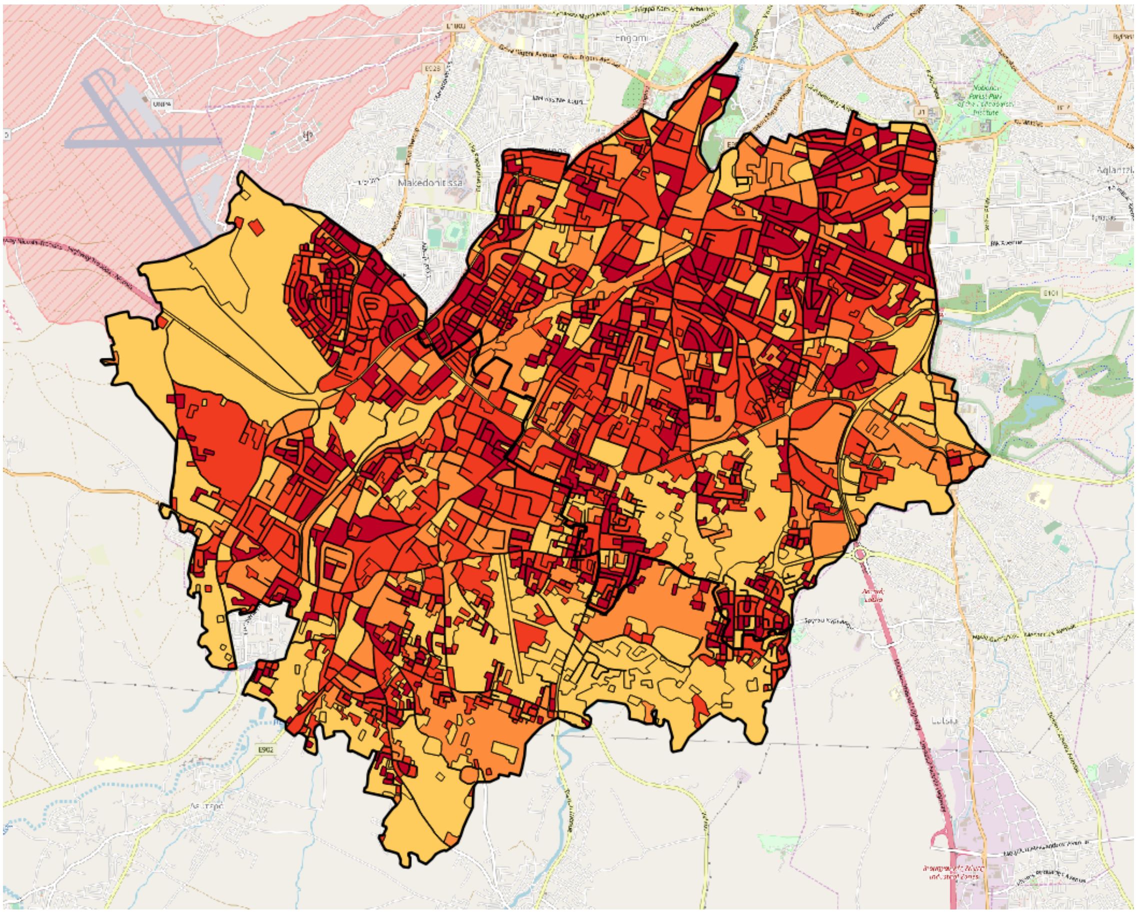


Figure 24: Impact assessment for future climate using RCP4.5 emission scenario

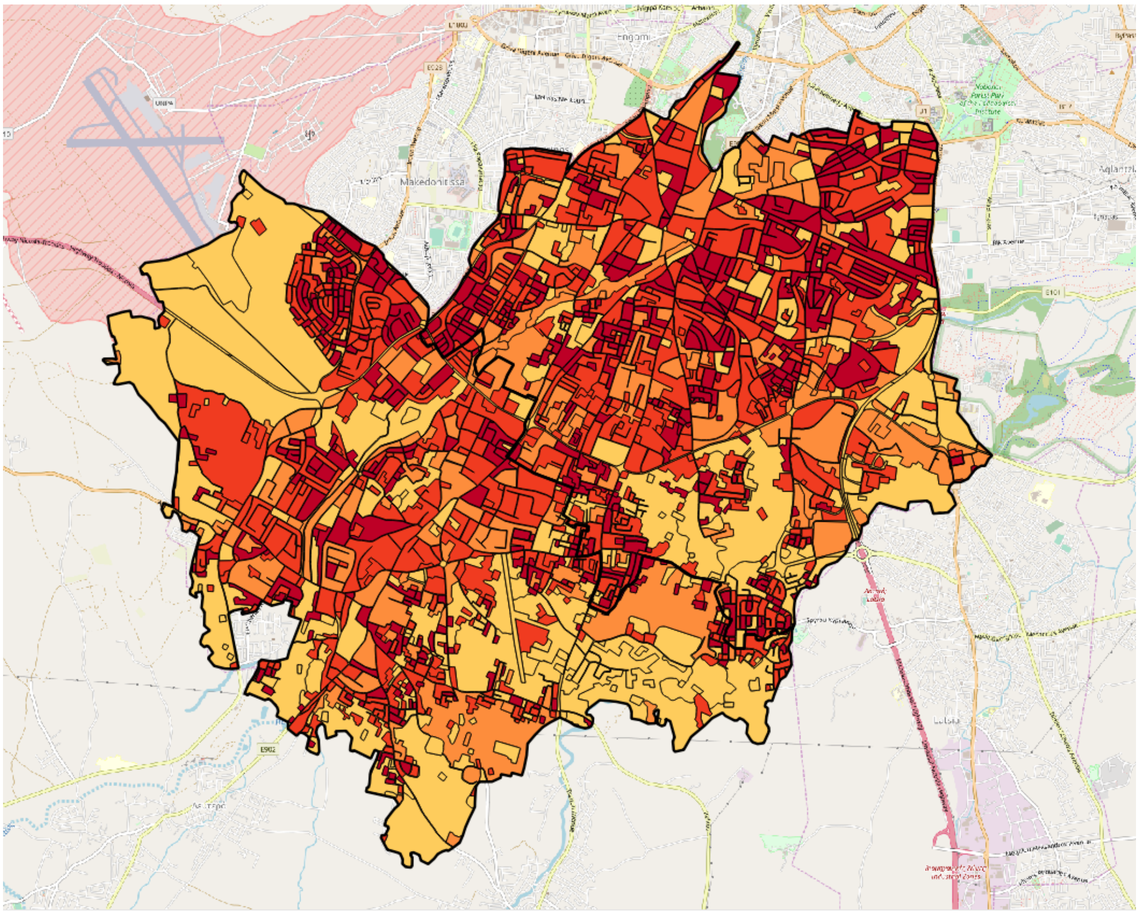


Figure 25: Impact assessment for future climate using RCP8.5 emission scenario

4.2.2 Municipality of Peristeri

Figure 26 depicts vulnerable areas within the municipality of Peristeri for the current climate. As it is shown, the largest part of the municipality is classified in classes 4-medium to high and 5-high impact namely 40% and 21.3% respectively demonstrating the high impact of climate change to Peristeri municipality ozone exceedances. As regards the remaining areas, about 28.3%, 3.8% and 6.6% are classified in classes 1-low, 2-low to medium, 3-medium impact respectively. Concerning future changes, under RCP4.5 (Figure 27) and RCP8.5 (Figure 28), municipality of Peristeri presents the same spatial distribution and the same scoring of vulnerable areas as in current climate.

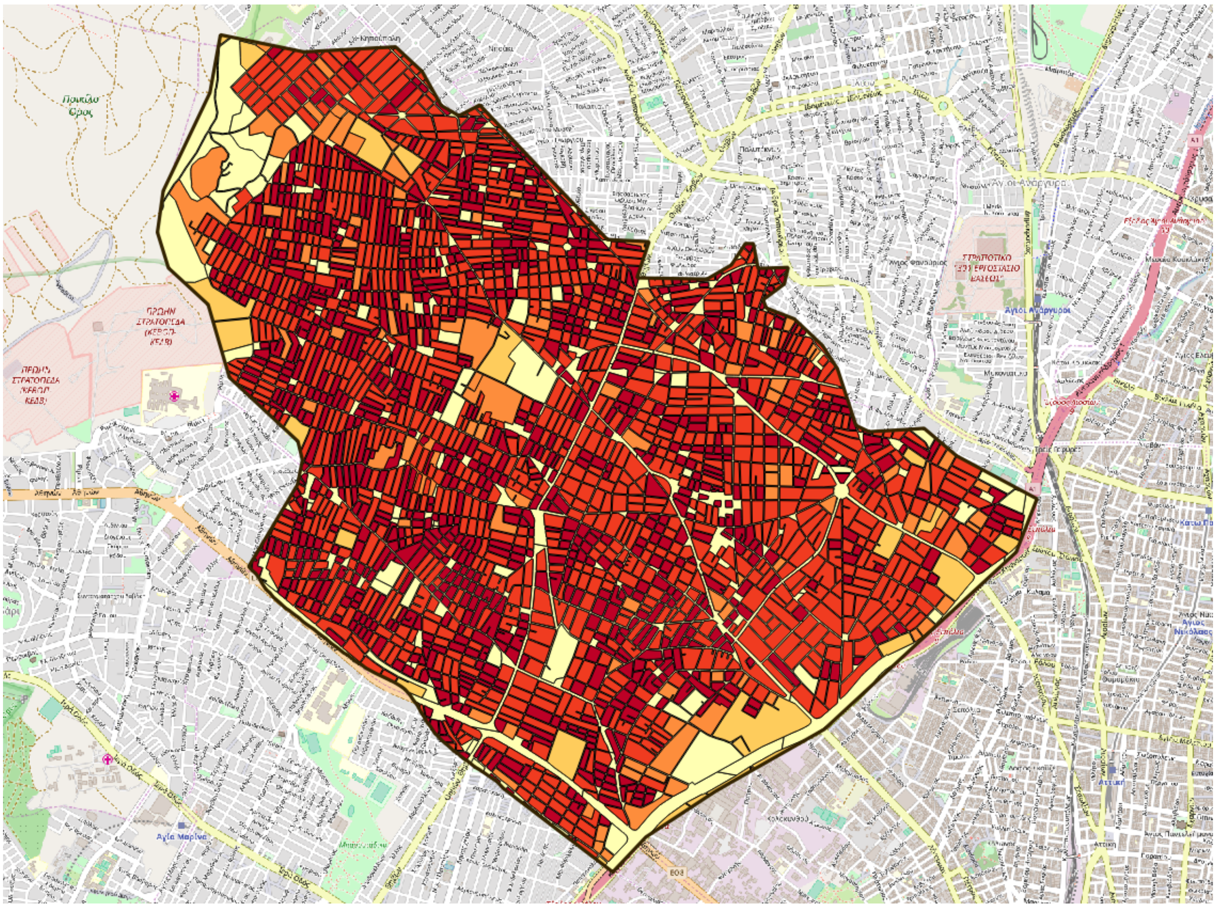


Figure 26: Impact assessment for present climate

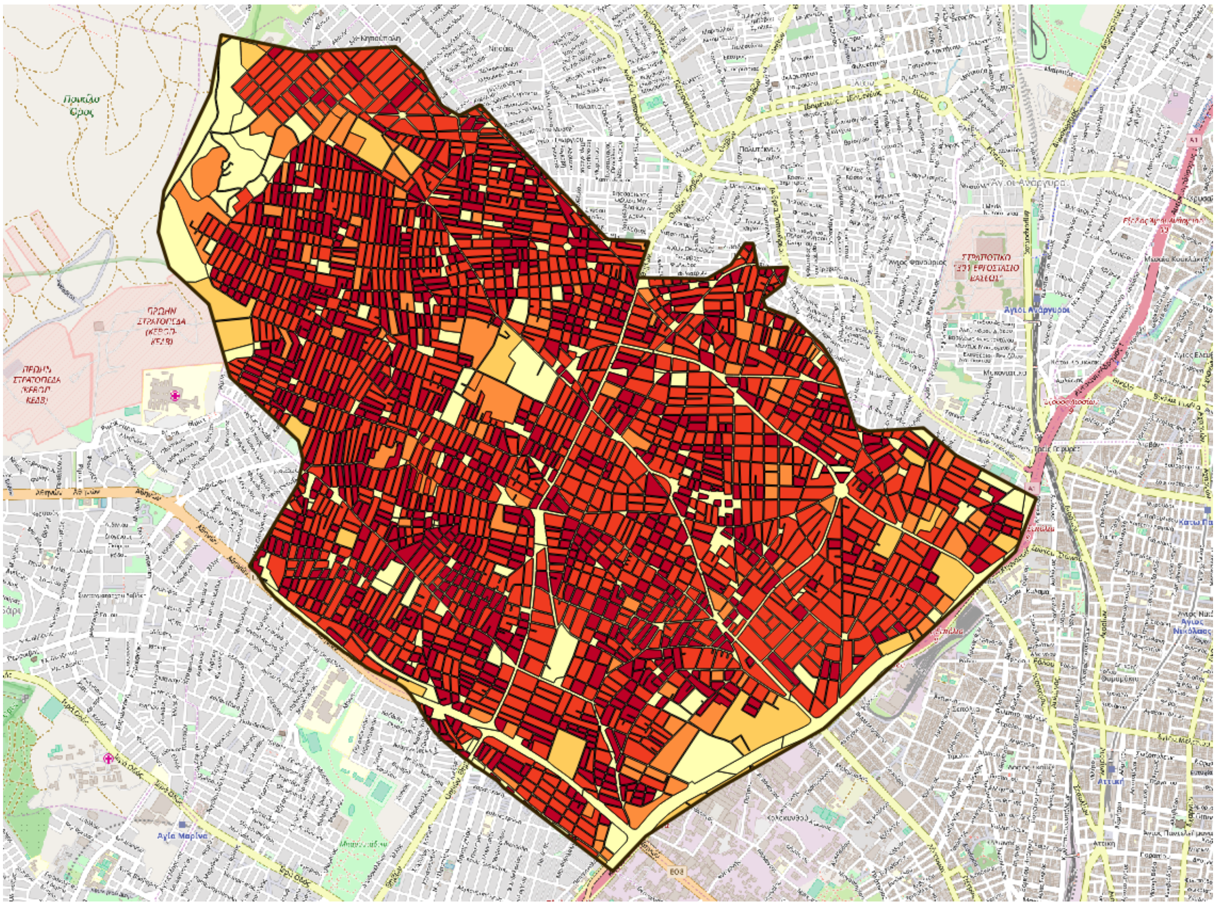


Figure 27: Impact assessment for future climate using RCP4.5 emission scenario

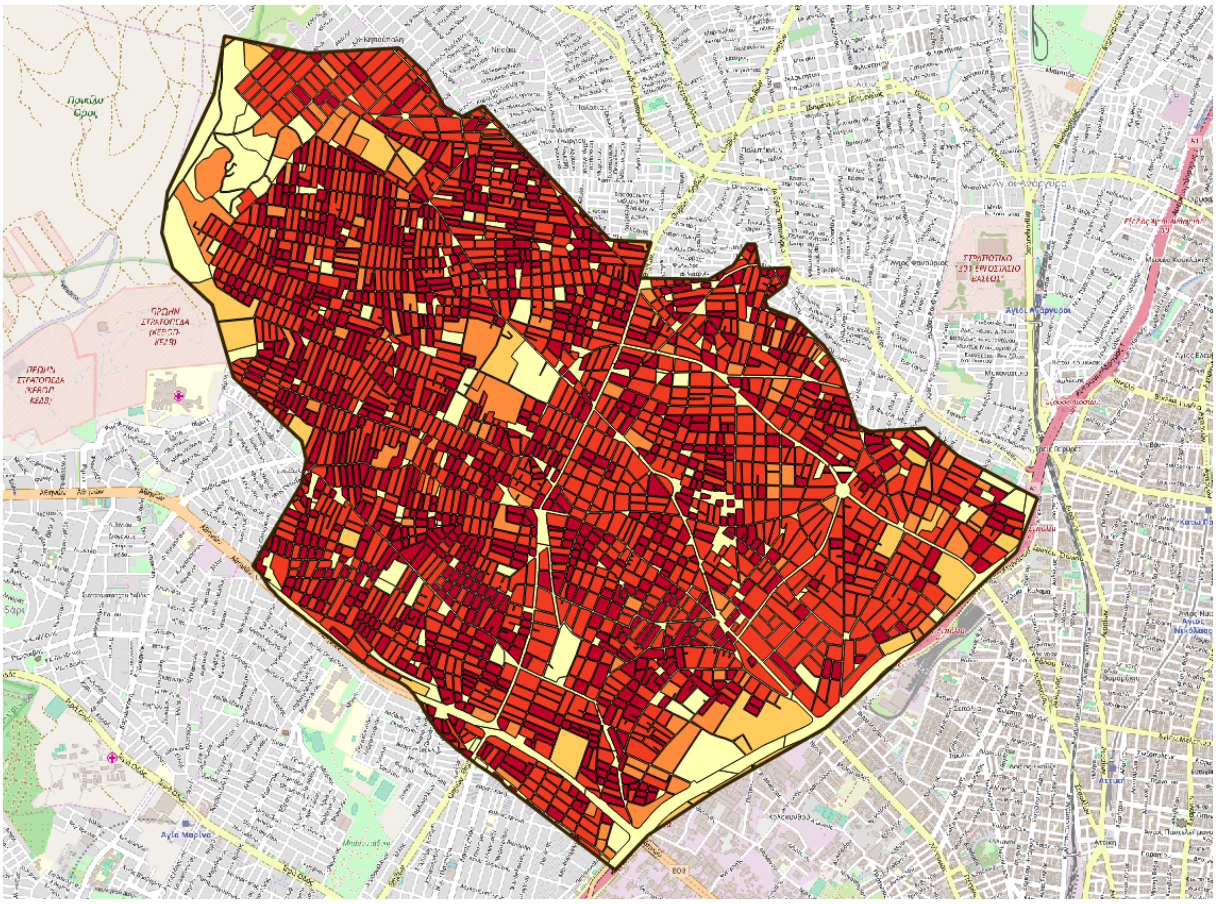


Figure 28: Impact assessment for future climate using RCP8.5 emission scenario

4.2.3 Municipality of Reggio Emilia

In Figure 29 the classification of Reggio Emilia municipality areas regarding the ozone exccedances under the current climate is presented. About 36.2% of the area is classified in class 1-low impact, about 43.2% in class 2-low to medium impact, about 12.1% in class 3-medium impact and about 8.5% is classified higher namely class 4-medium to high impact. As for future climate under RCP4.5 (Figure 30) and RCP8.5 (Figure 31), no changes in spatial distribution of vulnerable areas as well as in ranking are anticipated.

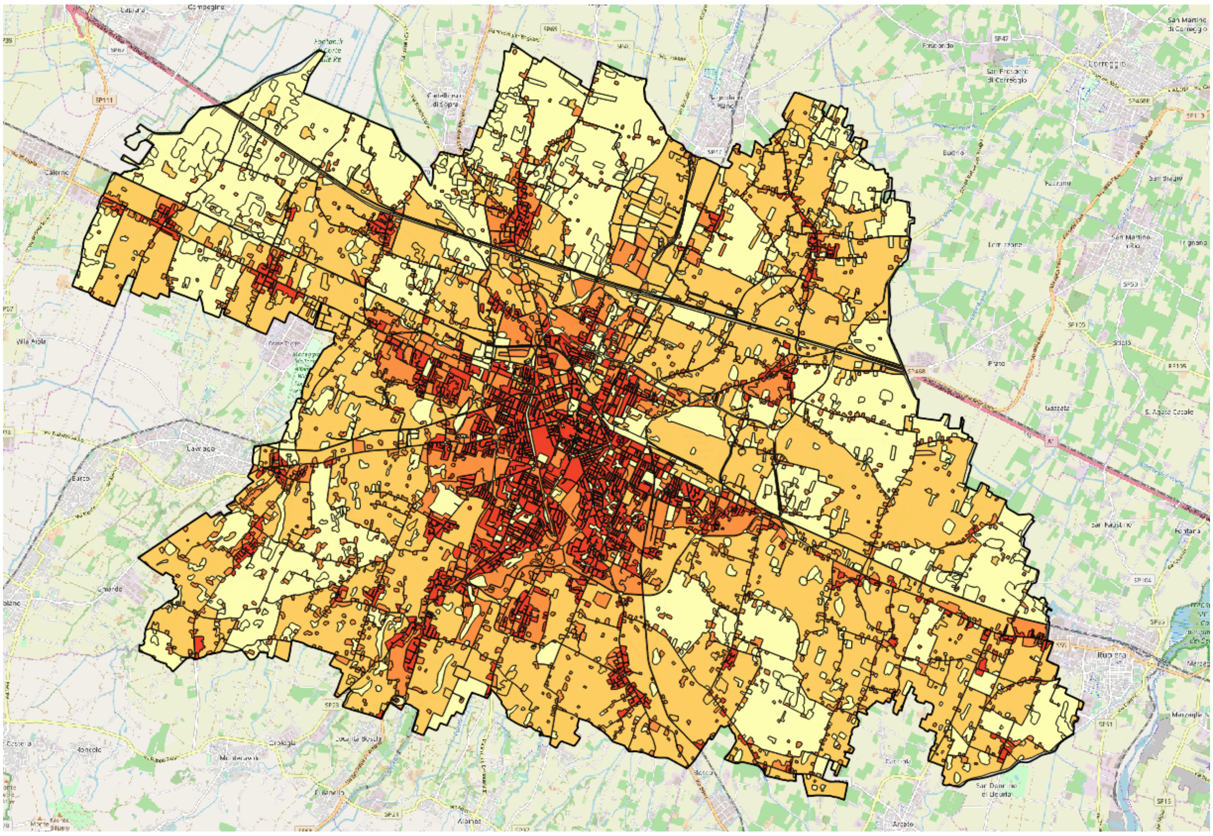


Figure 29: Impact assessment for present climate

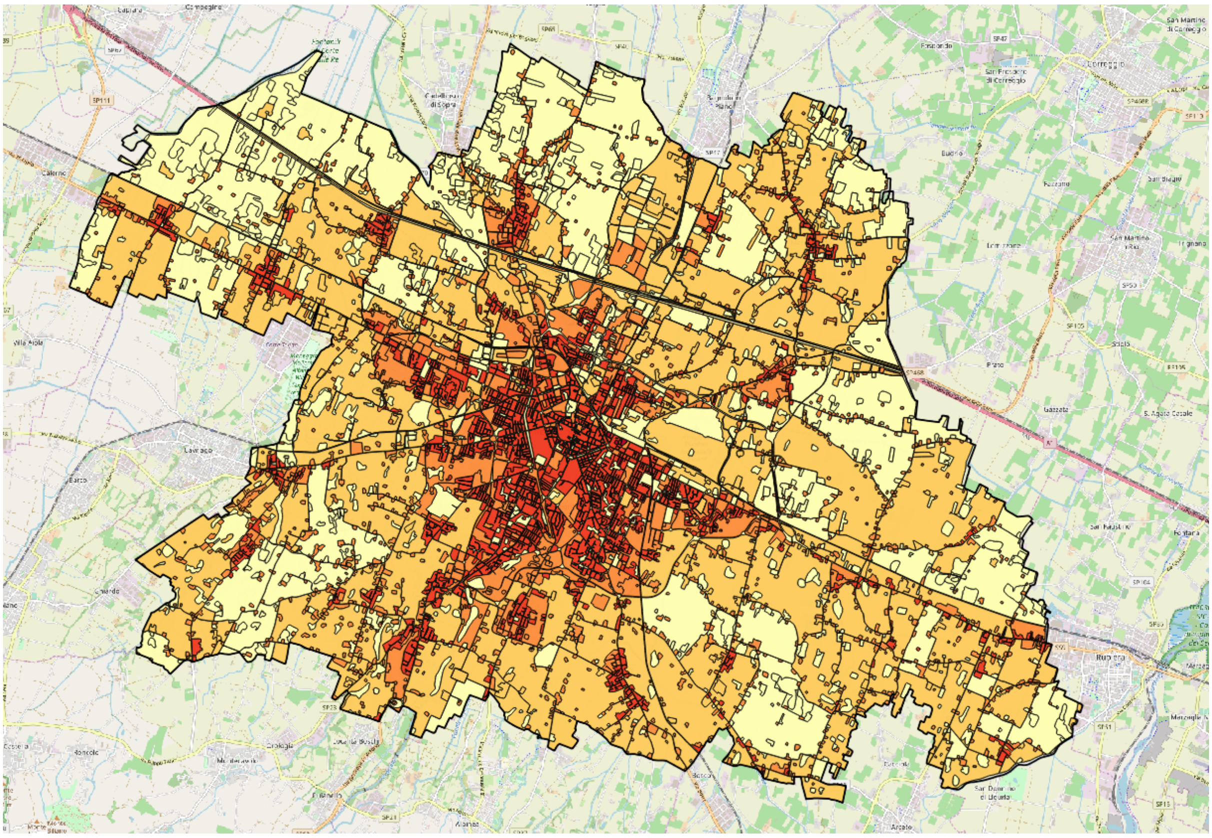


Figure 30: Impact assessment for future climate using RCP4.5 emission scenario

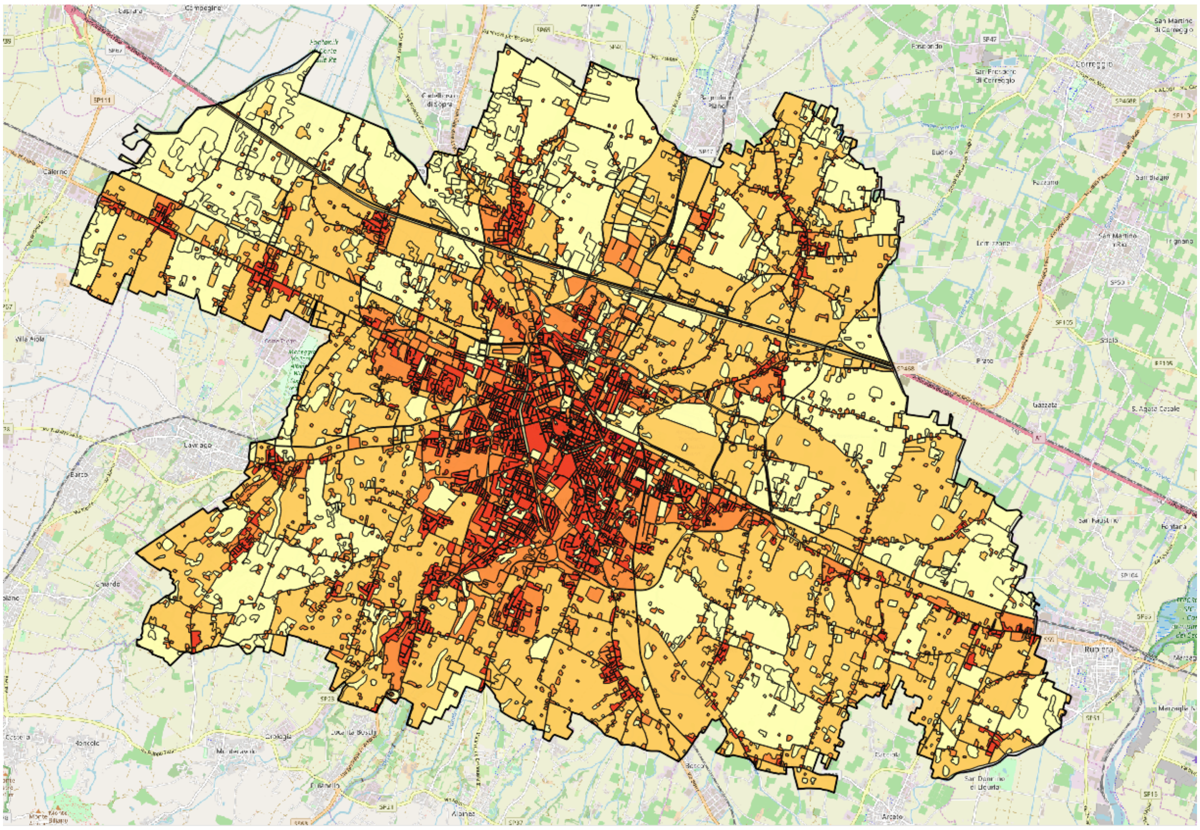


Figure 31: Impact assessment for future climate using RCP8.5 emission scenario

4.3 Proposed adaptation measures

The classification of the proposed adaptation measures is based on the mean score extracted from the four selected criteria. In Table 8, the mean score for each adaptation measure, as well as the individual scores for each evaluation criterion are also presented. More information on each adaptation measure is presented in Annex A.

Table 8: Proposed adaptation measures for the ozone exceedances and their evaluation

Adaptation measures	Evaluation criteria				Mean score
	Efficiency in addressing the impact	Environmental Friendliness	Economic Viability	Job growth	
Choose a cleaner commute — car pool, or use public transportation	70.00	76.67	60.00	26.67	**58.33**
Monitoring of air quality	68.33	85.00	40.00	38.33	**57.92**
Enhance public awareness and education	73.33	73.33	60.00	23.33	**57.50**
String inspections in service industries. Facilities should use best pollution abatement technologies available	65.00	80.00	41.67	41.67	**57.08**
Implementation of measures for air quality improvement in urban areas must be enhanced	70.00	70.00	51.67	33.33	**56.25**
Conserve electricity and set air condition at a higher temperature	62.00	74.00	78.00	6.00	**55.00**
Collection of air quality data and completion of inventory	63.33	66.67	53.33	35.00	**54.58**

Self protection measures (avoidance of external activities in days with high level of pollution)	73.33	48.33	80.00	6.67	**52.08**
Changes in driving habits (refuel cars and trucks after dusk, combine errands and reduce trips, limit engine idling	56.67	61.67	80.00	8.33	**51.67**
Actions in the areas of the Health Sector: preparation of facilities and staff	55.00	55.00	53.33	38.33	**50.42**

5 Peri-urban fires

In order to study peri-urban fires, a grid extending approximately 4km beyond the borders of each municipality at a horizontal resolution of 250m was constructed. The impact to peri-urban fires will be assessed only for the partner municipalities of Greece (Peristeri) and Cyprus (Strovolos-Lakatamia) as described in Del. C.1.1.

The potential impact of climate change to peri-urban fire risk in each municipality is calculated as a function of hazard and exposure indicators according to the methodology described in Section 1. As has already been mentioned, hazard depends on climatic factors; therefore, the meteorological Fire Weather Index (FWI) is used. Furthermore, as exposure depends on biophysical and morphological factors, vegetation and land cover data, and more precisely, the flammability (i.e. the ease of ignition) of each land cover category throughout the study grid as well as slope and aspect are used as exposure sub-indicator.

5.1 Impact assessment

5.1.1 Hazard indicators

- **Fire Weather Index (FWI)**

The contribution of meteorological factors to fire danger is simulated by various non dimensional indices. Viegas et al. (1999) validated several such indices in the Mediterranean against observed fire occurrence, with the Canadian Fire Weather Index (FWI, van Wagner 1987) being amongst the best performers.

The FWI model is non-dimensional, based on physical processes and has been used at several locations, including the Mediterranean basin (e.g. Moriondo et al., 2006, Carvalho et al., 2008; Giannakopoulos et al., 2012; Karali et al., 2014); thus it seems a sensible choice for exploring the mechanisms of fire danger change.

FWI is a daily meteorologically-based index used worldwide to estimate fire danger in a generalized fuel type. The FWI System provides numerical ratings of relative fire potential based solely on weather observations. The meteorological inputs to the FWI System are daily noon values of temperature, relative humidity, 10m wind speed and precipitation during the previous 24 hours and are described in detail in van Wagner (1987).

The FWI system consists of six standard components each measuring a different aspect of fire danger. The first three primary sub-indices are fuel moisture codes and are numerical ratings of the moisture content of litter and other fine fuels (FFMC), the average moisture content of loosely compacted organic layers of moderate depth (DMC) and the average moisture content of deep, compact organic layers (DC). The two intermediate sub-indices (ISI, BUI) are fire behaviour indices. The Initial Spread Index (ISI) is a numerical rating of the expected fire rate of spread. It combines the effect of wind and FFMC on rate of spread without the influence of variable quantities of fuel. The

Buildup Index (BUI) is a numerical rating of the total amount of fuel available for combustion that combines the DMC and the DC. The resulting index is the Fire Weather Index (FWI) which combines ISI and BUI. FWI represents the frontal fire intensity and is used to estimate the difficulty of fire control.

Furthermore, since 2007 the FWI has been adopted at the EU level by the European Forest Fire Information System (EFFIS) of the Joint Research Centre of the European Commission (part of the Copernicus Emergency Management Service since 2015). This was done following a test phase of 5 years, during which different fire danger methods were implemented in parallel by EFFIS, until the FWI was selected as the method to assess the fire danger level in a harmonized way throughout Europe. The FWI classification used by EFFIS is presented in Table 9.

Table 9: EFFIS FWI classification for Europe

FWI classes	FWI ranges
Very Low	<5.2
Low	5.2-11.2
Moderate	11.2-21.3
High	21.3-38.0
Very high	38.0-50.0
Extreme	≥50.0

As FWI is based solely on meteorological variables, projected changes in temperature and precipitation patterns under both RCP4.5 and 8.5 will be reflected in the FWI patterns throughout the domain of study. In the framework of the project the number of days with high fire danger (FWI>30) will be used as an hazard indicator.

For the classification of FWI indicator for each municipality the following methodology was used. The mean annual value of the index was calculated for the years 1971 to 2100 using the climatic output of MPI-RCA4 RCM (see Del. C.2 for more information on the model). The minimum and maximum values of the index for the abovementioned period for each partner municipality are extracted (as shown in Figure 32 below) and the index is divided into five classes. The next step concerns the estimation of the mean values for the current climate (1971-2000) and the future climate (2031-2060) under both RCPs, and their utilization for defining the class for each period (current climate, future-RCP4.5, and future-RCP8.5).

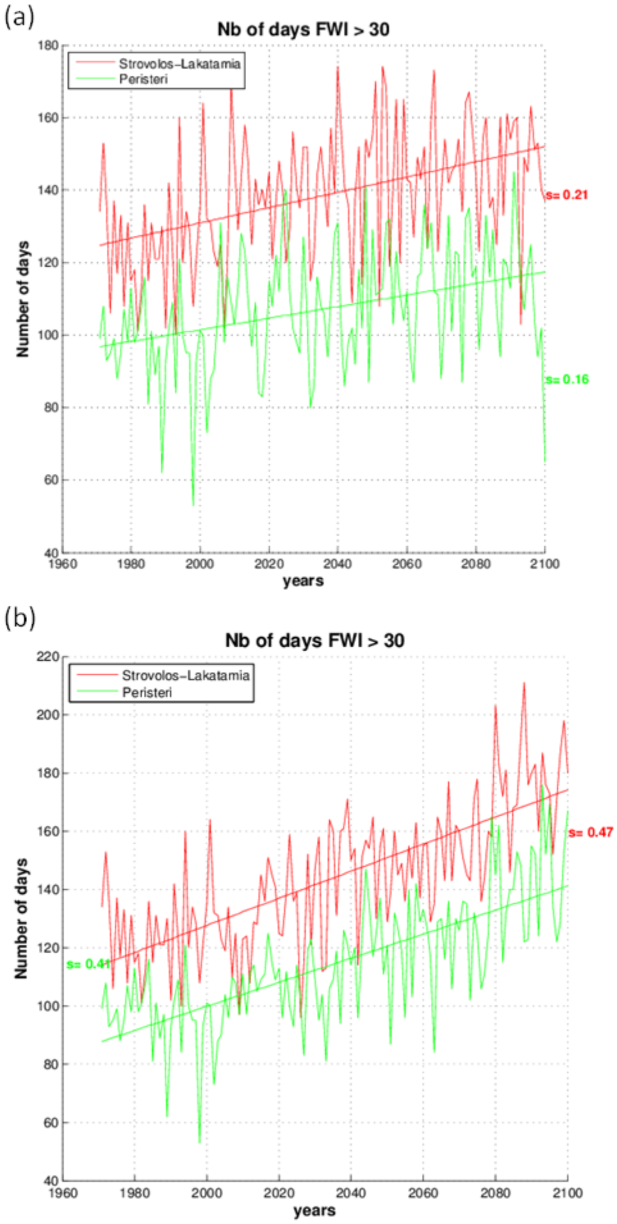


Figure 32: Annual evolution of the hazard indicator (no of days with high fire danger) for the years 1971-2100 for Peristeri and Strovolos –Lakatamia under (a) RCP4.5 and (b) RCP8.5.

5.1.2 Exposure indicators

- **Slope**

Intense slopes increase the fire spread velocity and also affect strongly the fire suppression capability. The rate of spread of a fire increases upstream in areas with a strong morphological gradient. Therefore, slopes are grouped as follows: (a) gradients 0% - 13% (low exposure), (b) 13,1% - 40% (medium exposure), and (c) >40,1% (high exposure).

- **Aspect**

Southern/southwestern orientation slopes favour drier and with less relative humidity environments as the soil temperature is increased due to higher solar radiation absorption. This leads to more fire prone conditions. The predominant aspect of the slopes, where sun exposure is longer, are the Southeast and the Southwest. Therefore, the slope directions are grouped as follows: (a) orientation 0° - 45°, 316° - 360° with low exposure (b) orientations 46° - 134°, 271° - 315° with medium exposure and (c) orientation 135° -270° with high exposure.

For the calculation of slope and aspect sub-indicators, the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) dataset at a spatial resolution of 15 arc-seconds is used in QGIS environment. The scores of aspect and slope are assigned according to the methodology developed within Forest Cities (Life08 ENV/GR/000553) project (Forest Cities, 2012).

- **Land cover types - Flammability**

For the calculation of the flammability sub-indicator, Corine land cover database (CLC2012) from the Copernicus Land Monitoring Service (CLMS) at a horizontal resolution of 100m was used. For each grid point the predominant land cover category was used. For each grid point and cover category, a flammability score is assigned according to the methodology developed within Forest Cities (Life08 ENV/GR/000553) project. In general, the following coarse classification is implemented: (a) Permanent crops and open areas with little or no vegetation (low flammability); (b) heterogeneous agricultural areas (medium flammability); and (c) areas with shrubs and forests (high flammability). Urban areas, arable land, as well as areas corresponding to inland and coastal wetlands, present no flammability. The complete table with all the land cover categories and their flammability scores are presented in section 5.1.3.3 below.

For the final calculation of climate change impact, each one of the aforementioned sub-indicators received a weight. These weights are: 45% for flammability, 35% for FWI, 15% for slope and 5% for aspect and were based on the weights given in the LIFE Forest Cities project except for the FWI that was not used in the project.

5.1.3 Indicator's scoring

5.1.3.1 Municipalities of Lakatamia and Strovolos

Number of days with FWI>30				
Classification		Score		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
100-115	1			

116-130	2	2		
131-144	3		3	3
145-159	4			
160-174	5			

5.1.3.2 *Municipality of Peristeri*

Number of days with FWI>30				
Classification		Score		
		Current climate	Future climate (RCP4.5)	Future climate (RCP8.5)
53-72	1			
73-91	2	2		
92-109	3		3	3
110-128	4			
129-147	5			

5.1.3.3 *All municipalities*

Slope (%)	Score
0%- 13%	1
13,1%-40%	3

> 40,1%	5

Aspect (degrees)	Score
0°-45° and 316°-360°	1
46°-135° and 271°-315°	3
135°-270°	5

Flammability			
Corine land cover category			Score
Artificial surfaces	Urban fabric	Continuous urban fabric	0
Artificial surfaces	Urban fabric	Discontinuous urban fabric	1
Agricultural areas	Arable land	Non-irrigated arable land	1
Agricultural areas	Arable land	Permanently irrigated land	2
Agricultural areas	Permanent crops	Fruit trees and berry plantations	2
Agricultural areas	Heterogeneous agricultural areas	Complex cultivation patterns	2
Agricultural areas	Heterogeneous agricultural areas	Land principally occupied by agriculture, with significant areas of natural vegetation	2
Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Natural grasslands	2

Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Sclerophyllous vegetation	3
Forest and semi natural areas	Forests	Broad-leaved forest	5
Forest and semi natural areas	Forests	Coniferous forest	5

5.2 Impact maps for each municipality

In the following sections, impact maps for the municipalities of Peristeri in Greece and Strovolos and Lakatamia in Cyprus, are presented. For each municipality, impact assessment is shown for the current climate (1971-2000), as well as for the future climate (2031-2060) under two emission scenarios, namely RCP4.5 and RCP8.5.

5.2.1 Municipalities of Lakatamia and Strovolos

In Figure 33, the impact map for the current climate for the two adjacent Cypriot municipalities is presented. Therein, most of the grid points contain low to medium values. This represents 74% of the total grid points, covering about 550ha out of 741ha of the gridded area. 16% of the total area presents no impact while about 6.5% presents low impact values. At the current climate only 3% of the total grid points shows medium impact. At the future climate (Figure 34-Figure 35), under both emission scenarios, only 4% of the grid points with low to medium impact changed to medium impact. The same is true for the medium impact grid points that reach the high impact class. The most vulnerable area on the map is the greater area of the Forest National Park of Athalassa, adjacent to Strovolos Municipality, where high impact values are found for the future climate. Some areas in the northern part, mainly covered by herbaceous vegetation as well as regions with rainfed agricultural use, are expected to move from the low to medium impact class to the medium one on the same period.

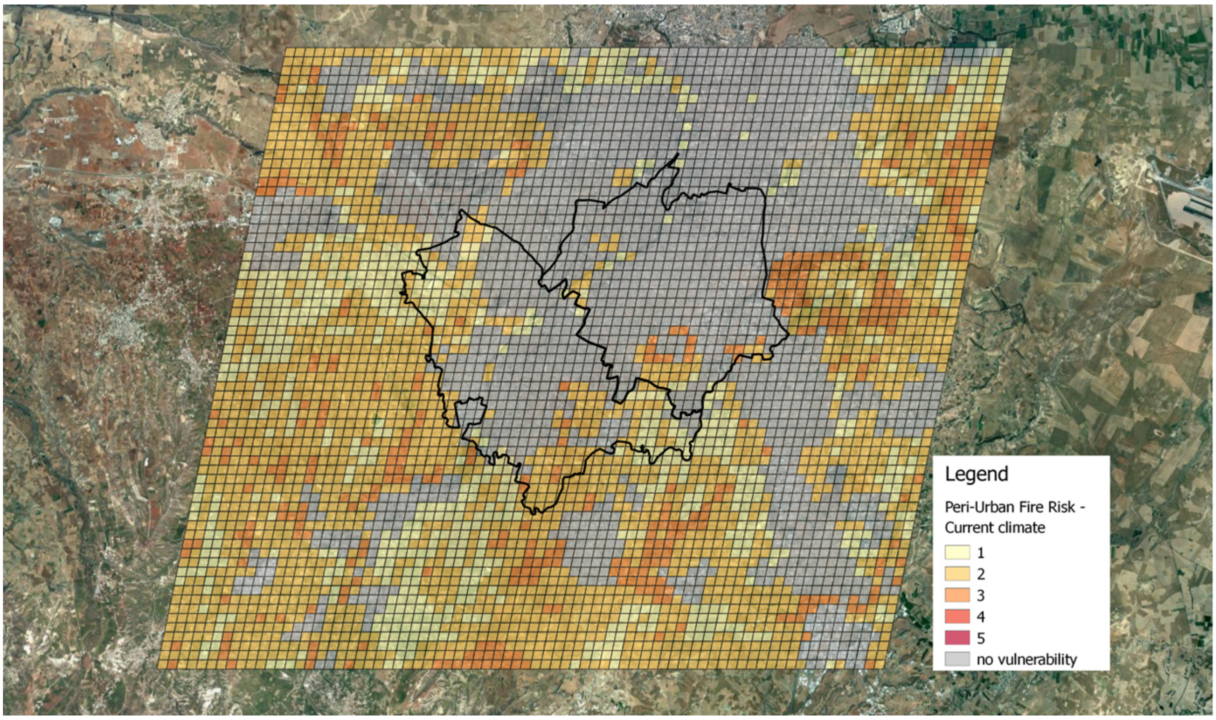


Figure 33: Impact assessment for current climate

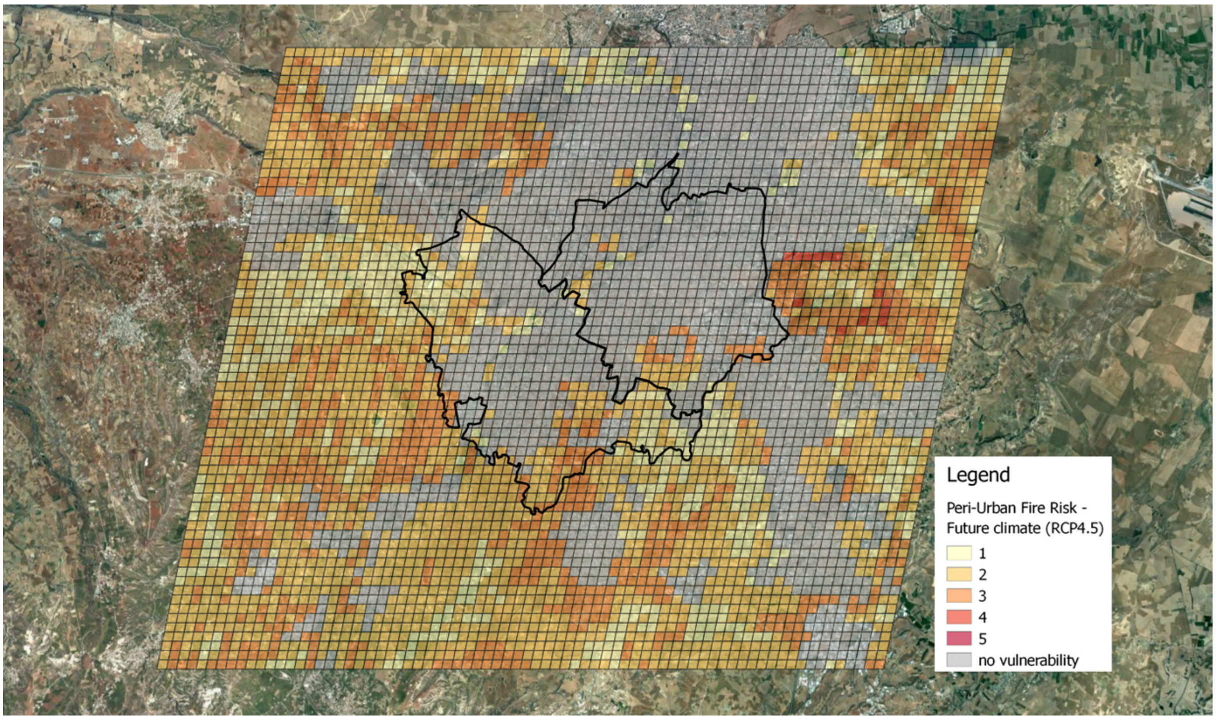


Figure 34: Impact assessment for the future climate under RCP4.5.

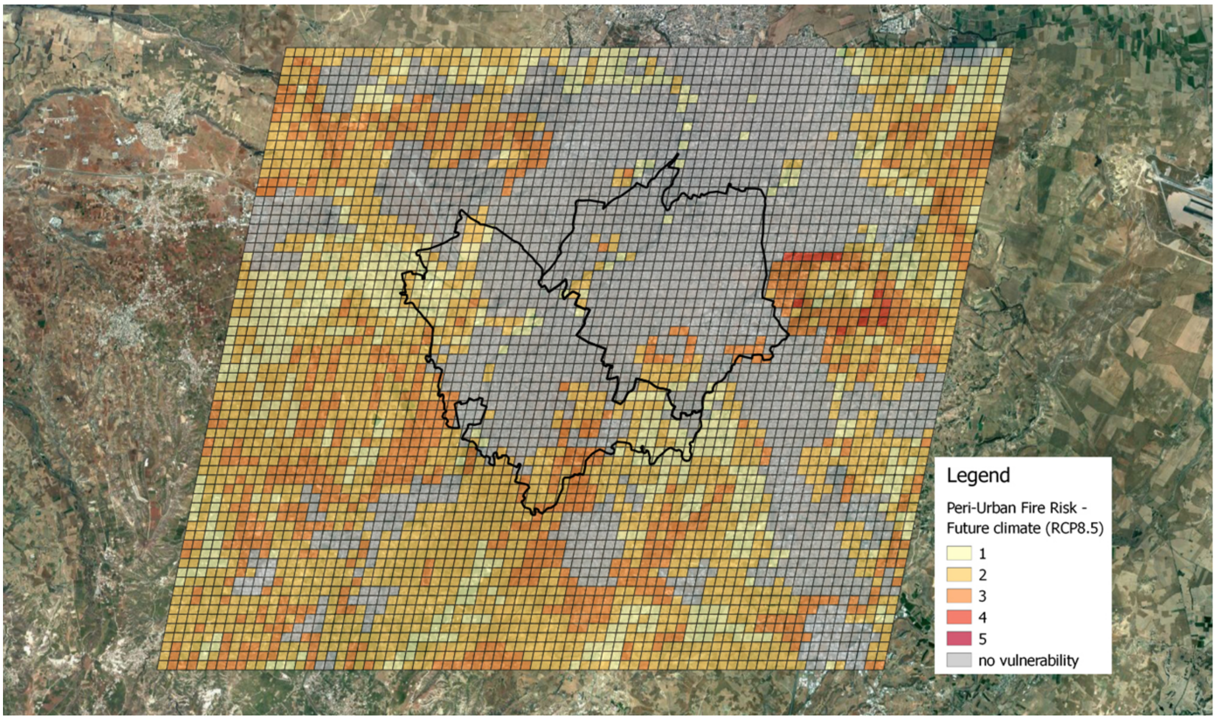


Figure 35: Impact assessment for the future climate under RCP8.5.

5.2.2 Municipality of Peristeri

In Figure 36, the impact map for the current climate for Peristeri is presented. To note, the extended grid for Peristeri was developed in order to include mainly Poikilo Mountain in the northern part of Peristeri, and Aigaleo Mountain at the southwestern part, both vulnerable to forest fires. In the current climate, 66% of the grid points have zero impact, being urban grid points. Almost 25% presents low to medium impact, while 9% medium impact. In the future (Figure 37 & Figure 38), the majority of the grid points that fell in low –to medium class (74%) move to the high impact class. Of the medium impact class in the current climate grid points, 84% will remain at the same class, while the rest 16% will climb to the next class in the distant future. The grid points on the fringes of Poikilo Mountain within the borders of Peristeri, covered manly by sclerophyllous vegetation (scrubs), will have medium impact values at the future.

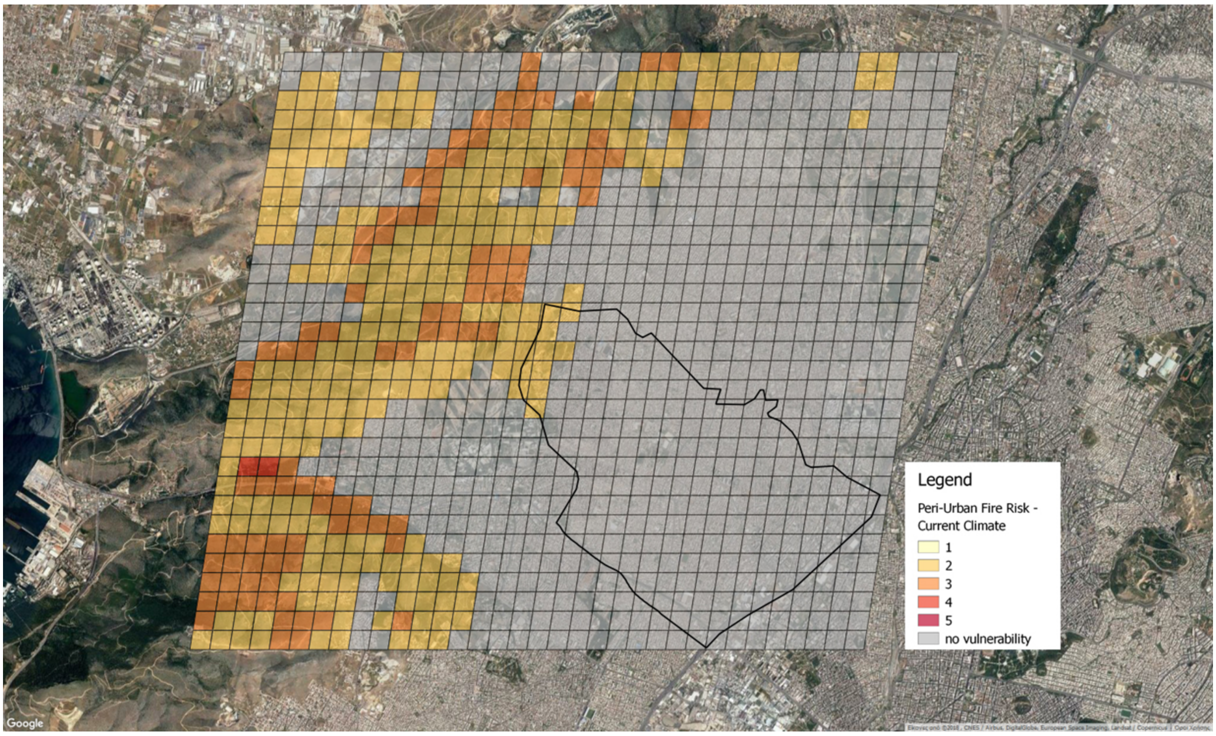


Figure 36: Impact assessment for the current climate

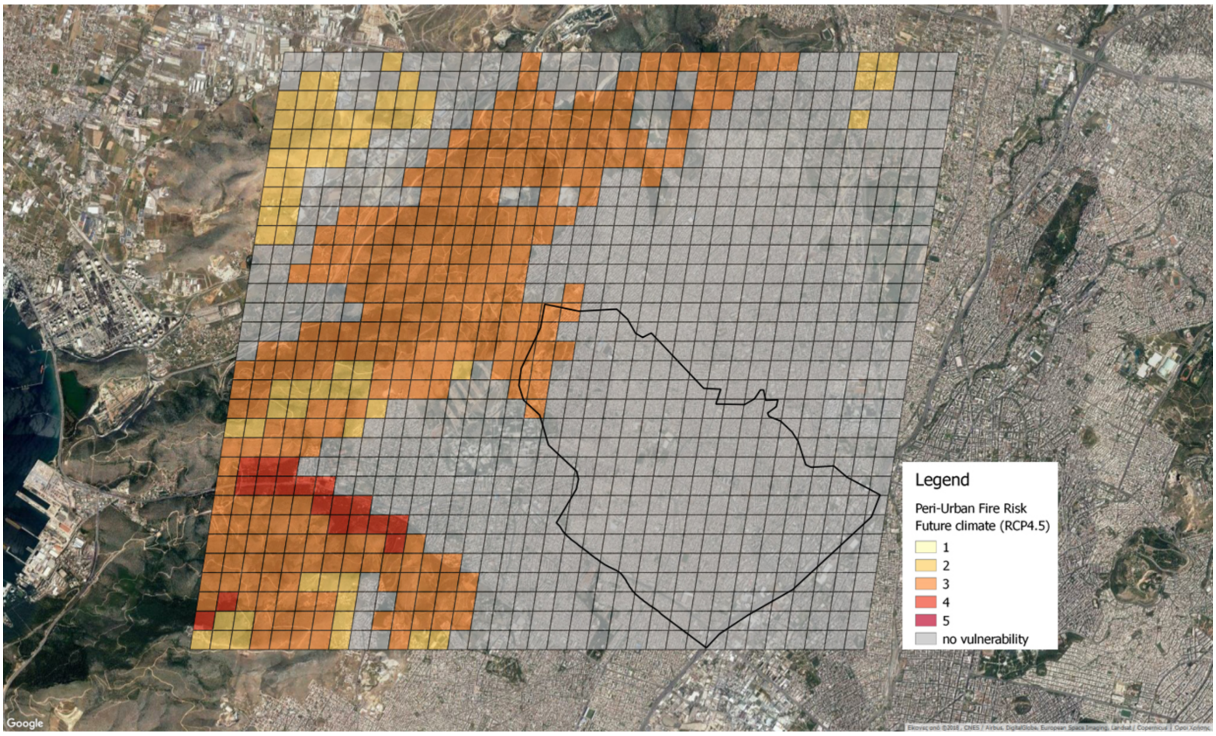


Figure 37: Impact assessment for the future climate under RCP4.5.

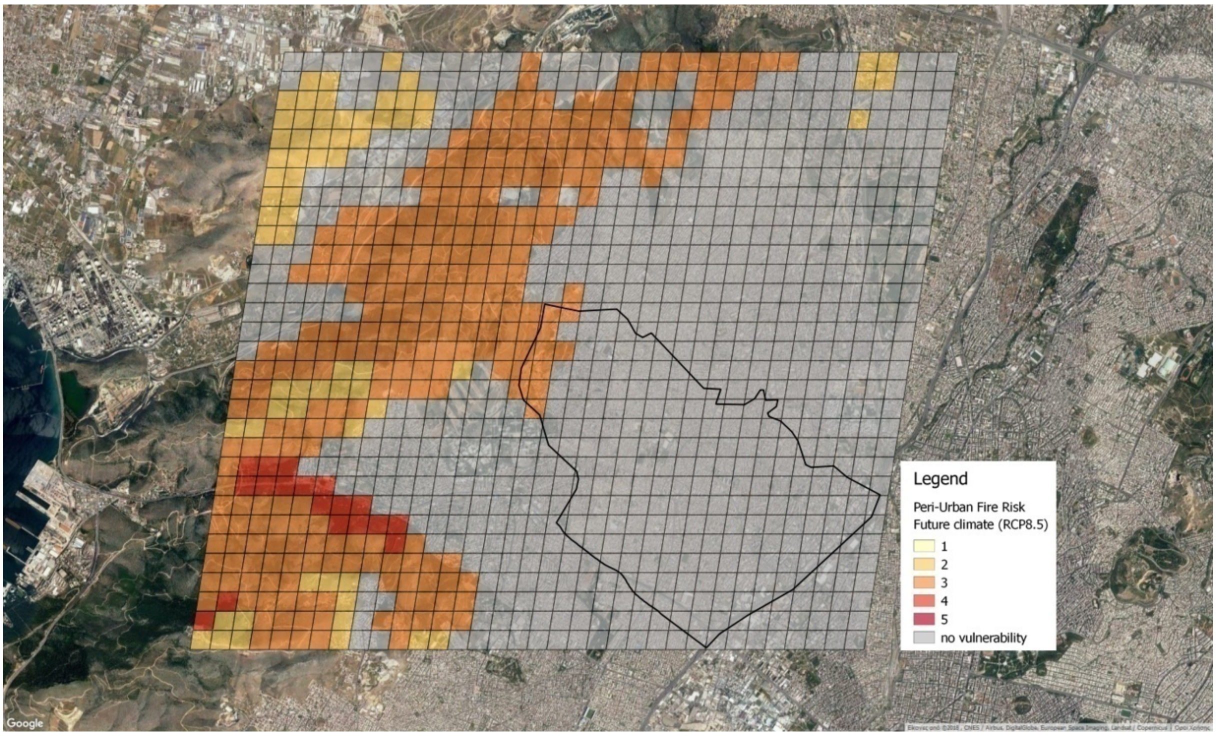


Figure 38: Impact assessment for the future climate under RCP8.5.

5.3 Proposed adaptation measures

The classification of the proposed adaptation measures is based on the mean score extracted from the four selected criteria. In Table 10, the mean score for each adaptation measure, as well as the individual scores for each evaluation criterion are also presented. More information on each adaptation measure is presented in Annex A.

Table 10: Proposed adaptation measures for peri-urban fires and their evaluation

Adaptation measures	Evaluation criteria				Mean score
	Efficiency in addressing the impact	Environmental Friendliness	Economic Viability	Job growth	
Reforestation /restoration actions of fire affected areas	78.57	92.86	44.29	47.14	**65.71**
Establishment of a forest	82.50	88.75	50.00	36.25	**64.38**

fire early warning system					
Monitoring fires, modelling and forecasting fire danger	77.50	82.50	50.00	43.75	**63.44**
Awareness campaigns for behavioural change	76.25	83.75	58.75	35.00	**63.44**
Establishment of a national forest registry	72.86	74.29	57.14	40.00	**61.07**
Classification of forests according to the risk of fire and identification of high risk areas	68.57	81.43	58.57	32.86	**60.36**
Creating a mosaic of forest types including species with reduced flammability	68.57	85.71	42.86	42.86	**60.00**
Strengthening fire-fighting measures	81.25	76.25	28.75	50.00	**59.06**
Implementation of policies to limit the abandonment of burnt areas and actions to prevent the spread of invasive species	66.25	78.75	56.25	33.75	**58.75**
Recovery planning and prompt implementation to reduce erosion and watershed damage, flooding and risks to public safety	71.43	80.00	41.43	37.14	**57.50**
Modernization of the legal framework for fire prevention	67.14	62.86	60.00	35.71	**56.43**
Incorporation of WUI areas in political/administrative instruments for forest fire	60.00	66.67	63.33	35.00	**56.25**

management					
Strengthen infrastructure to improve protection against forest forests	70.00	65.71	35.71	42.86	**53.57**
Fuel Treatment-Mechanical or Other non fire methods	53.33	50.00	50.00	50.00	**50.83**
Fuel Treatment -Prescribed burning	50.00	55.00	50.00	35.00	**47.50**

References

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ANNEX A POTENTIAL ADAPTATION MEASURES INFORMATION

5.4 Climate Change Adaptation Measures related to forest fires

Fuel Treatment -Mechanical or Other non fire methods

A variety of methods that do not directly involve fire often are used to change vegetation composition and structure and alter fuels to reduce hazard. These include various *mechanical thinning and debris disposal techniques*. Non-mechanical methods can involve livestock grazing to reduce fine fuels. These methods can be used wherever they are economically viable, especially where using fire as a management tool is undesirable or carries high risks. One advantage of such methods is that they often can be applied with a greater level of control over the location, timing, and desired outcome of the treatment. Mechanical treatments are particularly suited for fuels management following natural disturbances such as severe storms, intense droughts, or insect outbreaks that radically change forest structure.

Impacts:

- Reduce fuels available for combustion and thus fire risk

Costs and Benefits:

These methods can be used wherever they are economically viable, especially where using fire as a management tool is undesirable or carries high risks. One advantage of such methods is that they often can be applied with a greater level of control over the location, timing, and desired outcome of the treatment.

An added advantage of mechanical treatments in forested ecosystems is the potential to use the removed woody material for other purposes. Forest thinning might result in excess stocking being utilized as sawlogs, wood chips, or specialty products made from small-diameter trees. If markets exist for the byproducts of the treatment, then there is a greater chance of treatments being economically viable.

Fuel Treatment -Prescribed burning

This measure encompasses the method of planned or prescribed fire (i.e. the deliberate use of fire to meet specific management objectives) for fuel treatment and alteration in order to reduce fire risk, protect community, and restore ecosystem.

Planned fires are a very effective way to remove unwanted vegetation for a variety of objectives, but a critical issue of any planned burning programme is mitigating the effects of smoke. An effective smoke management programme is then necessary when prescribed fires are applied. In fact, prescribed burning could be an alternative or complementary technique for fuel management, but carefully adapted to the different contexts and according to the existing territorial patterns (rural abandoned areas, wildland urban interface (WUI), productive rural regions, etc.)

Impacts:

- Prescribed fire is one of the more effective and cost-efficient means of managing vegetation for multiple purposes, including hazard reduction, ecosystem restoration or maintenance, silviculture, and others. In general, prescribed fire is an effective tool in areas with fire-adapted or fire-dependent vegetation that has evolved with fire.

Costs and Benefits:

Prescribed fire carries inherent risk, as fires can escape the prescribed perimeter or produce hazardous smoke if not managed correctly. Prescribed fire also varies widely in cost because of terrain, weather, and the spatial pattern of fuels, meaning that its application is not always economically feasible. Implementing and maintaining a prescribed fire regime, therefore, requires properly trained personnel, adequate resources, and the willingness on the part of the landowners and nearby communities to accept the costs and potential disadvantages of prescribed fire in exchange for the potential benefits.

Strengthen infrastructure to improve protection against forest forests

This measure includes the reinforcement /improvement of existing pre-suppression measures (fire breaks, forest roads, etc.)

Impacts:

- **Fire breaks** are designed to interrupt the continuity of fuels. In case of fire, the fire breaks normally will slow the rate of spread, thus enabling the ground fire fighting forces to reach the head of the fire and suppress it easily and with relative safety.
- **Forest Roads** are necessary and extremely important both for forest management and fire protection purposes.

Creating a mosaic of forest types including species with reduced flammability

This measure can be implemented by designing and developing less flammable or mixed ecosystems, as different species behave differently against forest fires and thus are more resistant to fires. This requires conducting appropriate studies to identify the appropriate species and appropriate sites for their development.

Impacts:

- Forest management techniques aiming at reducing the risk of forest fire ignition and expansion

Classification of forests according to the risk of fire and identification of high risk areas

Impacts:

- This measure is helpful for the forest fire management to minimize forest fire risk and avert damage

Reforestation /restoration actions of fire affected areas

This measure proposes reforestation / rehabilitation of affected areas with the use of appropriate forest reproductive material, the implementation of appropriate silvicultural measures and introduction of new techniques. Also, reforestation practices should be explored under the perspective of their suitability for adaptation to climate change.

Impacts:

- This measure prevents from floods and soil erosion and enables more rapid recovery for the burned areas

Establishment of a national forest registry

This measure proposes an establishment of a national forest registry (in countries lacking) with the registration of land uses, vegetation composition and ownership status. The registry should be produced or be compatible with Earth Observation information.

Impacts:

- This measure enhances forest protection and reduces fires related to public land violation

Modernization of the legal framework for fire prevention

Basic prevention regulations should address the following aspects: (a) forest management to avoid fires; (b) preventive silviculture measures in defensive and preventive infrastructures; (c) risk zoning to delimit areas regarding their fire risk and regulated land uses and activities according to fixed levels of risk; (d) establishment of risk periods in each country; (e) regulation on traditional and prescribed burnings; (f) social prevention measures (public awareness, governance mechanisms, etc.).

Recovery planning and prompt implementation to reduce erosion and watershed damage, flooding and risks to public safety

Indicatively, the sowing with graminaceous plants within the first 10 days after the fire in order to protect and stabilize forest in the first critical post-fire period.

Costs and Benefits:

- This intervention restricts the need for costly hydro-geomorphic projects, prevents erosion and floods and improves the useable water equilibrium

Implementation of policies to limit the abandonment of burnt areas and actions to prevent the spread of invasive species in burned areas

Impacts:

- This measure limits the change in the forest ecosystem profile and controls the increase of fuel abundance indirectly reducing future fire frequency.

Strengthening fire-fighting measures

This measure includes the strengthening of the fire-fighting system with significant investments in technical equipment, fire trucks and fire fighting resources and personnel training. This measure also includes the enhancement of volunteerism in forest fires suppression.

Incorporation of WUI areas in political/administrative instruments for forest fire management

The transitional areas between wildlands and urbanized spaces – the wildland urban interface (WUI) – represents an increasing fire risk factor and are highly vulnerable. These areas demand different policy and management measures regarding the biophysical and social components of the fire problem.

Tailored (e.g. higher resolution) spatial data is critical on the WUI extent, location and their evolution over time provide key information to develop effective fire planning in order to both avoid fire initiation and prevent negative impacts for the population.

Provisions for local emergency plans are also critical towards fire-adapted human communities to ensure public safety, reduce loss of property and direct more effectively fire response activities.

The WUI particularities call for social preventive measures regarding public information, social awareness and new governance mechanisms allowing existing stakeholders to participate in an integrated fire management scheme. Awareness raising of wildfire risk should be prioritized in wildland urban interfaces.

Finally, the WUI necessitates refining of forest related policies including urban spatial planning issues, fuel treatments around the structures, fire use activities and other owners' obligations, building material regulating codes etc.

Monitoring fires, modelling and forecasting fire danger

This measure proposes the use and of Earth Observation (EO) and Geographic Information System (GIS) techniques for real time fire detection and monitoring as well as post-assessment in order to support evidence-based decision making, increase preparedness, protect human lives, private property, infrastructures, and ecosystem services and enhance fire management. Furthermore, it proposes the development of short and long term fire danger forecasts in order to support wildfire management, prevention and preparedness.

Costs and Benefits:

Significant direct benefits typically derive from the combination of monitoring, modelling and forecasting systems with EWS (Early Warning Systems).

Awareness campaigns for behavioural change

This measure encompasses actions that promote awareness for the altered conditions under climate change and adaptation. However, not all stakeholders are aware and informed about their vulnerability and the measures they can take to pro-actively adapt to climate change. Public awareness is important to increase enthusiasm and support, stimulate self-mobilization and action, and mobilize local knowledge and resources. Raising political awareness is important as policy makers and politicians are key actors in the policy process of adaptation. Awareness raising requires strategies of effective communication to reach the desired outcome. The combination of these communication strategies for a targeted audience for a given period can broadly be described as 'awareness raising campaign'. The aim of awareness raising campaigns most often differs between contexts but generally includes increase concern, informing the targeted audience, creating a positive image, and attempts to change their behaviour.

Impacts:

- Awareness raising is an important component of the adaptation process to manage the impacts of climate change, enhance adaptive capacity, and reduce overall vulnerability.

Costs and Benefits:

Awareness rising is a complex task with results hard to predict. Option may be efficient, leading to reduction of property damage at relatively low investment costs.

Establishment of a forest fire early warning system

Early warning systems can enhance the preparedness of decision-makers and private individuals for climate-related natural hazards and their readiness to harness favourable weather conditions. Early warning systems for natural hazards need to have not only a sound scientific and technical basis, but also a strong focus on the people exposed to risk, and with a systems approach that incorporates all of the relevant factors in that risk, whether arising from the natural hazards or social vulnerabilities, and from short-term or long-term processes. To be effective and complete, an early warning system needs to comprise four interacting elements namely: (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication and (iv) response capability.

Impacts:

- The early warning systems can enhance the preparedness of decision-makers and private individuals to forest fires.

Costs and Benefits:

Early warning systems are usually cost-effective non-structural measures. Their cost, non-negligible in absolute terms, is extremely low in comparison with the potential amount of losses that these systems allow to reduce.

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5.5 Climate Adaptation Measures related to health

Early warning systems

Use of consistent, standardised warning system activated and deactivated according to weather conditions. Issuing of early warnings and provision of appropriate advice through mass media and/or digital warning signs at certain places, is an essential measure for self protection of the population from an extreme weather event. Forecasting of heat waves and prediction of storms and floods are necessary and can be carried out in collaboration with research institutions.

Impacts

Less people exposed to high risk weather conditions. Lower risk of accidents and injuries due to floods. Fewer incidents of cardiovascular and respiratory failures.

Air conditioned public buildings

Access to air conditioning is the most effective intervention to reduce mortality from heat waves (Kilbourne E.M., 1997). Municipalities could contribute by opening buildings to the public and by providing transportation for the citizens to reach the place. Priority should be given to people most at risk (elderly, very young persons, chronically ill patients, disabled persons and people without any other access to air conditioning).

Impacts: Less people exposed to high air temperatures. Fewer incidents of cardiovascular and respiratory failures.

Urban parks

Municipalities could focus on conservation planning and urban park creation to protect residents from the effects of climate change. Green space such as parks, tree canopies and small rooftop gardens can help cool the urban landscape during heat waves. Urban parks can and also help at the urban storm water runoff problem, by collecting and cleansing storm water and preventing overflow in the streets. Water flowing over rooftops and roads also peaks up contaminants that include bacteria, oil and grease, metals and pesticides. Green infrastructure mimics how nature handles rainwater through the use of porous surfaces, rather than impervious surfaces like roadways, and it also helps removing a part of pollution.

Impacts

Cooling of the urban landscape: residents experience lower temperatures. Storm water runoff: fewer accidents due to streets overflow, residents not exposed to bacteria and chemical contaminants.

Strategies for public buildings restoration

Adaptation measures for civil protection should also take into account adaptive strategies for buildings. Municipalities could undertake the restoration of public buildings. More specifically, the changes can be summed up to the following points:

- Greater strain on building material fixtures, cladding and fasteners and strengthening of tile fixtures securely to the roofs to avoid wind damage.
- Use of low emissivity environmentally safe building paints to improve the thermal performance of the building and to reduce heat transfer and heat radiation.
- External shading for hot surfaces.
- Replacement of concrete and steel, where possible. These materials absorb and radiate heat, causing late afternoon temperature to rise.

Impacts

Reduced thermal emission from the buildings during afternoon: residents leaving close to the public buildings experience lower temperatures in the afternoon. Reduced risk for injuries from detached objects due to strong winds.

Water pollution monitoring

Monitoring of the water pollution is an essential adaptation measure for protecting public health as climate change may cause a broad range of water quality-based health concerns:

Seasonal and geographic changes in waterborne illness risk: Changing water temperature may mean that waterborne Vibrio bacteria and harmful algal toxins will be present in the water at different times of the year or in places where they were not previously threats.

Extreme precipitation events increasing exposure risk: Toxins produced by harmful algal and cyanobacterial blooms in the water may all be exacerbated by increased runoff, warmer temperatures and discharges from point sources of pollution.

Extreme weather leading to water infrastructure failure: Extreme weather events and storm surges will increase the risk that drinking water, wastewater and stormwater infrastructure will fail due to either damage or exceedance of system capacity. As a result, the risk of exposure to water-related pathogens, chemicals, and algal toxins will increase in receiving waters and, when that enters source waters may complicate drinking water treatment efforts.

Impacts:

Less people exposed to bacteria and chemical contaminants in the water.

Raising public awareness

With climate change, extreme heat events will become more frequent and intense. However, little is known about public awareness of heat warnings or behaviors during hot weather. Municipalities can raise the awareness about risk factors, symptoms of heat-related illness, and when and how to seek treatment. Outreach programs and education can help build awareness of heat island risks and establish a foundation for action. A city council can issue resolutions, a public statement documenting a group's interest in heat island mitigation. This can be the first step in getting an initiative started.

Impacts

Prevention of incidents and health problems related to high air temperatures.

Pavements redesign

Pavements could be redesigned so that they reflect most of the solar radiation. The use of cool pavements can reduce the urban heat island effect. In addition, pervious pavements can reduce storm water storage and prevent overflow.

Impacts

Cooling of the urban landscape: residents experience lower temperatures. Storm water runoff: fewer accidents due to streets overflow.

Limitation of outdoor activities

More novel adaptation strategies target outdoor workers and activities during a heat wave through rational organisation of work schedules, such as start work early, take breaks often, scheduling most physical activity early in the morning or late in the afternoon.

Impacts

Less people exposed to high air temperatures during the hot hours of the day.

Strict controls/health inspections in food industry

Adaptation measures during heat waves could also contain advice on food hygiene, preparation and storage along with health inspections in food industry. In excessive temperatures, food spoils sooner and rates of food poisoning can increase. Food poisoning can increase dehydration and exacerbate the ill effects of heat.

Impacts:

Less people exposed to the risk of food poisoning.

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5.6 Climate adaptation measures related to the energy sector

Renovation of municipality buildings to Nearly Zero-Energy Buildings

Buildings represent the largest available source of cost effective energy saving and CO_2 reduction potential. "Nearly zero-energy building" means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. Some interventions to achieve this goal are:

- Installation of photovoltaic solar modules
- Improving existing insulation to high performance insulation to limit the losses and thus limit the heating and cooling consumption
- Installation of a central heating network using wood pellet boilers in cases buildings heated electrically
- Installation of adjustable external slats to protect from the sun
- Replacement of existing windows with low-e double-glazed windows and frames with thermal break
- Replacement of existing lighting with LED
- Presence control for lighting and heating
- Appropriate reconstructions for natural night ventilation for summer comfort
- Renovation of the roof - Green roof
- Renovation of the facade

Impacts:

The renovation of municipality buildings can reduce in a high extent the energy demand for heating and cooling. Actually, the final energy (for heating, cooling, ventilation and lighting) savings after renovation rages from 60-70% (Vazquez et al. 2016)

Financial incentives for the Holistic Energy Efficient Retrofitting of Residential Buildings

Retrofitting include various types of insulation materials such as Aerobel/aerogel, starch micro-porous insulation, vacuum insulated panels, smart windows, surface coatings, multi-functional lightweight materials integrated with phase change material for thermal storage and integrated heat recovery panels. Energy efficient solutions will also be deployed including energy efficient lighting using LED and light pipes, energy efficient HVAC (Heating Ventilation & Air Conditioning) such as natural ventilation, passive heating/cooling, heat pumps integrated with heat recovery and thermal storage, and renewable energy systems based on solar thermal and photovoltaics.

Impacts:

- Cumulative annual energy savings of at least 80% measured against building performance before retrofit
- At least a 60% reduction of CO_2 emissions
- A global energy consumption (excluding appliances) of 50 kWh/m²/year while reducing peak loads against the values measured before retrofit
- At least 80% energy saving for lighting over the average consumption of the installed base.

Cool Roofs

This adaptation measure refers on the installing of cool roofs to reduce the urban heat island effect. Cool roofs reflect more light and absorb less heat than traditional roofs. Or in more technical terms, cool roofs have both a high solar reflectance (or albedo) and a high thermal emittance, so that much of the heat that is absorbed is quickly radiated back to the atmosphere. As a result, cool roofs can be 10 to 15 °C cooler than traditional roofs.

Cool roof materials come in a variety of colors from light to dark and are available for both low-sloped and steep-sloped roofs. They work for a variety of building types and aesthetic requirements. Creating a cool roof can be as simple as spraying on a light-colored, paint-like coating. There are two basic types of coating that reflect more light and energy than a traditional roof: cementitious and elastomeric. Cementitious coatings contain cement particles. Elastomeric coatings include polymers to reduce brittleness and improve adhesion. Both types have a solar reflectance of 65 percent or higher when new and have a thermal emittance of 80 to 90 percent or more. Slightly more complex approaches include membranes that can be applied to the roof, roof tiles that reflect the sun much better than traditional tiles, cool-colored metal roofing, and asphalt shingles.

Impacts:

- Reduce the urban heat island effect
- Lower peak electricity demand, which can help prevent power outages
- Reduce power plant emissions, including carbon dioxide, sulfur dioxide, nitrous oxides, and mercury, by reducing cooling energy use in buildings

In addition cool roof can benefit a building and its occupants by:

- Reducing energy bills by decreasing air conditioning and needs
- Improving indoor comfort for spaces that are not air conditioned, such as garages or covered patios and finally
- Decreasing roof temperature, which may extend roof service life

Costs

Although costs will vary greatly depending on location and local circumstances, cool roof coatings on a low-slope roof might cost €7,5-€15 per square meter, while single-ply cool roof membrane costs vary from €15-€30 per square meter

Green roofs

Traditional roofs absorb sunlight and radiate heat into the surrounding air. Vegetation on green roofs shades the roof and cools the air through evapotranspiration. These effects cool green roofs by 37°C compared to traditional black roofs. The cooler roofs transfer less heat to the ambient air. Green roofs do not have as great a cooling effect on air temperatures as ground-level vegetation does, but they have the advantage of not taking up additional land and of keeping building occupants cooler

Green roofs are made up of several layers: a waterproof membrane to protect the underlying roof, a drainage layer, a growing medium such as soil, and the plants themselves. There are two basic types of green roof -extensive and intensive- vary in the depth of growing medium and the amount of vegetation. Extensive green roofs have a thinner layer of soil and vegetation and are the simpler, lower-maintenance option. Plants used on these roofs include sedum (a hardy flowering plant) and/or herbs that have minimal maintenance requirements.

On the other hand, intensive green roofs have deep layers of growing media that can support a diverse array of plants from herbs and sedum up to full-grown trees. Intensive green roofs are much heavier than extensive roofs because of their added depth, heftier plants, and retained water. As a result, they require more structural support. They also require irrigation and fertilization to maintain the plants. Intensive green roofs work well for commercial buildings or parking garages that have the necessary structural strength.

<u>Impacts</u>

Green roofs reduce the heat flux through the roof, and less energy for cooling or heating can lead to significant cost savings. Shading the outer surface of the building envelope has been shown to be more effective than internal insulation.

Other impacts are as follows:

- In summer, the green roof protects the building from direct solar heat.
- In winter, the green roof minimizes heat loss through added insulation on the roof.
- Energy conservation translates into fewer greenhouse gas emissions.

In addition, a concentration of green roofs in an urban area can even reduce the city's average temperatures during the summer, combating the urban heat island effect. Traditional building materials soak up the sun's radiation and re-emit it as heat, making cities at least 4 °C hotter than surrounding areas. A modeling study found that adding green roofs to 50 percent of the available surfaces in downtown Torodo, Canada would cool the entire city by 0.1 to 0.8°C (EPA, 2008a)

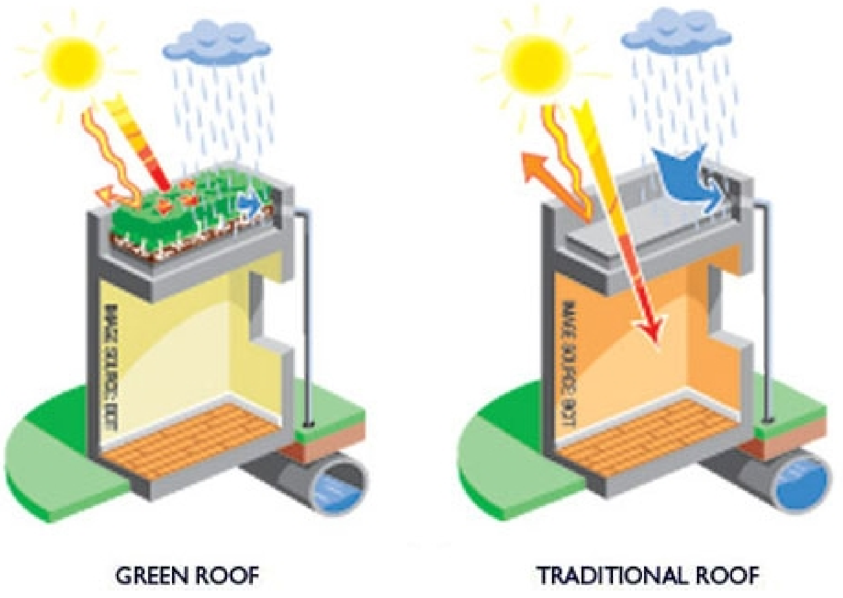

Figure 39: Benefits of a green roof compared to a traditional roof.

Figure 40: Temperature differences between a Green and Conventional Roof. Green roof is almost 40 °C cooler than the neighboring conventional roof

<u>Cost</u>

As mentioned before

Cool pavements

Cool pavement is a road surface that uses additives to reflect solar radiation unlike conventional dark pavement. Conventional dark pavements contribute to urban heat islands as they absorb 80-95% of sunlight and they can reach peak surface temperature of 48-67°C. Conventional pavements can transfer heat downward to be stored in the pavement subsurface, where it is re-released as heat at night contributing greatly to the urban heat islands (especially at nighttime) (EPA, 2012).

Existing dark pavement can be altered to increase solar reflectance (albedo) through whitetopping (covering of an existing asphalt pavement with a layer of Portland cement concrete) or by adding reflective coats and seals. New pavement can be constructed to increase albedo by using modified mixes, permeable pavements, and vegetated pavements.

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Figure 41: Conventional pavement temperatures during summer. Temperature reaches up to 67°C (EPA, 2012)

Impacts

Installing cool pavements can be part of an overall strategy to reduce air temperatures, which can result in a wide range of benefits. As far as energy sector is concerned, the reduction of air temperature through the increase of solar reflectance from cool pavements could lower energy use. Actually, an increase of about 10-35% in the pavement reflectance throughout a city could potentially reduce air temperature about 0.6°C which would result in significant benefits in terms of lower energy use and reduces ozone levels (EPA, 2012). Resenfeld et al. (1998) estimate over $90 million/year in savings from temperature reductions attributed to increased pavement albedo in the Los Angeles area.

Similarly, when permeable pavements evaporate water and contribute to lower air temperatures, they also provide other energy benefits. Permeable pavements can allow stormwater to infiltrate into the ground, which decreases stormwater runoff. With reduced runoff, communities may realize energy savings associated with pumping stormwater and maintaining conveyance structures. These cost savings may be significant in areas where there are old, combined sewers (where stormwater drains into the sanitary sewer system) (EPA, 2012)

Cost

Cool pavement costs will depend on many factors including the following:

- The region
- Local climate
- Contractor

- Time of year
- Accessibility of the site
- Underlying soils
- Project size
- Expected traffic
- The desired life of the pavement

Approximate installed cost for new construction of cool pavement varies from €0,8/m^2 to €8/m^2 depending on pavement type. Costs for maintenance of existing pavement to cool pavement varies from €0,8/m^2 to €5/m^2.

Urban forest

An urban forest is a forest or a collection of trees that grow within a city, town or a suburb. In a wider sense it may include any kind of woody plant vegetation growing in and around human settlements. Care and management of urban forests is called urban forestry. Urban forests may be publicly-owned municipal forests, but the latter may also be located outside of the town or city to which they belong.

Urban forests play an important role in ecology of human habitats in many ways: they filter air, water, sunlight, provide shelter to animals and recreational area for people. They moderate local climate, slowing wind and stormwater, and shading homes and businesses to conserve energy. They are critical in cooling the urban heat island effect, thus potentially reducing the number of unhealthful ozone days that plague major cities in peak summer months.

Impacts

The energy sector of an urban center benefits from urban forests mainly due to the capacity of the latter to reduce the air temperature and thus reduce the urban heat island effect. Trees and vegetation reduce heat in two ways. First, trees shade buildings, pavements, and other surfaces. Akbari et al. (1997) reveal that tree shade reduced the surface temperatures of walls and roof at two buildings by 11 to 25°C. In addition, Sandifer et al. (2002) examined the effects of vines on wall temperatures and found reductions of up to 20°C. Also, Scott et al. (1999) found that tree shading reduces the temperatures inside parked cars by about 25°C. This direct shading of the trees reduces energy needed to cool buildings.

The second way trees reduce air temperatures is through evapotranspiration. In this process, trees absorb water through their roots and emit it back into the air. Ambient heat converts the water into vapor, thus dissipating the energy. Evapotranspiration, alone or in combination with shading, can help reduce peak summer air temperatures. Measurements show that peak air temperatures in tree groves are 5°C cooler than over open terrain while temperatures over grass sports fields are 1 to 2°C cooler than over bordering areas (Huang et al. 1990, Kurn et al. 1994)

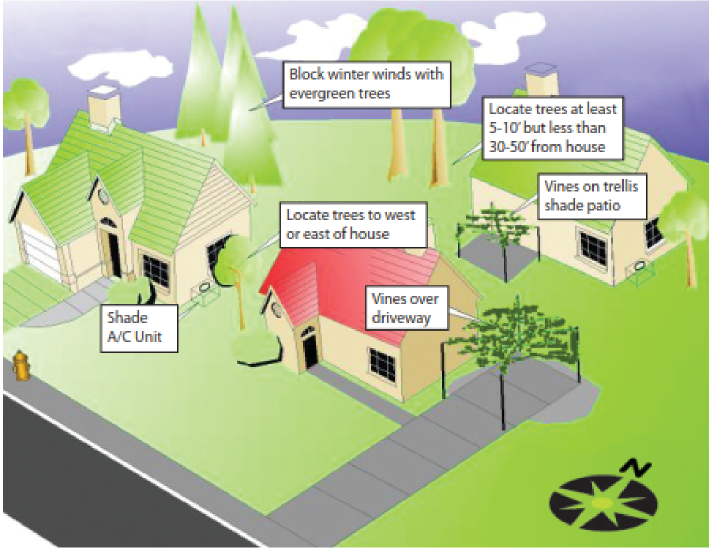

Figure 42: Tree placement to maximize energy savings. Picking the right trees and putting them in the right location will maximize their ability to shade buildings and block winds throughout the year (EPA, 2008b)

Cost

The primary costs associated with planting and maintaining trees or other vegetation include purchasing materials, initial planting, and ongoing maintenance such as pruning, pest and disease control, and irrigation. Other costs include program administration, lawsuits and liability, root damage, and tree stump removal. However, the benefits of urban trees almost always outweigh these costs. More precisely, the annual cost per tree is about €15-50 while the net benefits ranging from approximately €25-75 per tree (EPA, 2008b).

Economic incentives to reduce urban heat island

Incentives have proven to be an effective way to spur individual heat island reduction actions. Incentives from governments, municipalities, and other organizations can include below-market loans, tax breaks, product rebates, grants, and giveaways. Such initiatives that have already been implemented in other areas are as follows:

- Provision of coupons to homeowners to purchase trees from local nurseries
- Provision of free shade trees to residents to plant them around their homes
- Green and cool roof grant programs
- Provision of grants to building owners to encourage planting vertical gardens (green or living walls).

Economic incentives for Renewables and energy efficiency

Upfront costs are a major barrier to implementing energy efficiency projects in homes and businesses. An important goal of efficiency policies and programs is to help minimize these upfront project costs so owners are encouraged to invest in energy efficiency improvements and significant retrofits. Such initiatives that have already been implemented in other areas are as follows:

- Rebates provisions for lighting (replacement of conventional lamps with LED), upgrading of heating, ventilation, and air conditioning (HVAC) systems (e.g. replacing old thermostats), upgrading of water heater (e.g. installment of solar water heater), roof improvements (e.g. reflective roof), purchasing energy efficient appliances, improvement of building insulation, installation of photovoltaic panels

Demonstration projects and educational programs

Local governments, municipalities, universities, and other organizations have used projects to demonstrate a specific heat island reduction strategy and quantify its benefits in a controlled environment (e.g. energy savings). Documenting the project and its results can provide the data and publicity needed to develop larger initiatives, promote new technologies and help get them to market, and sometimes even encourage local economic development.

In addition educational programs that focus on teaching elements of residential energy efficiency to adults (homeowners, renters, builders and other housing professionals) and youth (students) can lead to an important behavioral change against issues such as the upgrading of home’s thermal performance, putting efficient appliances in homes, implementation of actions reducing heat island effect etc.

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5.7 Climate Adaptation Measures related to ozone exceedances

Increases in ground level ozone (tropospheric ozone) pollution levels due to climate change may make it more difficult to attain or maintain ozone standards. This will need to be taken into account when designing effective ozone precursor emission control program. The adaptation plans regarding surface ozone concentrations are under the broader air-quality umbrella of adaption plans including emissions and particulate matter. However due the non linear relationships of ozone with its precursor emissions the impact of reduced emissions on ozone needs to be addressed more thoroughly. The adaptation measures can be divided into those taken by the authorities as well as voluntary. The first category of measures includes:

- Monitoring of air quality and strict inspections in service industry must be applied. Facilities should cut emissions by using the best pollution abatement technologies available
- Collection of data and an inventory must be completed
- Actions in areas of the Health Sector (preparation of facilities and staff).
- Implementation of measures for air quality improvement in urban areas must be enhanced.
- Enhance public awareness and education.

Voluntary measures may include:

- Self-protection measures (avoidance of external activities, on early morning exercise or in days with high levels of pollution)
- Changes in driving habits (refuel cars and trucks after dusk, combine errands and reduce trips, limit engine idling.
- Choose a cleaner commute — car pool, or use public transportation.
- Conserve electricity and set air condition at a higher temperature.

Benefits

Increased air-quality can lead to a reduction in lung diseases and as a result fewer premature deaths associated with poor air-quality.

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