Deliverable C9: Replication and transfer strategy

LIFE URBANPROOF
CLIMATE PROOFING
URBAN MUNICIPALITIES

[April 2021]

Acknowledgments

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The project is being implemented by the following partners:

Coordinator Beneficiary	
DEPARTMENT OF ENVIRONMENT	Department of Environment, Ministry of Agriculture, Rural Development and Environment *(Cyprus)*
Associated beneficiaries	
	National Technical University of Athens *(Greece)*
	National Observatory of Athens *(Greece)*
I U A V Università Iuav di Venezia	University of Venezia *(Italy)*
S P Q R COMUNE DI REGGIO NELL'EMILIA	Municipality of Reggio Emilia *(Italy)*
STROVOLOS MUNICIPALITY	Municipality of Strovolos *(Cyprus)*
LAKATAMIA MUNICIPALITY	Municipality of Lakatamia *(Cyprus)*
Municipality of Peristeri	Municipality of Peristeri *(Greece)*

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Executive summary

In this report the technical and economic viability of the implementation of the proposed UrbanProof toolkit is evaluated and a transfer and replication strategy is laid down. In particular for the former, the toolkit was evaluated against the criteria set by the project steering committees, selected experts and wider stakeholders through the evaluation questionnaire. In addition, an economic evaluation takes place where a comparison is made of the financial resources devoted to the development of the toolkit for conducting the impact assessment for the ~3,000 UrbanProof municipalities of the 3 project countries (in terms of €/municipality) with the financial resources that will be needed for conducting a similar impact assessment without the use of the toolkit. In that framework, the cost savings that the use of the toolkit generates, are calculated. The same exercise is performed for the case of the urban municipalities in non-project countries of the EU and the cost for extending the toolkit databases for including the urban municipalities of these countries as well is estimated.

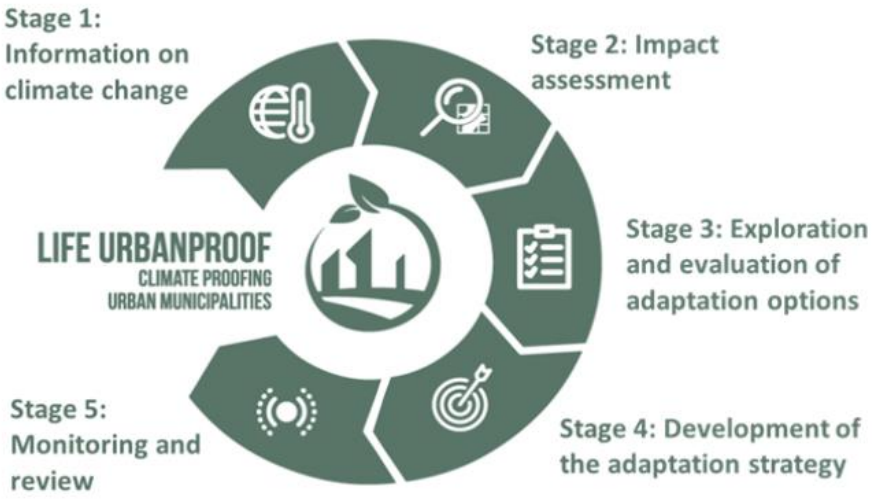
Following, the transfer and replication strategy is laid down including a clear set of activities for replicating the toolkit to other municipalities. The ultimate aim of the strategy is broken down into the short-term aim which foresees the implementation of the proposed UrbanProof toolkit to other urban municipalities of the project countries and the long-term aim which foresees the expansion of its databases to include data from other European countries so as to enable its replication to their urban municipalities. To this end, the replication strategy includes guidelines regarding the steps that need to be followed in order for other municipalities to employ the toolkit for assessing climate change impacts and developing their own adaptation strategy, based on the Reporting guidelines of the Covenant of Mayors.

1 Evaluation of the UrbanProof toolkit

1.1 Brief overview of the UrbanProof toolkit

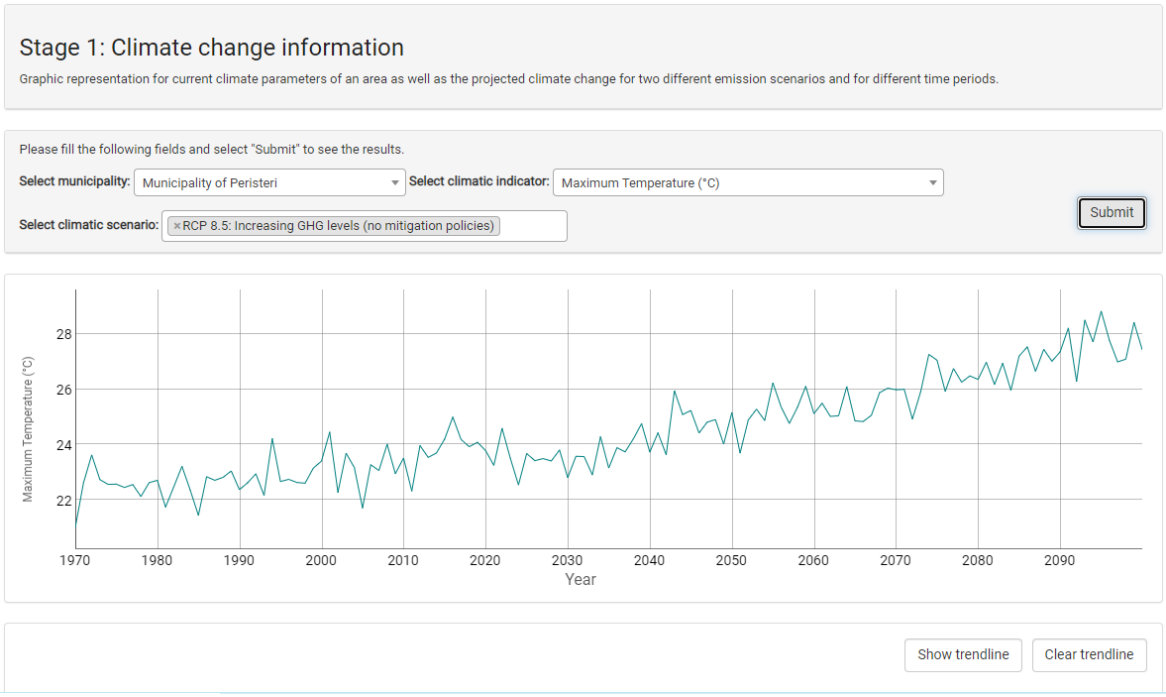
The URBANPROOF toolkit is a powerful decision support system aimed to enable better informed decision making for climate change adaptation planning. In specific, the user is guided though the different stages of the toolkit in order to gain insight into the climate change impacts to the urban environment, to explore and evaluate the available adaptation options and to investigate the effect of adaptation interventions in increasing climate change resilience.

The UrbanProof toolkit consists of 5 interdependent stages which altogether comprise the adaptation process:



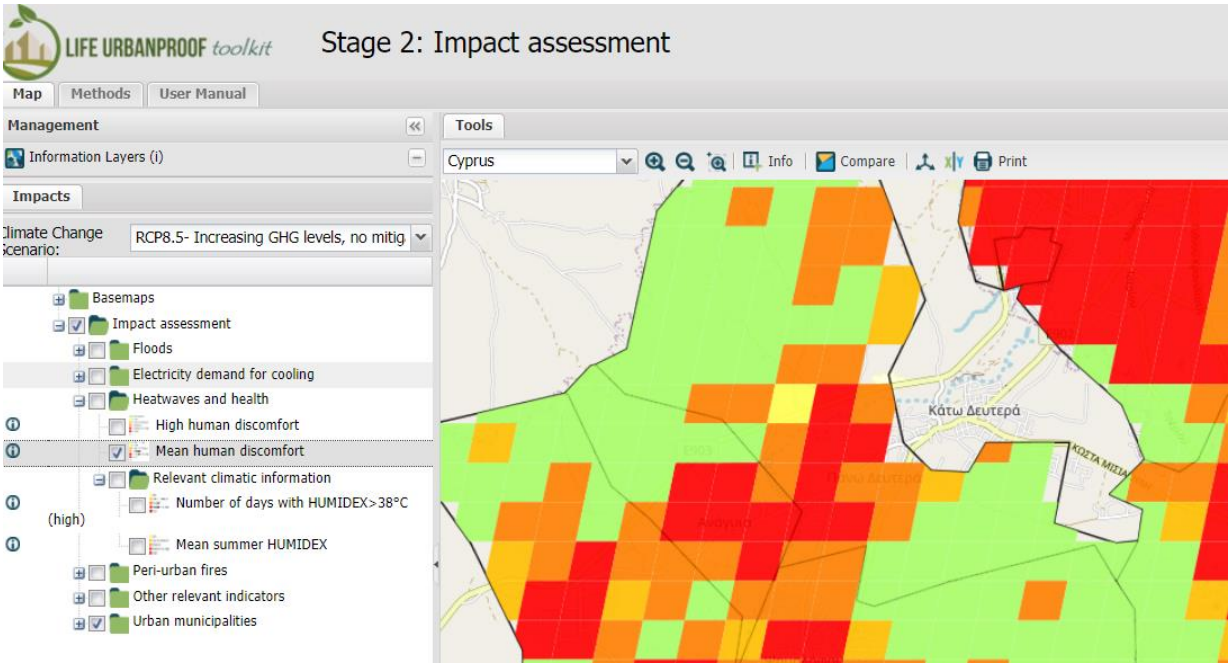
STAGE 1: CLIMATE CHANGE INFORMATION.

In **Stage 1**, one may explore through interactive charts, information on climatic projections based on the greenhouse concentration levels of two Representative Concentration Pathways.



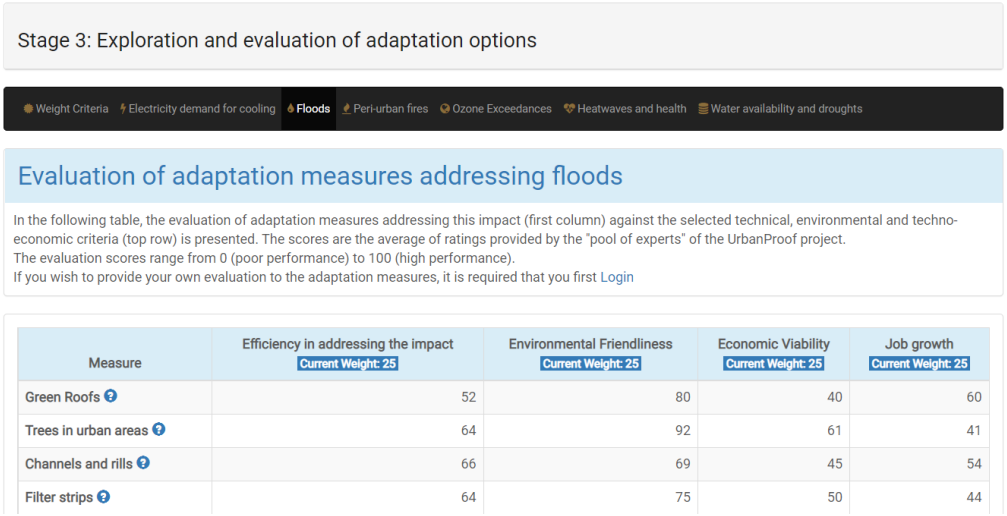
STAGE 2: IMPACT ASSESSMENT

In **Stage 2,** the users may investigate through interactive GIS maps useful information with respect to selected climate change impact indicators relevant to the urban environment, as well as gain insight into the individual parameters (physical, structural & socio-economic) contributing to the creation of these impacts.



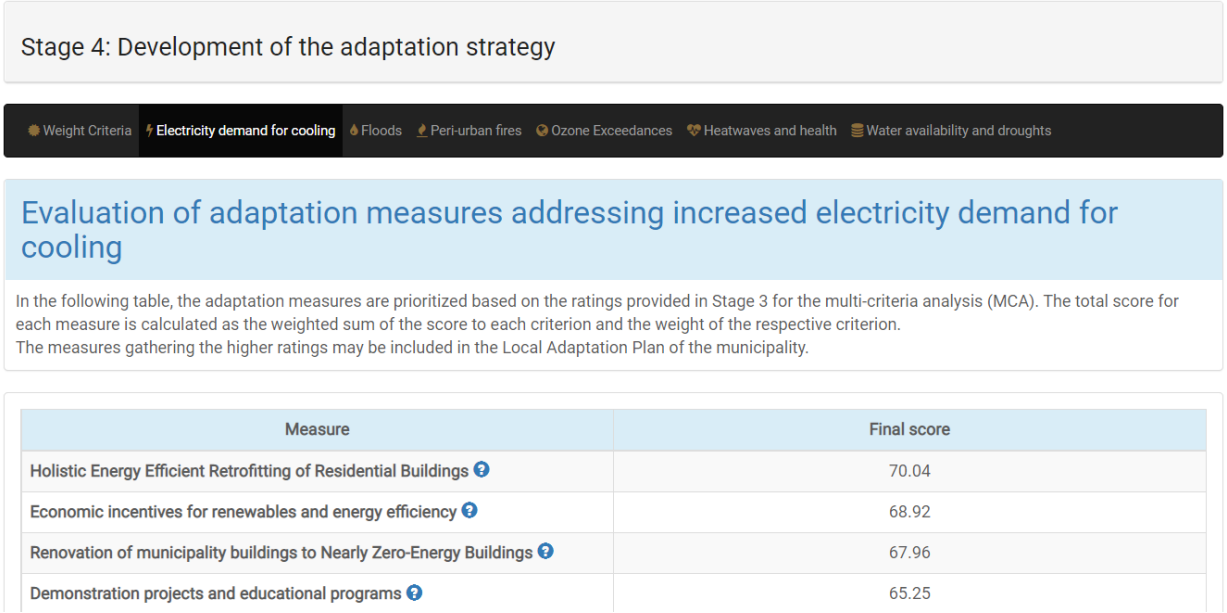
STAGE 3: EXPLORATION AND EVALUATION OF ADAPTATION OPTIONS

In **Stage 3,** the users may explore information on the available adaptation measures and their evaluation against several criteria (MCA), while local stakeholders or experts may also evaluate the measures and set their own weights to the evaluation criteria.



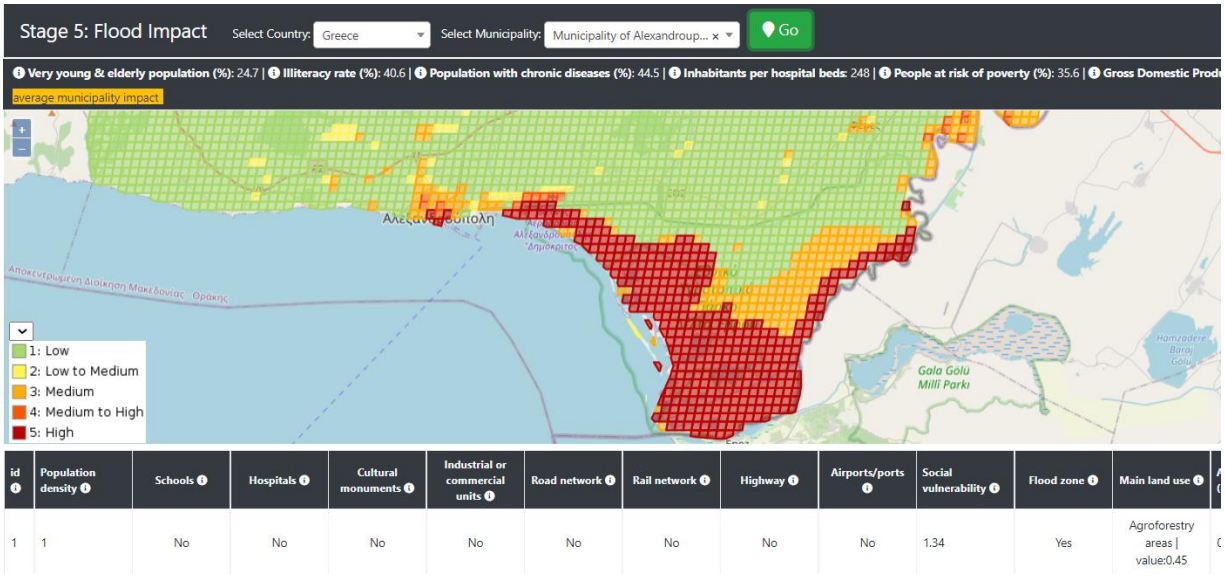
STAGE 4: DEVELOPMENT OF THE ADAPTATION STRATEGY

In **Stage 4,** one may see the results of the prioritization of the evaluation that took place in Stage 3, and to select the ones that gathered the highest scoring for inclusion in the local climate action plan.



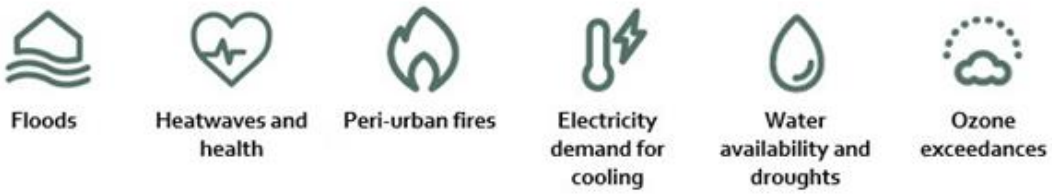
STAGE 5: MONITORING AND REVIEW

In **Stage 5,** the users may investigate the effect of adaptation measures in reducing the expected impacts for the municipality. This is useful both for the targets setting phase and for the monitoring phase of the local adaptation plan.



id	Population density	Schools	Hospitals	Cultural monuments	Industrial or commercial units	Road network	Rail network	Highway	Airports/ports	Social vulnerability	Flood zone	Main land use
1	1	No	No	No	No	No	No	No	No	1.34	Yes	Agroforestry areas | value:0.45

The climate change impacts examined are those relevant to the urban context as shown next:



The UrbanProof toolkit:

- ✓ allows for different geospatial information layers to be visualized and combined to present total impact assessment **results with sufficient spatial differentiation at municipal level**. The available resolution analysis (grid cells of 0.25km2) may provide relevant stakeholders with precise information with respect to where the highest impacts are expected and to guide adaptation.

- ✓ presents information through **dynamic information layers**. In specific, the user my zoom at a specific location of the map within a municipality and see the exact value for a certain indicator by clicking at the map. In addition, the parallel comparison of two indicators or climate change scenarios is possible through a swipe layer function.
- ✓ adopts the composite indicator approach in order to **capture the multi-dimensionality of impacts in a comprehensible form** and to support practical decision-making processes. One can always examine however the individual indicators in isolation.

1.2 Methodology

In this section the methodology for developing the information provided through the UrbanProof toolkit is presented. Information is also provided with respect to the quality of input data used as well to the limitations and uncertainties related to the results presented.

1.2.1 Impact assessment

1.2.1.1 Impact assessment methodology

The impact assessment methodology is based on the relevant conceptual framework presented within the 5th Assessment Report (AR5) of the IPCC (2014). Impacts are considered to result from the interaction of hazard and vulnerability, while the latter is considered to be a function of the exposure, sensitivity and adaptive capacity of population and infrastructure.

Hazard indicators
- Relevant climatic information for each impact

Exposure indicators
- Exposure of population, land and/or critical infrastructure to an impact

Sensitivity indicators
- Population groups which are considered sensitive to climate change

Adaptive capacity indicators
- Capacity of the health care system and of the economy to address climate change impacts

The hazard indicators are assessed with the use of the outputs of Regional Climate Models on selected climatic parameters for the future, based on two Representative Concentration Pathways (RCP4.5, RCP8.5). The exposure indicators are based on information provided through several geospatial databases, such as the Global Human Settlement Layer of the Joint Research Centre and the databases of the Copernicus Land Monitoring Service. For the sensitivity and adaptive capacity indicators, the

relevant economic and demographic data are sourced from Eurostat, as well as from the national statistical authorities of Italy, Greece and Cyprus.

1.2.1.2 *Impact assessment approach*

For assessing total climate change impacts, the composite indicator approach is selected, as composite indices capture the multi-dimensionality of impacts in a comprehensible form and therefore may support practical decision-making processes. The assessment is made at spatial level with the use of maps, in order to provide relevant stakeholders with information about where the highest impacts are expected and to guide the allocation of resources for targeting adaptation assistance (USAID, 2014).

The methodology for the formulation of composite indices 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 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.

Table 1: Rating scale of impact indicators

Qualitative scale	Numerical scale
Low	0 < I ≤1
Low to Medium	1 < I ≤2
Medium	2 < I ≤ 3
Medium to High	3 < I ≤ 4
High	4 < I ≤ 5

Indicators were **normalized and rescaled to the new range** [0-5]**,** by applying the min-max method (OECD 2008) according to the following formula.

$$x' = a + \frac{(x - \min(x))(b - a)}{\max(x) - \min(x)}$$

where x' is the normalized value, x the original value and a, b are respectively the minimum and maximum values of the selected new range.

The values of the social vulnerability indicators were normalized based on their position with regard to the respective European average value (above/below average values), an approach which was also applied in the study of Defra (2006).

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 our study, the weights were predefined based on expert judgement, however it is possible through the UrbanProof tool

to modify the weights, thus giving flexibility to the users to tailor the assessment based on their perception.

Limitations

The methodology used and the impact assessment approach followed although developed based on well-founded literature, is adjusted to the available resources, know-how and value judgment of the project consortium. The input data used, the indicators selected, the weights applied, as well as, the formulas developed for the impact assessment may however be modified and tailored through "Stage 5: Monitoring and review" of the toolkit, based on the contextual needs of the users. Specific guidance on this is provided in the manual of the tool. The results of the impact assessment may provide an indication of the intensity of impacts expected and of the areas that will be mostly affected, however, more detailed field research and consultation with stakeholders are necessary in order to determine what is needed for adaptation programming and how to develop local resilience.

1.2.2 Climatic Data

An extensive evaluation analysis of the outputs of four state-of-the-art Regional Climate Models (RCM) developed within the EURO-CORDEX initiative was performed. The outputs of the RCMs were evaluated against the gridded observational datasets of E-OBS(v17) for the period 1971-2000 as well as against observational data. Based on the analysis, the outputs of the model with the lowest biases were used in the UrbanProof toolkit, i.e. the MPI-ESM-LR/RCA4 RCA4, developed by the Swedish Meteorological and Hydrological Institute (SMHI) (Stranberg et al., 2014) and driven by the Max Planck Institute for Meteorology (MPI-ESM-LR) model (Popke et al., 2013). Daily bias adjusted temperatures and precipitation were used for the calculation of the hazard indicators for all urban municipalities. The indicator trends were calculated for the continuous periods 1971-2100 under two future GHG emission scenarios (Representative Concentration Pathways-RCP), namely the RCP4.5 and RCP8.5, which are implanted in the simulations after 2005.

GHG Emission Scenarios

The period 1971-2000 was used as the base period providing a reference for comparison with future projections for the period 2031-2060.

- **Stabilization of GHG levels, with mitigation policies (RCP4.5)**

RCP4.5 is a stabilization scenario that assumes that global annual GHG emissions peak around 2040 and then decline, leading to a radiative forcing of 4.5 W/m2 in the year 2100. This scenario assumes the imposition of emissions mitigation policies.

- **Increasing GHG levels, no mitigation policies (RCP8.5)**

RCP8.5 is a so-called 'baseline' scenario that does not include any specific climate mitigation target. The greenhouse gas emissions and concentrations in this scenario increase considerably over time, leading to a radiative forcing of 8.5W/m2 at the end of the century.

Reliability of Climatic Data

Due to the relative coarse resolution of the RCMs for municipality scale analysis, the models output was bias adjusted based on observational data.

Bias correction methods applied: The local intensity scaling (LOCI) method (Schmidli et al., 2006) was applied to precipitation data and the variance scaling (Chen et al., 2011) to temperature data. In brief, the LOCI method adjusts the mean values as well as both wet-day frequencies and wet-day intensities of precipitation time series. The variance scaling method corrects both the mean values and the variance of temperature time series.

Uncertainties related to the evaluation results are mostly associated to the quality of the observational dataset used to evaluate the model output. E-OBS is a product derived through interpolation from station data across Europe. In areas with low density of stations and/or in areas with complex topography, the gridding procedure tends to smooth the spatial variability of both temperature and precipitation.

E-OBS despite its uncertainties is considered a state-of-the-art gridded interpolated product for the European domain compared to other gridded products available during the early stages of the project (ERA5 and AgMERRA). The use of observational data from the project municipalities for the evaluation, further verified the results of the evaluation analysis against the gridded observational dataset.

It is noted that bias adjustment is a technique to post-process regional climate projections and it cannot overcome major model errors.

1.2.3 Social Vulnerability Index

The social vulnerability indicators are combined to form the composite Social vulnerability index, which reflects the population groups sensitive to climate change impacts and the adaptive capacity of the health care system and of the economy. The socio-economic indicators selected are among those widely used in the literature for the assessment of the vulnerability to climate change impacts on the urban environment.

The selection criteria for the indicators were: relevancy, adequacy as well as uniform and consistent data availability at the relevant geospatial level for the three project countries. 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 indicators are normalized based on their position with respect to the respective European average value (above/below average EU value). The data are sourced from the National Statistical Services of the three countries as well as from Eurostat.

Socio-economic Indicators

Very young & elderly population: The 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.

Illiteracy rate: The indicator created to reflect this population group is actually the percentage of people within the age group 15-75, with educational level up to lower secondary school, including the illiterate and the literate with lack of an official educational level or those who gave up school. This is the lowest

education attainment level for which data could be found for the same age groups at municipal level. However, it is considered to be indicative of the illiteracy level. The data are available at municipal level.

Population with chronic diseases: The indicator refers to the percentage of people with chronic diseases (asthma, chronic lower respiratoryexcluding asthma, high blood pressure, stroke or chronic stroke disease, diabetes, chronic depression). This information is available at national level only and therefore the values assigned to each municipality are the respective national ones.

Available hospital beds: The indicator refers to the available hospital beds per 100,000 inhabitants and is available at regional level. Therefore, the values assigned to each municipality are the respective regional ones.

Population with chronic diseases: The indicator refers to the percentage of people with chronic diseases (asthma, chronic lower respiratoryexcluding asthma, high blood pressure, stroke or chronic stroke disease, diabetes, chronic depression). This information is available at national level only and therefore the values assigned to each municipality are the respective national ones.

People at risk of poverty: The indicator created to reflect this population group is actually the percentage of population exposed to poverty risk. This information is available at national level only and therefore the values assigned to each municipality are the respective national ones.

GDP per capita: The indicator refers to "Euros per inhabitant" and is expressed as percentage of the EU average value. This information is available from Eurostat (2016) at regional (NUTS2) level and therefore the values assigned to each municipality are the respective regional ones.

1.2.4 Climate Change Impacts

Flood Impact

The flood impact is conceived as a function of climate change hazards, exposure and social vulnerability, whereas adaptation is considered to reduce flood impact. To estimate hazard, flood hazard maps for 100-year flood return periods were used for identifying the location and extent of the area potentially affected by flooding. Exposure to floods was estimated based on both population density and critical infrastructure. Critical infrastructure with respect to floods, includes hospitals, schools, commercial and industrial areas, public facilities, cultural units and transport infrastructure. Adaptation is assessed through the permeability of surfaces, the increase of which reduces overall runoff and flood risk.

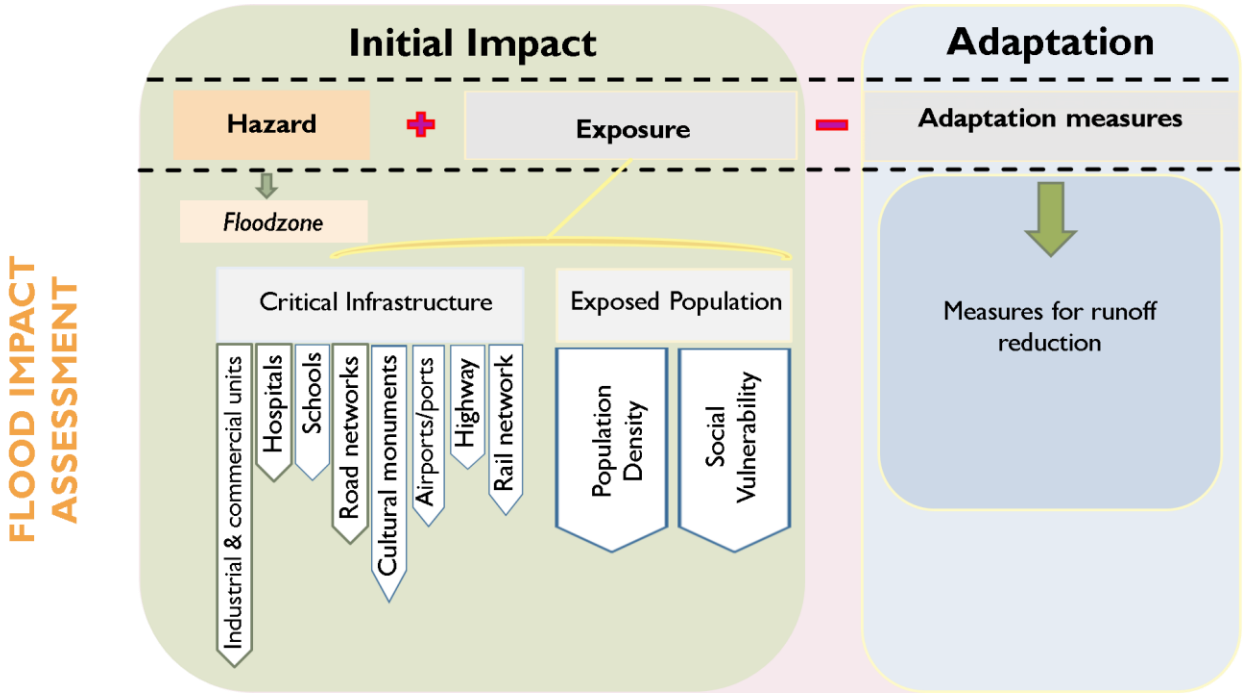


Figure 1:Flood impact assessment

Heatwaves and health

The impact of heatwaves on health is conceived as a function of climate change hazards and the vulnerability of the exposed population. HUMIDEX, which is a climatic indicator reflecting the impacts of temperature and humidity on human discomfort, was used to depict hazard. In specific, the number of days with HUMIDEX above 38°C which expresses high discomfort, was selected as indicator of hazard. The vulnerability of the exposed population was estimated based on the composite Social Vulnerability index and the population density. The implementation of adaptation measures addressing human discomfort due to heat is considered to reduce impact.

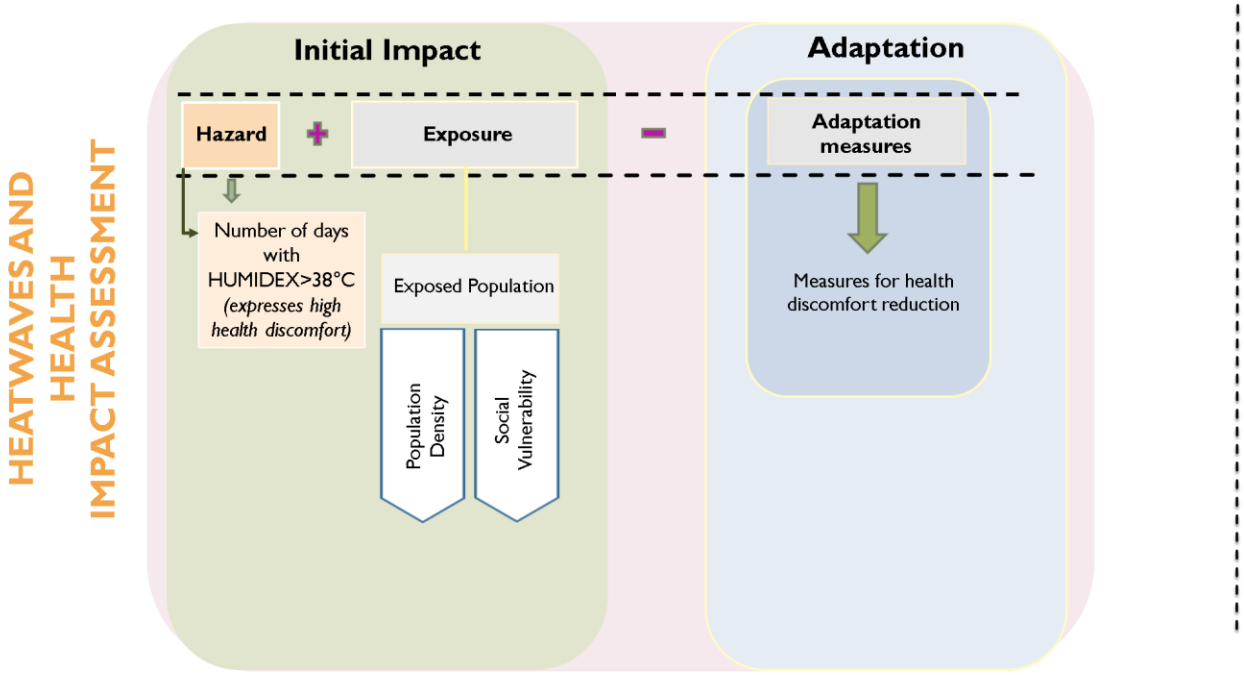


Figure 2: Heatwaves and health impact assessment

Electricity Demand for Cooling

The impact of increased temperatures on the electricity demand for cooling is conceived as a function of climate change hazards and the vulnerability of the exposed population. The assessment was based on the indicator CDD (Cooling Degree Days), which reflects the demand for energy needed to cool a building. In specific, the number of days where the Cooling Degree Days (CDD) is above 5 (i.e. days with great electricity demand for cooling) was used for the assessment of the climatic hazard. The vulnerability of the exposed population was estimated based on the composite Social Vulnerability index and the population density. The implementation of adaptation measures addressing increased electricity demand due to heat is considered to reduce impact.

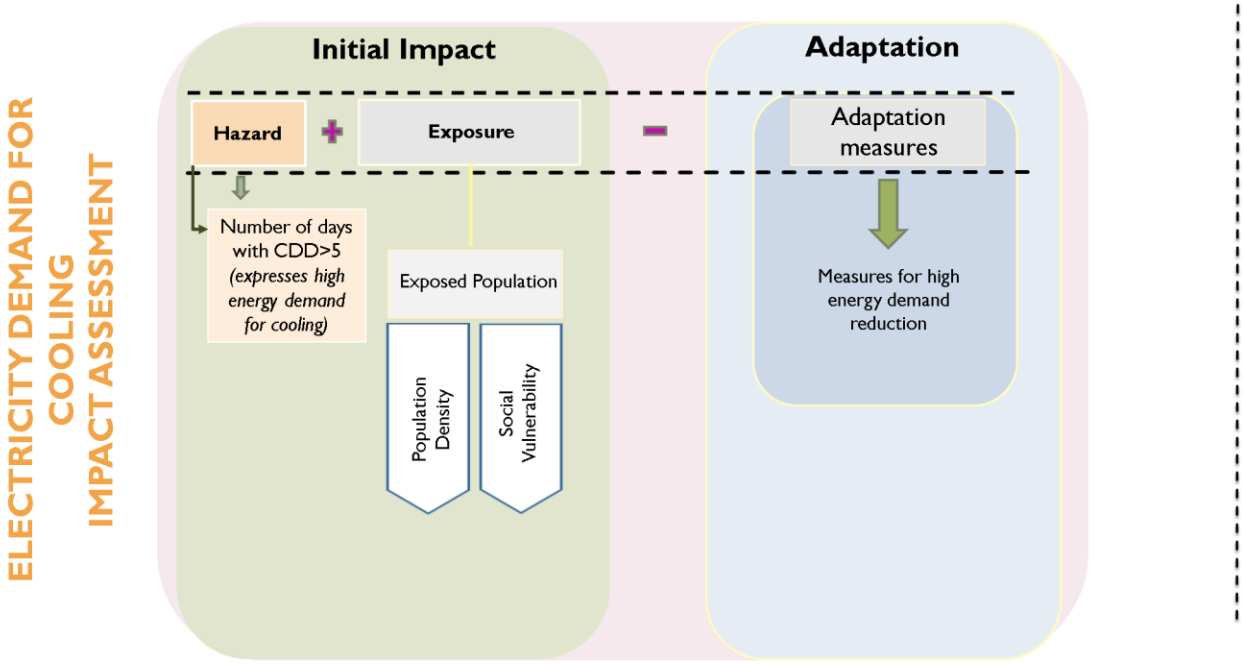


Figure 3: Electricity demand for cooling impact assessment

Ozone Exceedances

The impact of ozone exceedances is conceived as a function of climate change hazards and the vulnerability of the exposed population. For the assessment of ozone exceedances, the number of days with ozone exceedances above the threshold value for protection of human health, was used for the assessment of the climatic hazard. The threshold value of ozone exceedance is 8-hour average ozone concentration above 120 μg/m3. The vulnerability of the exposed population was estimated based on the composite Social Vulnerability index and the population density. The implementation of adaptation measures addressing ozone exceedances is considered to reduce impact.

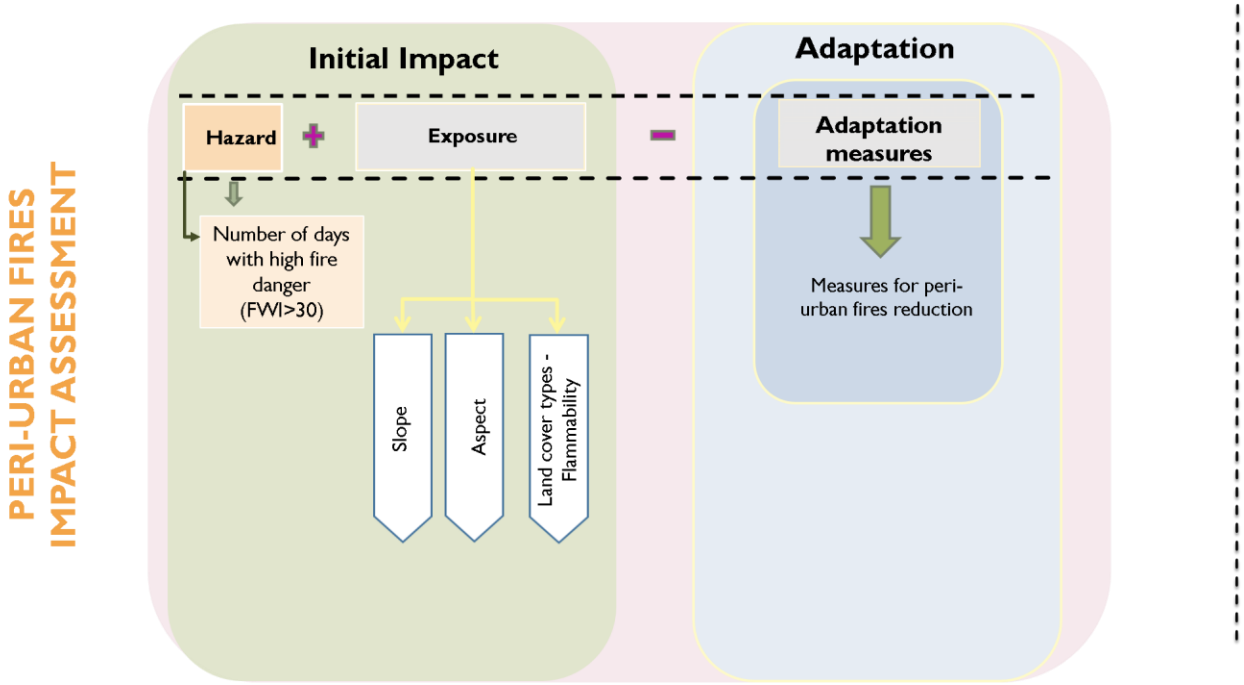


Figure 4: Ozone exceedances impact assessment

Peri-Urban Fires

For the assessment of peri-urban fires, the Fire Weather Index (FWI) was used for the assessment of climatic hazard. FWI is a meteorologically -based index used to estimate fire danger based on temperature, relative humidity, wind speed and precipitation. In specific, the expected number of days with (FWI) above 30 (i.e. days with high fire danger) was used for the assessment. Other parameters of relevance for the assessment were also used, i.e. slope, aspect and land cover flammability.

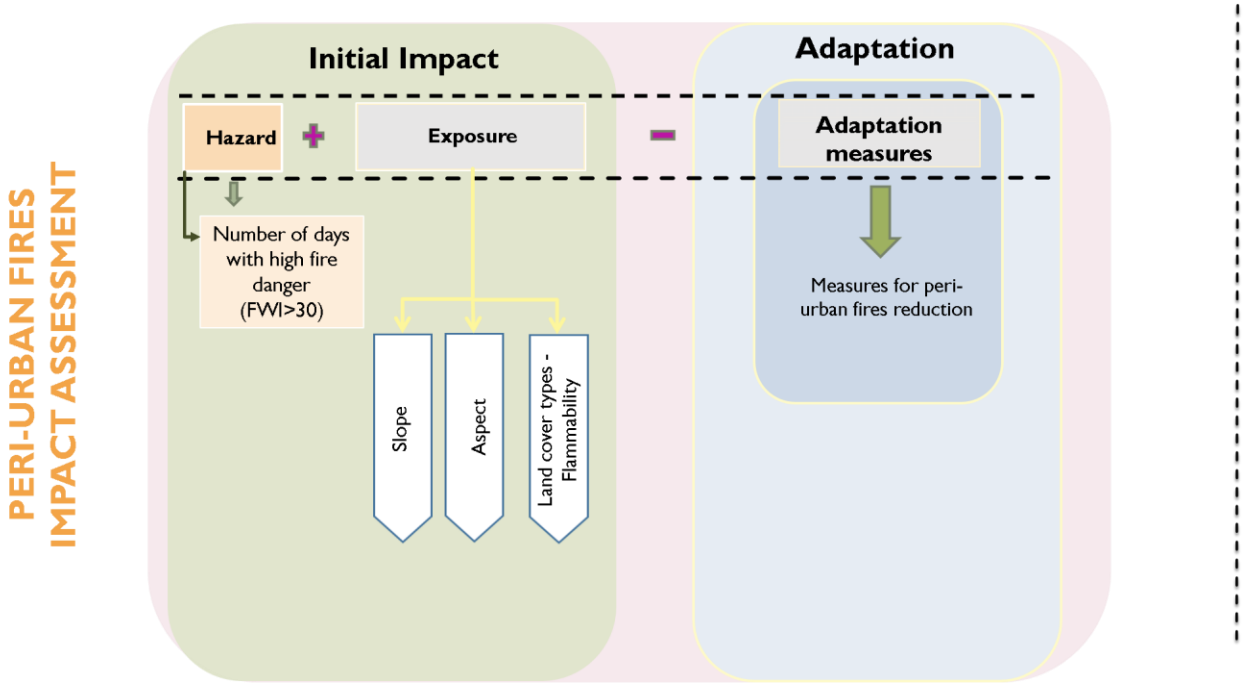


Figure 5: Peri-Urban fires impact assessment

1.2.5 Evaluation of Adaptation Measures

The included adaptation measures are the outcome of an extensive literature review, including the reports of European and international organizations providing guidance on the available techniques and methods implemented worldwide for the adaptation of municipalities to climate change. The adaptation measures were evaluated and prioritized with the Multi-criteria analysis (MCA) method against technical, environmental, social and economic criteria.

The evaluation criteria are related to efficiency, environmental friendliness, economic viability and job growth. The measures were evaluated by a number of experts & stakeholders (national, regional, local authorities; neighbouring municipalities and Unions; NGOs & CSOs; companies; academic bodies & research institutes) from Italy, Greece and Cyprus. MCA enabled capturing stakeholder and policy-makers views with a consistent and transparent way.

1.3 Geospatial Databases

The UrbanProof toolkit integrates a large set of European and nation-wide geospatial databases which were used for the assessment of impacts. These databases can be viewed through the toolkit, while there is no need for installing a GIS software. The databases used and their respective sources are presented in the table that follows.

Table 2: Geospatial databases used in the UrbanProof toolkit

Geospatial data	Databases
Climatic data	CORDEX regional climate model (RCM) simulations for the European domain (EURO-CORDEX) database
Population density (urban block resolution)	Urban Atlas database - Copernicus Land Monitoring Service
Population density (grid resolution: 500x500m)	Global Human Settlement (GHS) Population grid (LDS) – Joint Research Centre
Urban trees, urban green areas	Urban Atlas database - Copernicus Land Monitoring Service
Land use	Corine Land Cover - Copernicus Land Monitoring Service
Schools, Hospitals, Cultural units	OpenStreetMap - Open Data Commons Open Database License Geodata.gov.gr
Floods hazard zones	EIONET Reporting Obligations Database (ROD) - European Environment Agency
Soil-hydraulic properties	European Soil Data Centre (ESDAC) - Joint Research Centre
Socio-economic data	Eurostat, National Statistical Services

1.4 Evaluation criteria

In this section, information for the evaluation of the UrbanProof toolkit against a set of additional criteria is provided.

1.4.1 Criterion 1: Level of spatial analysis

The level of spatial analysis of the different information layers presented through maps in Stage 2 of the UrbanProof toolkit is as follows:

- **Hazard/climatic indicators**: The horizontal resolution of the relevant maps is of the magnitude of 12km.
- **Critical infrastructure:** The information on critical infrastructure is presented as points or with a 100m horizontal resolution
- **Flood hazard zones:** The relevant maps have a horizontal resolution of 100m**.**
- **Corine land use indicators**: The Corine land use databases used have an initial horizontal resolution of 100m while they were converted to a resolution of 500m, based on the dominant land use in the area (stage 2 and 5).
- **Population density:** Population density is provided at building block level for the case of the project municipalities and at an analysis of 500x500m for all urban municipalities of the three project countries.

- **Composite impact indicators:** The information provided through maps for the composite impact indicators is given in the same analysis as population density (see above).
- **Socio-economic indicators:** The socio-economic indicators are presented at municipal, regional or national level, depending on the indicator.

- **Background maps:** Open Street maps provide additional useful information in the highest level of analysis, such as roads, municipality boundaries, water bodies, green areas, urban trees etc.

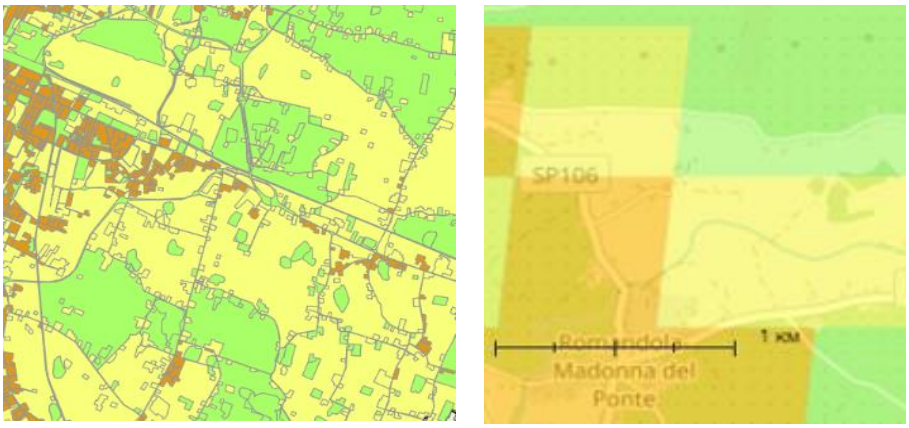


Figure 6: Urban block level resolution (left), 500x500m resolution (right)

1.4.2 Criterion 2: Comprehensibility of the toolkit and its results

With this criterion it is intended to evaluate whether the results presented through the toolkit are comprehensible. Firstly, a distinction is being made in the presentation forms applied, i.e. geospatial form (maps), graphical form (diagrams) and tabular form (tables).

Maps in general present a large amount of information at a geospatial level in a simplified and visually attractive manner. However, the available interface for the presentation of maps is the GIS environment, which, for those not very familiar with such applications, may seem difficult to understand. In particular, it was noticed that not everyone could easily understand which of the selected information layers were depicted at the map.

To this end, a pop-up window opens before entering the GIS environment for providing simple and accurate guidance for using this function. In addition, detailed guidance on the use of the toolkit is provided through the User manual. Furthermore, considering that the terminology used throughout the toolkit has been simplified to the degree possible, but still it would seem difficult to understand by someone not engaged in the relevant fields, explanatory information is provided where necessary next to the terms under the (i) symbols, as well as through the Tab Methods.

1.4.3 Criterion 3: Clear visualization of results

Clear visualization of the results is one of the most important criteria for the evaluation of the tool. For that purpose, special focus was paid on the following issues/features:

a) Logical color coding used in the maps E.g. A common colour scale from green to red was used to signify low to high impact values of indicators.

b) Zoom level capacity of the maps. The information provided through the background maps is available at the 100m scale (1:2133).

In addition, a number of useful visualization features are provided through the toolkit:

a) "Opacity" feature: With this feature the user may adjust the opacity of selected information layers to see the results of more than one indicator at the same time.

b) "Identify" feature: With this feature the user may investigate the exact value for a specific point at the map.

c) "Compare" feature: With this feature the user may see the results for two different emission scenarios or two different indicators at the same time

1.4.4 Criterion 4: Interactivity

As the UrbanProof toolkit is interactive, it enables stakeholders to intervene in the impact and adaptation assessment, so as to incorporate their own views and to personalize the toolkit results.

- For example, in Stage 5 of the toolkit the users may modify the weights assigned to the sub-indices formulating the composite impact indicators.
- Also, local stakeholders may provide their own evaluation on the adaptation measures and the weights of the evaluation criteria, which may be taken into account for the selection of adaptation measures to be included in the local adaptation strategy (Stage 3 and 4 of the toolkit).

Therefore, it supports the participation of stakeholders in the development, consultation and monitoring process of the adaptation strategy

1.4.5 Criterion 5: Data transparency and accessibility

The data presented throughout the toolkit may be assessed through the relevant features of the toolkit for further processing or direct use. In particular:

- The results presented in the form of maps may be downloaded as pictures
- The results presented through the diagrams may be copied from the respective tables located below the diagrams and pasted to an excel file.
- The results presented in Stage 5 of the toolkit may be downloaded as a GIS file.

1.4.6 Criterion 6: Innovation and complementarity

The UrbanProof toolkit for adaptation planning in the urban environment is an **innovative** instrument for providing local decision makers, stakeholders and target groups with access to visual information on climate change, vulnerability and adaptation in the form of maps and graphs and presenting the results, step-by-step, of the whole adaptation process.

Although a number of decision support tools on vulnerability and adaptation have been developed, most of them do not take into account all adaptation stages. Currently there is only one similar application for supporting the assessment of climate change impacts at urban level towards the development of climate action plans, i.e. the Urban Adaptation Map Viewer (UAMV) which is hosted under the Urban Adaptation Support toolkit of the Climate-Adapt Platform. It is considered that the UrbanProof toolkit could provide additional useful information for the urban municipalities and **complement** the UAMV, as:

a) Level of analysis: The available indicators in the UAMV are presented through geospatial maps but at a courser analysis, or as bullets only for the case of cities.

b) Background maps: In the UAMV the background maps show only country boundaries and the location of big cities. In the UrbanProof toolkit, the maps have higher analysis, showing roads, municipality boundaries, water bodies, green areas etc.

c) Dynamic: Several indicators are provided in the form of static maps while the UrbanProof toolkit presents information through dynamic information layers.

d) Multi-dimensional: In the UAMV the indicators are presented separately or by groups of two. In the UrbanProof toolkit, the composite indicator approach is selected. One can always examine however the indicators in isolation.

1.4.7 Criterion 7: Expendability and replicability

The UrbanProof toolkit (except Stage 1) can be readily used by **all urban municipalities (cities, towns and suburbs) of Cyprus, Greece and Italy (~3000)** for the development of their Climate action plans, meaning that all relevant databases are integrated to the toolkit and therefore **the users do not have to insert any data**.

In particular, urban municipalities, as defined within the UrbanProof toolkit, include all the Local Administrative Units level 2 (LAU2 or communes) which are classified as: Cities (densely populated areas) and Towns & suburbs (intermediate density areas). This classification is based on the "New degree of urbanization" adopted by the European Commission (Dijkstra & Poelman 2014). In particular, these two groups are defined as:

- **Densely populated area** (alternate name: cities or large urban area): At least 50% lives in high-density clusters
- **Intermediate density area** (alternate name: towns and suburbs or small urban area) : Less than 50% of the population lives in rural grid cells and Less than 50% lives in a high-density cluster

In numbers this is translated as:

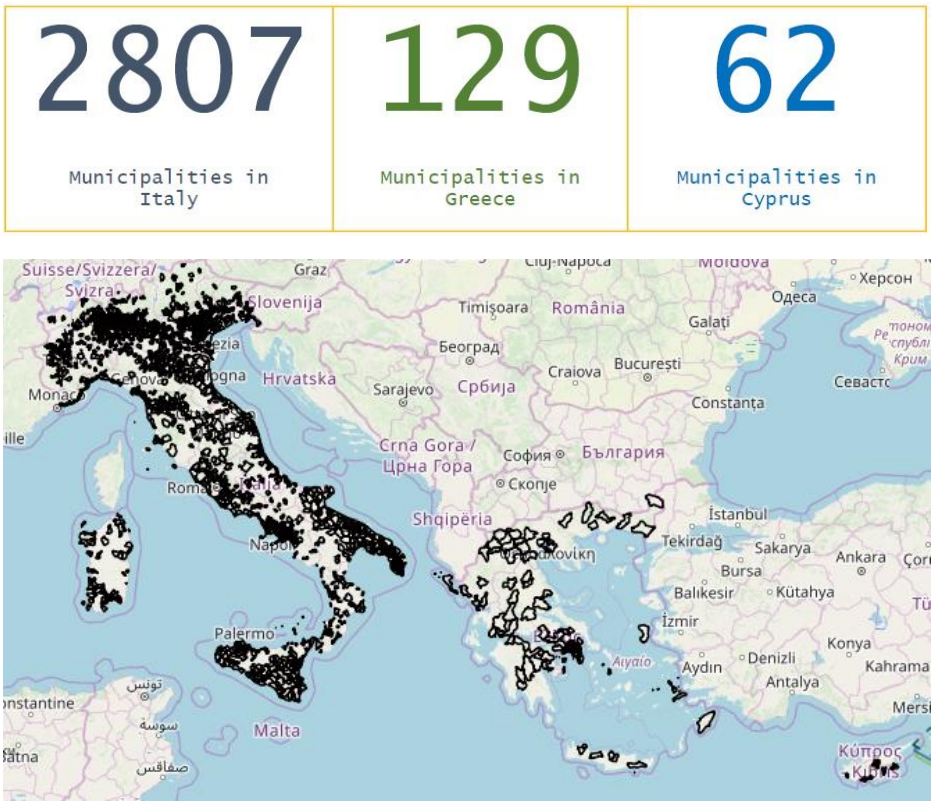


Figure 7: Urban municipalities in Italy, Greece and Cyprus

Taking into account the above, it is considered that the toolkit has an important expendability and replicability potential.

In case there is interest, its databases may be expanded in order to include data from other EU countries. In addition, other climate change impact related indicators can also be added, while the climatic information layers can be enriched with other emission scenarios or future periods. However, for this to be achieved additional funding is required. Considering that the replication potential is at wide European level, EC funding sources can be utilized.

1.5 UrbanProof compatibility with official tools and guidance

1.5.1 Urban Adaptation Support tool

The UrbanProof toolkit is built upon 5 stages which are considered to guide municipalities through the whole adaptation process. The UrbanProof toolkit process is in line with the Urban adaptation process indicated by the **Urban Adaptation Support Tool** of the Covenant of Mayors –Europe Office and the European Environment Agency. See for example Stage 1-5 of the UrbanProof toolkit and Steps 2-6 of the Urban Adaptation Support Tool, in the following figure.

Figure 8: The adaptation process: LIFE UrbanProof toolkit (left), Urban Adaptation Support tool (right)

1.5.2 Guidebook on the development of SECAP

The UrbanProof toolkit is also consistent with the **JRC Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP), part 1 and 2"** (Bertodi et al., 2018)[1]. In particular, the UrbanProof toolkit methodology for elaborating a Climate action plan is fully in line with the respective guidance provided in Part 1 of the JRC Guidebook. In addition, the UrbanProof toolkit is also in line with the methodological approach suggested by the JRC Guidebook – Part 2, for conducting a Risk and Vulnerability Assessment (RVA) for a SECAP.

1.5.2.1 Risk and Vulnerability Assessment methodology

In particular, the Guidebook (part 2) proposes two methodological approaches for conducting an RVA, which differ in the level of detail, required data, tools and technical skills needed to calculate the vulnerability to a specific hazard.

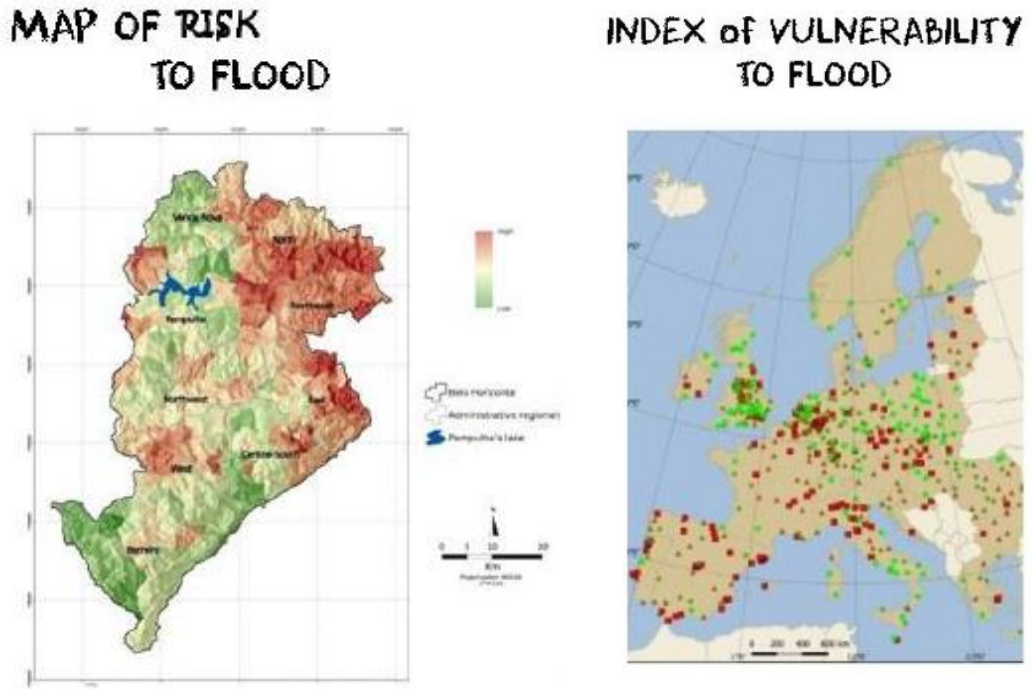
- The **Spatially explicit approach** which relies on climate impact-models to produce hazard maps according to specific climate stressor and city biophysical attributes. Using spatially-explicit

[1] Bertoldi P. (editor), *Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 1 - The SECAP process, step-by-step towards low carbon and climate resilient cities by 2030,* EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96847-1

Bertoldi P. (editor), *Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 2 - Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA)*, EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96929-4

modelling demands technical skills and robust georeferenced datasets, not always available in small and mid-size cities. Therefore, it is most suited for greater local authorities that usually have the necessary resources and capacities to use the models and act on the main outcomes.

- The **Indicator-based assessment** helps users to identify the factors that shape city vulnerability to climate threats through comparable composite indicators. This approach is particularly suitable for smaller and mid-size cities since it doesn't demand particularly technical skills or modelling tools and can be fed by using public available datasets.



Spatially explicit approach **Indicator-based vulnerability assessment**

Figure 9: Examples of the two methodological approaches for RVA proposed in Bertodi et al. (2018)

The UrbanProof toolkit is developed based on the Spatially explicit approach, thus providing highly detailed information for small and medium sized urban municipalities as well, without demanding particularly technical skills or tools, as all the required work has been already carried out for all urban municipalities and is available in a comprehensible form through the UrbanProof toolkit.

Following, the steps for conducting an RVA based on the Spatially explicit approach according to Bertodi et al. (2018) are presented, while next to each step the respective UrbanProof toolkit approach is laid down.

The output of the Risk and Vulnerability assessment carried out in the UrbanProof toolkit is presented in Stage 2 of the toolkit.

Table 3: Spatially explicit approach for conducting an RVA based on Bertodi et al. (2018) and the respective UrbanProof toolkit approach

Steps	Description of the approach in the JRC Guidebook	The UrbanProof toolkit approach
STEP 1: Exploratory analysis with key-stakeholders	Meeting with city stakeholders in order to contextualize the study, understand needs and expectations, identify climate change impacts, explain the RVA approach and the required data	Not covered.
STEP 2: Downscale global climate data to regional context	Downscaling the results of global climate models (GCMs) to high resolution in order to capture the spatial and temporal variability of projected changes in climate at a sound scale for urban RVA.	The outputs of the MPI-ESM-LRRCA4 RCA6 Regional Climate Model were used for the calculation of climatic hazard indicators.
STEP 3: Climate-impact modelling - linking system attributes to climate projections	Use of GIS-based tools to link climatic hazard indicators to biophysical and socioeconomic data. The model output comes in the form of maps representing – for a specific time window and climate scenario – the spatial variability within the urban perimeter of the potential impacts	The geospatial climatic hazard information was linked to other biophysical indicators and socio-economic pathways to produce different maps for the reference and future periods (1971-2000, 2030-2060) for two emission scenarios (RCP4.5, RCP4.8)
STEP 4: Map city vulnerabilities	Each hazard affects different areas within a city, and the consequences depend on specific socioeconomic and institutional weaknesses relevant to the impact at stake.	Development of the Social Vulnerability Index for each municipality, comprising of several socio-economic indicators relevant to the examined impacts
STEP 5: Define Exposure by mapping important assets within the city	Information about the location and properties of relevant city assets, such as buildings, roads, historical monuments, and population density, has to be included into an assets inventory map. This map represents the exposure of the system.	Critical infrastructure (hospitals, schools, cultural monuments, industrial/commercial units, airports/ports, road/rail network) and population density are included in relevant maps
STEP 6: Overlay hazard, vulnerability and asset maps (exposure) to assess the number of assets at risk	The hazard map is combined with the vulnerability map and the assets map (exposure) to quantify the number of assets and vulnerable communities at risk. All the explanatory variables of risk are geo-referenced and normalized to become spatially comparable and aggregable in a weighted index. Finally, the urban risk map is computed by integrating its determinants - i.e. hazard, vulnerability and exposure.	Creation of composite impact indicator maps through the integrated assessment of hazard, vulnerability and exposure indicators by applying the appropriate normalization, weighting and aggregation methods.
STEP 7: Assess the risk (potential loss and damage)	Assess unit damage costs and damage functions for each asset	Not covered.

1.5.2.2 Development of the Climate Action Plan

The JRC Guidebook – Part 1 (Bertodi et al. 2018)[2] suggests that before the development of a Climate Action Plan, municipalities should establish a long-term vision with clear objectives and targets (Chapter 7). The UrbanProof toolkit may support municipalities in this task through Stage 5.

In specific, in Stage 5 of the UrbanProof toolkit, one may explore the potential of the implementation of adaptation measures in increasing the resilience for the municipality towards a climate change impact. Therefore, municipalities may use this Stage to set quantitative targets for reduction of the level of the expected impacts locally, as well as at a wider municipality level, with a set of adaptation actions.

Furthermore, in Chapter 8 of the JRC Guidebook – Part 1 (Bertodi et al. 2018)[2] a list of recommended steps for drafting a successful SECAP is provided as shown below:

i. **Make a prospective of good practices**
ii. **Set priorities and select key actions / measures**
iii. Carry out a risk analysis
iv. Specify timing, clear responsibilities, budget and financing sources of each action
v. Draft the Action Plan
vi. Approve the Action Plan and its associated budget
vii. **Perform regular SECAP reviews**

The UrbanProof toolkit may support municipalities in carrying out the tasks highlighted in bold above, as further explained in the table that follows.

Table 4: Proposed methodology for selecting adaptation measures according to Bertodi et al. (2018) and the respective UrbanProof toolkit approach

Proposed methodology in the JRC Guidebook	The UrbanProof toolkit approach
○ Make a prospective of good practices ○ Set priorities and select key actions / measures: – Conduct a preliminary analysis of the possible actions: what are the costs and benefits of each of them. – Rank the possible measures by importance in a table summarising the main characteristics of each action: duration, level of required resources, expected results, associated risks, etc. – Define which criteria you want to consider for the selection of measures (investment required, energy savings, reduction of climate impacts and related costs, cross-cutting and infra-sectoral benefits, employment growth, improved air quality, relevance to the overall objectives of the local authority, political and social acceptability, timeframe, payback, ¡K) – Decide which weight you give to each criterion. – Evaluate each criterion, measure by measure, in order to obtain a "score" for each measure	○ In Stage 3 of the UrbanProof toolkit, there is a list of adaptation measures for addressing the examined climate change impacts. For each of these measures, information is provided with respect to their philosophy, the expected results and the associated costs ○ A Multi Criteria Analysis application is built for prioritizing adaptation measures based on their evaluation against a set of criteria: efficiency in addressing the impact, environmental friendliness, economic viability, employment growth ○ The users may assign weights to the criteria and evaluate the adaptation measures against each criterion according to their perception of their relevant importance in the evaluation of the adaptation measures. Alternatively, the may use the evaluation provided by a pool of experts. ○ Then in Stage 4 of the UrbanProof toolkit, the adaptation measures are prioritized based on the score they obtained from the MCA evaluation in Stage 3. ○ The measures gathering the higher ratings may be included in the Local Adaptation Plan of the municipality.
○ Perform regular SECAP reviews	○ Stage 5 of the UrbanProof toolkit may be used to track the progress achieved towards the initially foreseen targets and revise if necessary

1.6 External evaluation of the toolkit

The UrbanProof Toolkit was evaluated by the project stakeholders and experts on the field during the toolkit demonstration events and through the evaluation questionnaire. In particular for the latter, a number of stakeholders were selected from a pool of external (unrelated to the project) experts and

potential end-users and were invited to evaluate the technical viability of the tool. The toolkit was evaluated through a specifically designed survey questionnaire which is presented following.

The questionnaire was structured in such a way so as to be able to evaluate the set evaluation criteria. However, as one may not be fully familiar with the toolkit and/or may have not participated in the toolkit demonstration events and/or may have not read very carefully the toolkit manual and methods/glossary, help is provided in each question in the form of gifs. This is believed to make the evaluation of the toolkit easier for the respondents, while minimizing the possibility for misunderstandings in the comprehension of the questions. At the same time, the questionnaire provides for a quick overview of the capabilities of the tool, which can also be regarded as a toolkit demonstration. The questionnaire is available in the three project languages (Greek, Italian, English) through the toolkit website at the homepage menu, tab "Evaluate the tool"

https://docs.google.com/forms/d/e/1FAIpQLScPsb5YI2ZKRhOPz6pmdwcuIhFLytUAmTT_9ivrveaHvs40oA/viewform

The questionnaire is built using the *Google forms* application. It is noted that, to fill the questionnaire using this application, it is necessary that the evaluator signs in with a google account, while only one response is allowed for each google account.

Overall, by the time of the submission of this Deliverable, there were 70 responses to the evaluation questionnaire, 31% in the Italian version, 9% in the English version and 60% in the Greek version.

The overall feedback on the toolkit received by the participants in the demonstration events as well as the individuals that filled in the questionnaire was positive. The vast majority of the stakeholders evaluated positively the toolkit and in particular the set evaluation criteria and stated their belief that there would be quite high interest in replicating the toolkit to other regions. Many positive remarks were made on the usability of the toolkit and its user interface and experience, boosted by the accompanying material. With respect to the actual content, again the feedback was overwhelmingly positive in terms of robustness and plurality of indicators. Constructive criticism was also provided, which, although sometimes stemming from a different perspective than the tool's scope is a testament to the triggering capacity of the tool.

Following, the evaluation questionnaire is presented together with the cumulative statistical analysis results per question while, in Annex I, the statistical analysis provided by google forms for each question of the three UrbanProof toolkit evaluation questionnaires (Greek, English, Italian), is presented.

1.6.1 Feedback on the Toolkit evaluation questionnaire

Question no.1: Is the information presented through the different stages of the UrbanProof toolkit comprehensible?

The responses in this question are considered quite positive as the vast majority of respondents stated that the information provided is comprehensible.

	Yes	No	Total
1.a. Comprehension of information provided in the form of maps, in Stage 2 of the toolkit.	96%	4%	100%
1.b. Comprehension of information provided in the form of diagrams.	100%	0%	100%
1.c. Comprehension of information provided in the form of tables.	94%	6%	100%
1.d. Comprehension of the terminology used.	99%	1%	100%

Question no.2: Do you think that the available climatic scenarios are useful to the development of adaptation strategies?

The responses in this question are considered quite positive as the vast majority of respondents stated that the range of climatic scenarios is useful.

Yes	No	Total
98%	2%	100%

Question no.3: How would you rate the level of spatial analysis' results provided in Stage 2?

The responses in this question are considered quite positive as the vast majority of respondents rated the spatial resolution in all sections as excellent or good.

3.a. Project municipalities. Urban block level resolution.

Excellent	Good	Fair	Poor	Total
49%	47%	3%	1%	100%

3.b. All urban municipalities. 500x500m resolution.

Excellent	Good	Fair	Poor	Total
39%	49%	9%	3%	100%

Question no.4: How would you rate the visualization of the results in Stage 2?

The responses in this question are considered quite positive as the vast majority of respondents stated that the visualization of results is effective.

4.a. Data values have been normalized using a 5-degree scale, where 1 refers to low impact indicators and 5 to high impact indicators. Do you think that the range of classes and the colors used to display the information on the map are practical and understandable?

Yes	No	Total
95%	5%	100%

4.b. Do you find the zoom level capacity of the maps adequate?

Yes	No	Total
96%	4%	100%

4.c. Do you find the "Transparency" feature (right-click on a thematic layer) useful for investigating information at multiple layers?

Yes	No	Total
97%	3%	100%

Question no.5: How would you rate the additional features provided through the toolbar menu of Stage 2? [1: not useful – 5: very useful]

The responses in this question are considered quite positive as the vast majority of respondents stated that the toolbar features are quite useful.

	1	2	3	4	5	Total
5.a. "Info" feature	1%	1%	13%	44%	40%	100%
5.b. "Compare" feature	2%	0%	14%	32%	53%	100%

Question no.6: How would you rate the applicability of the UrbanProof toolkit? [1: very low – 5: very high]

In this question, 91% of the respondents replied that there would be high to very high interest for the toolkit to be applied to other regions and the vast majority of them replied that they believe it is easy to use this function. Therefore, the replies to both questions are considered very positive.

1	2	3	4	5	Total
0%	2%	7%	52%	39%	100%

Question no.7: Do you think that it would be useful to apply the UrbanProof toolkit in other urban municipalities of Greece, Italy and Cyprus to investigate climate change impacts and on the development of adaptation strategies? [1: not useful – 5: very useful]

The responses in this question are considered quite positive as the vast majority of respondents stated that it would be useful to apply the UrbanProof toolkit in other urban municipalities of Greece, Italy and Cyprus to investigate climate change impacts and on the development of adaptation strategies.

1	2	3	4	5	Total
1%	0%	9%	38%	52%	100%

Question no.8: Do you find it easy to use Stage 5 to investigate the effects of adaptation measures to reduce climate change impacts on a municipality? [1: very difficult – 5: very easy]

The responses in this question are considered quite positive as the vast majority of respondents found the use of Stage 5 of the Toolkit in investigating the effects of adaptation measures to reduce climate change impacts on a municipality easy.

1	2	3	4	5	Total
1%	6%	32%	32%	28%	100%

Question no.9: How would you rate the guidance provided throughout the toolkit? [1: Poor – 5: Excellent]

The responses in this question are considered quite positive as the vast majority of respondents found the guidance provided through the toolkit from Good to Excellent.

1	2	3	4	5	Total
4%	4%	15%	38%	38%	100%

Question no.10: How would you rate data accessibility? [1: Poor – 5: Excellent]

The responses in this question are considered quite positive as the vast majority of respondents found the data accessibility from Good to Excellent.

1	2	3	4	5	Total
2%	0%	20%	37%	42%	**100%**

Question no.11: How would you rate the following characteristics of the toolkit:

The responses in this question are considered quite positive as almost 90% or the respondents found each of the examined characteristics to be Good or Excellent.

	Operational ease	Speed and	User friendliness	Interactivity

		response time		
Excellent	50%	30%	39%	49%
Good	44%	61%	48%	40%
Fair	3%	7%	12%	9%
Poor	3%	1%	1%	3%
Total	**100%**	**100%**	**100%**	**100%**

Question no.12: From your experience using the UrbanProof toolkit, what did you enjoy most and what would you recommend for future developments?

In the table that follows the replies received in this question are summarized. The replies are classified to the positive comments, the concerns and the suggestions for the future. It is noted that with respect to the concerns of the evaluators, these mainly refer to inherent restrictions that do not refer to the capacities of the UrbanProof toolkit but to the available means. The suggestions received where indeed very useful and will be taken into account for the future development of the toolkit, based on user-specific requirements.

Positive comments	Concerns	Suggestions
• Very good/useful tool • Very good representation of the overall picture for a municipality • Very useful information • Stage 5 very useful • Exceptional effort for informing climate change adaptation and supporting decisions • Very good level of detail • Holistic approach • User friendliness • Many capabilities • Opportunity for combination of layers • Interesting analyses - graphs - proposals	• The available databases used are not frequently updated • Low resolution of the existing statistical databases • Uncertainties related to climatic data • For the public some details are too scientific which is however, a general problem for such interfaces • Too much information at the same screen • Failure in providing essential support and new information, directly exploitable by the local authorities	• Add more useful information relevant to spatial planning • Add indication on uncertainties • Slightly improved graphics and color selection • Addition of longer-term climatic projections • Projections for the future based on different scenarios and real impact on citizens. • Addition of RCP2.6 scenario • Better resolution in the non-project urban municipalities • Better explanation of the maps' layers (description of the indicators and the scale of values) for the facilitation of the 'GIS surfing'

• Very concrete tool for a correct territorial planning based on certain and technical criteria and not on arbitrary and groundless ones • Focus on the Mediterranean city and its climatic risks		• Wider dissemination, involvement of communities and schools • Further improve interface, user experience

Question no.13: How would you rate the quality of the input data used to evaluate impacts and adaptation capabilities? [1: Poor – 5: Excellent]

The responses in this question are considered quite positive as the vast majority of respondents stated that the quality of input data is Good or Excellent.

1	2	3	4	5	Total
2%	0%	15%	47%	37%	100%

Question no.14: How would you rate the reliability of the toolkit's outputs? [1: Poor – 5: Excellent]

The responses in this question are considered quite positive as the vast majority of respondents found the toolkit's output data reliable.

	1	2	3	4	5	Total
14.a. Evaluation of impacts	2%	0%	12%	48%	38%	100%
14.b. Climatic data	2%	0%	11%	41%	46%	100%
14.c. Evaluation of adaptation measures	0%	2%	13%	38%	47%	100%

1.6.2 Feedback on the short surveys/polls

The UrbanProof toolkit was also evaluated through short surveys/polls conducted in the framework of the toolkit demonstration events and the final project conference. The results of the feedback received are presented next.

- In the question of the short surveys "*Do you believe that the UrbanProof toolkit is useful for assessing climate change impacts at the urban environment and developing local adaptation plans?*" with a rating scale from 1-5 (not useful→very useful) and a total of 140 respondents, we had the following results:

- 100% of the respondents gave rating ≥3 and 96% gave rating ≥4
- the (weighted) average evaluation was 4.8/5.

1.7 Assessment of the economic viability

The methodology applied is considered very cost-efficient since the toolkit is capable of providing impact assessment results for all urban municipalities of Greece, Cyprus and Italy (~3000). In particular, by integrating to the UrbanProof toolkit the relevant databases for all urban municipalities of the three project countries, instead of isolating the respective ones for the four project municipalities (as it was foreseen in the proposal), the toolkit now can be readily used by all these municipalities.

Therefore, the use of the UP toolkit by urban municipalities is expected to save substantial resources, as these municipalities may exploit its results to develop their own adaptation strategy, instead of conducting a climate change impact and adaptation assessment from scratch. Otherwise, the candidate users/municipalities would have to search for, create and load their relevant databases to the toolkit, which would be a quite time-consuming process, requiring skilled personnel from both the municipalities and the project team.

To estimate the cost savings that the use of the UrbanProof toolkit generates, an economic evaluation took place where a comparison was made of the financial resources devoted to the development of the toolkit for conducting the impact assessment for the ~3,000 UrbanProof municipalities of the 3 project countries (in terms of €/municipality) with the financial resources that will be needed for conducting a similar impact assessment without the use of the toolkit. The same exercise was performed for the case of the urban municipalities in non-project countries of the EU-27 and the cost for extending the toolkit databases for including the urban municipalities of these countries as well was estimated.

This comparison allows to conclude if there are significant cost savings, due to the avoidance of the duplication of work already done during the course of the LIFE UrbanProof project for setting up a unified approach and methodology and for providing the means (the UrbanProof toolkit) for applying the approach in order to conduct a new impact and adaptation assessment. Experiences gained and lessons learned throughout the project are also taken into account, since they play an important role in providing precise guidance for conducting only those tasks that are absolutely necessary for conducting a new impact and adaptation assessment. The economic assessment is based on the budget foreseen for the project under the cost categories Direct personnel costs and External Assistance costs.

It must be noted that for the case of the project municipalities, the analysis is carried out in a greater detail compared to the case of the urban municipalities of the 3 countries, where the level of detail is lower and this is reflected in the relevant costs. In any case, the level of detail for all urban municipalities is acceptable, as it satisfies the SECAP reporting requirements of the Covenant of Mayors (2020)[2].

[2] CoM, 2020. Reporting Guidelines. Covenant of Mayors for Climate and Energy Europe

1.7.1 Assessment of costs per Action

Following, a detailed breakdown is made with respect to the activities per action that will have to be repeated. Although the **cost allocation per action may not be 100% realistic, it is believed that a representative overall result** may be provided when considering the sum of all actions.

Action C.1: Recording of the existing situation in the partner municipalities

- Activity C.1.1: Investigation of current climate change impacts and vulnerability. This Activity is advisable to be repeated for any urban municipality, for the 3 project countries as well for every other country of the EU-27.
    - Approximate budget of the Activity: ~25,500€ (6,400€ per project municipality). For the case of other (than those of the project) urban municipalities, a less detailed work may be carried out (e.g. 30% of the budget, ~2,000€ per municipality)
- Activity C.1.2: Spatial and bio-physical mapping. This is an optional step with a very high level of analysis which does not have to take place.
- Activity C.1.3: Recording of the socio-economic profile. The Activity involves the screening of the available socio-economic indicators in the national and European statistical databases and the formulation of the Social Vulnerability index. This task does not have to be repeated in the case of replication. Furthermore, the socio-economic profile has been recorded for every urban municipality of the 3 project countries and compared to the respective European average ones. Therefore, the recording does not have to be repeated for the urban municipalities of these countries but for the municipalities of the remaining 24 countries of the EU-27.
    - Approximate budget of the Activity: ~24,500€, of which 50% (12,300€) is allocated to the recording of the socio-economic profile (~4,100€ per project country).

Action C.2: Simulation of current climate and projection of future changes in climate

This Action was actually broken down into the following tasks:

a. Acquisition of Regional Climate Model simulations and evaluation
    - Approximate contribution to overall budget: 20%

b. Climatic indicators in current climate
    - Approximate contribution to overall budget: 30%

c. Future Projections of climatic indicators based on different emission scenarios
    - Approximate contribution to overall budget: 50%

In the case of the toolkit replication in project countries, task (a) as well as the methodology for calculating the indicators in current climate as well as in future, parts of tasks (b) and (c), do not have to be repeated.

Overall, it can be said that 30% (20,500 €) of the budget for this Action is a saving in the case of the toolkit use to other urban municipalities of project countries. Regarding other EU countries, the investment cost for the expansion of the toolkit databases is ~7000€ per country.

Action C.3: Water-related vulnerability and adaptation assessment

This Action was actually broken down into the following tasks:

a. Formulation of the overall methodology for assessing impacts and adaptation of the methodology for the case of the water-related impacts (water availability, droughts, floods). Development of composite impact indicators.
    - Approximate contribution to overall budget: 20%
b. Assessment of water-related impacts for the project municipalities
    - Approximate contribution to overall budget: 55% (3 assessments in total, the assessments of Strovolos and Lakatamia municipalities were conducted jointly)
c. Identification and evaluation of the available adaptation measures for addressing the water related impacts
    - Approximate contribution to overall budget: 25%

In the case of the toolkit replication, tasks (a) and (c) do not have to be repeated, while task (b) is actually a highly detailed assessment which is not necessary in the framework of the development of Climate Action Plans. Therefore, it can be said that 45% (41,600 €) of the budget for this Action is a saving in the case of the toolkit replication to other urban municipalities of the EU.

Action C.4: Heat-related vulnerability and adaptation assessment

This Action was actually broken down into the following tasks:

a. Adaptation of the overall impact assessment methodology for the case of heat-related impacts (human discomfort, electricity demand for cooling, peri-urban fires, ozone exceedances). Development of composite impact indicators.
    - Approximate contribution to overall budget: 20%
b. Assessment of heat-related impacts for the project municipalities (3 assessments in total, the assessments of Strovolos and Lakatamia municipalities were conducted jointly)
    - Approximate contribution to overall budget: 65%
c. Identification and evaluation of the available adaptation measures for addressing the heat related impacts
    - Approximate contribution to overall budget: 15%

In the case of the toolkit replication, tasks (a) and (c) do not have to be repeated, while task (b) is actually a high detailed assessment which is not necessary in the framework of the development of Climate Action Plans. Therefore, it can be said that 35% (36,000 €) of the budget for this Action is a saving in the case of the toolkit replication to other urban municipalities of the EU.

Action C.5: Development of the UrbanProof toolkit for supporting cities in adaptation planning

In this Action the knowledge developed so far is synthesized into a web-based decision support toolkit for adaptation planning (the UrbanProof toolkit). The UrbanProof toolkit (except Stage 1) can be readily used by all urban municipalities (cities, towns and suburbs) of Cyprus, Greece and Italy for the development of their Climate action plans, while it may also host the databases for other urban municipalities of the EU-27. Therefore, it is considered that the total of the budget for this Action (~157,700€) is a saving in case of replication.

Action C.6: Implementation, optimization and demonstration of the UrbanProof toolkit

Activity C.6.1: Implementation, evaluation and optimization of the UrbanProof toolkit

This Activity may be broken down in the following phases and associated costs: Implementation phase; Optimization phase; Evaluation phase; Other.

Implementation phase: The implementation phase involved the uploading to the toolkit of the relevant databases for all urban municipalities of the three project countries and the application of the impact assessment formulas for the calculation of the impact indicators geospatially. Approximate contribution to overall budget: 30% (~24,500€).

- Replication to the urban municipalities of the project countries: This phase does not have to be repeated and therefore is considered as 100% saving.

- Replication to the urban municipalities of non-project EU countries: This phase has to be repeated as a whole, while the associated costs will be higher in the case of 24 EU countries by a factor of ~2 (~49,000€ for 24 EU countries, ~2000€ per country).

Optimization phase: The optimization phase of the toolkit involved testing of the displayed results, changes to its databases in order to achieve the desired format, improvements in the visualization of results, fixes of operational problems/bugs, improvements in wordings, provision of explanatory information. Approximate contribution to overall budget: 55% (45,000€).

- Replication to the urban municipalities of the project countries: This phase does not have to be repeated and therefore is considered 100% saving.

- Replication to the urban municipalities of non-project EU countries: It is considered that 70% of the costs allocated to this phase could be avoided, as most of this work has already been carried out and will not need to be repeated in the case of a new assessment (45,000€×30%=13,500€ for 24 EU countries, ~600€ per country).

Evaluation phase: The toolkit was evaluated by the project team against the set evaluation criteria, as well as by the project steering committees and other stakeholders and experts. In addition, this phase

involved the evaluation of the technical and economic viability of the tool (current document). Approximate contribution to overall budget: 10% (8,000€).

- Replication to the urban municipalities of the project countries/ non-project EU countries: This phase does not have to be repeated and therefore is considered 100% saving.

Other: Apart from the above, this Activity included the development of a demonstration and tutorial video and of a user manual. This work will not have to repeated and therefore the associated costs are considered a saving in both replication cases. Approximate contribution to overall budget: 5%.

Activity C.6.2: Demonstration of the UrbanProof toolkit

This Activity does not have to be repeated.

C.7. Implementation of selected green and soft adaptation measures

This is an optional Action and does not constitute a prerequisite for a Climate Action Plan.

Action C.8. Development of local adaptation strategies for the partner municipalities

In the framework of this Action, the UrbanProof toolkit was used in order to develop the adaptation strategies for the project municipalities. For each of the selected adaptation measures, the following are defined (i) the responsible department(s) for their implementation, (ii) the implementation timeline, (iii) the funding source and, (iv) the relative objectives, indicators of progress and targets. Before the official submission of the strategies to the Covenant of Mayors, the municipalities also published the draft plans for public consultation.

The budget foreseen for this Action may be divided by 4 to estimate the respective average budget for each project municipality (~21,000€) while this may be further reduced to 60% (~12000€), as the scientific support from academic institutions (NTUA, NOA) is not necessary. This work will have to be implemented as a whole by each municipality.

1.7.2 Overall assessment of economic viability

In the table that follows, the foreseen replication costs relevant to the development and use of the UrbanProof toolkit are summarized. In particular, the costs are classified in two categories:

(i) the costs for the municipalities for developing a Climate Action Plan (CAP) with and without the use of the UrbanProof toolkit (columns A, C and E). These costs may refer both to the work assigned to municipal staff and to third parties.

(ii) the investment costs for developing the UrbanProof toolkit and the expansion of its databases to cover all urban municipalities of the project countries (column B, already invested in the framework of the UrbanProof project) and of the non-project countries

(column D). The later refers to the costs that should be invested at a higher administrative level (e.g. national level) in order to support municipalities in the development of their CAPs. The foreseen costs for the expansion of the toolkit to the urban municipalities of non-project EU countries (column D) is estimated first at European level and then reduced to national level by dividing with the number of non-project EU countries (24 countries).

It is noted that the costs are provisional as they are based on the work effort made by the project team, while a third party could provide a different estimation for undertaking such tasks. In any case, the costs may provide a useful indication of the savings that may be achieved.

Table 5: Assessment of the economic viability of the UrbanProof toolkit in case of replication

		Project countries (3)		**Other EU countries (24)**	
	(A) Development of a CAP without the use of the Urbanproof toolkit (cost/ municipality)	**(B) Development of the UrbanProof toolkit and expansion to all urban municipalities (invested costs for replication, total for the 3 countries)**	**(C) Development of a CAP with the use of the Urbanproof toolkit (cost/ municipality)**	**(D) Expansion of the UrbanProof toolkit to the urban municipalities of other EU-27 countries (investment cost for replication, national level)**	**(E) Development of a CAP with the use of the Urbanproof toolkit (cost/ municipality)**
Action C.1	2,000€ (C1.1) 500€ (C1.3)	- 24,500€ (C1.3)	2,000€ (C1.1) -	- 4,100€ (C1.3)	2,000€ (C1.1) -
Action C.2	N/A	20,500€	N/A	7,000€	N/A
Action C.3	4,000€	41,600€	0€	N/A	0€
Action C.4	4,000€	36,000€	0€	N/A	0€
Action C.5	N/A	157,700€	N/A	0€	N/A
Action C.6	N/A	24,500€ 45,000€ 8,000€ 5,000€	N/A	2,000€ 600€	N/A
Action C.8	12,000€	N/A	12,000€	N/A	12,000€
Total	**22,500€**	**362,800€**	**14,000€**	**13,700€**	**14,000€**

As it may be seen in the table above, the use of the UrbanProof toolkit by a municipality for the development of its CAP may save approximately 40% of the foreseen costs (14,000€ instead of 22,500€). In the case of the toolkit expansion to the urban municipalities of non-project EU countries, the overall savings would be even higher, as the additional investment costs for replication are low considering the very high replication potential (on average ~700 urban municipalities per country).

Another metric that be used for assessing the economic viability of the toolkit, is the critical number of municipalities using the toolkit that will compensate for the investment on its development. This is estimated as follows:

$$N_{municipalities} = \frac{Investment\ cost\ for\ the\ development\ of\ the\ toolkit}{Cost\ savings\ from\ the\ use\ of\ the\ toolkit} = \frac{362{,}800\ €}{(22{,}500€ - 14{,}000€)/municipality} = 42.7$$

Thus, it may be said that approximately 42 municipalities have to use the UrbanProof toolkit for the initial investment to be compensated for. This is relatively low requirement, considering the high replication potential of the toolkit.

1.8 Overall evaluation

The methodology applied for the development of the toolkit for adaptation planning is considered quite successful since it allows for different geospatial information layers to be visualized and to be combined to present total impact assessment results with sufficient spatial differentiation at municipal level. Although there are published results on impact assessments at European and national level, these are of courser analysis thus the results at municipal level are not differentiated. The resolution analysis provided through the toolkit may provide relevant stakeholders with precise information with respect to where the highest impacts are expected and to guide adaptation.

What is more, for assessing total climate change impacts, the composite indicator approach is selected, as composite indices capture the multi-dimensionality of impacts in a comprehensible form and therefore may support practical decision-making processes. The developed indicators encompass all relevant information for the impact assessment according to the relevant conceptual framework presented within the 5th Assessment Report (AR5) of the IPCC (2014), such as climatic hazards, exposure (exposed population, land and/or critical infrastructure), sensitivity (sensitive population groups) and adaptive capacity (capacity of the health care system, economy) indicators.

The UrbanProof toolkit is structured upon 5 interdependent modules/stages which altogether comprise the adaptation process, as this is defined in the **Urban Adaptation Support Tool** (UAST), which is developed by the Covenant of Mayors and the European Environment Agency (EEA). The UP toolkit is fully compatible with UAST and therefore it may provide further support to the municipalities for the development of their local Climate Action Plans, in the framework of the Covenant of Mayors.

The methodology applied is considered very cost-efficient since the toolkit is capable of providing impact assessment results for all urban municipalities of Greece, Cyprus and Italy (~3000). This is considered to substantially increase the replication potential of the toolkit. Therefore, the use of the UP toolkit by urban municipalities is expected to save substantial resources, as these municipalities may exploit its results to develop their own adaptation strategy, instead of conducting a climate change impact and adaptation assessment from scratch. Last but not least, in Stage 5 of the toolkit, the users may investigate the effect of adaptation measures in reducing the expected impacts for the municipality. This stage is evaluated as exceptionally useful by the project stakeholders for the selection of adaptation measures, the setting of targets and the monitoring of the progress achieved. Overall, it can be said that the UrbanProof toolkit has been warmly accepted by the vast majority of stakeholders who have acknowledged its usefulness and its potential for replication and have positively evaluated its features and capabilities.

The most important outcome of the project **replication** efforts is that by integrating to the UrbanProof toolkit the relevant databases for all urban municipalities of Greece, Cyprus and Italy, instead of only the respective ones for the four project municipalities as foreseen in the proposal, the toolkit now can be readily used by all these municipalities. Otherwise, the candidate users/municipalities would have to search for, create and load their relevant databases to the toolkit, which would be a quite time-consuming process, requiring skilled personnel from both the municipalities and the project team. As a result, the majority of the respondents to the evaluation questionnaires/polls conducted stated that they find the UP toolkit very useful and that they are interested in using it for other urban municipalities of Greece, Cyprus and Italy.

Replication vehicles: With that in mind, the project seeks to promote the UrbanProof toolkit through the Covenant of Mayors and its widely established network of Covenant Coordinators. With respect to the latter, they commit to support signatories within their geographical scope in different ways including technical support to develop Sustainable Energy and Climate Action Plans, such as the Cyprus Energy Agency. The toolkit may be transferred to those that provide technical support to municipalities, if there is interest.

2 Replication and transfer plan

In this section the transfer and replication strategy is laid down including a clear set of activities for replicating the toolkit to other municipalities. The process for identifying the necessary activities for promoting the replication of the toolkit has initiated early in the project, with many of these activities actually taking place during and after the toolkit demonstration until the project end, in addition to those activities planned for beyond the project end.

The ultimate aim of the strategy is broken down into (i) the **short-term aim** which foresees the implementation of the proposed UrbanProof toolkit to other urban municipalities of the project countries and (ii) the **long-term aim** which foresees the expansion of its databases to include data from other European countries so as to enable its replication to their urban municipalities.

The project team has placed particularly high emphasis in the replication potential of the UrbanProof toolkit. To this end, a great load of work was directed to maximizing this potential by integrating to the UrbanProof toolkit the relevant databases for all urban municipalities of Greece, Cyprus and Italy - instead of only the respective ones for the four project municipalities as foreseen in the proposal. As a result, the toolkit can now be readily used by all these municipalities without having to insert any data. Otherwise, the candidate users/municipalities would have to search for, create and load their relevant databases to the toolkit, which would be a quite time-consuming process, requiring skilled personnel from both the municipalities and the project team.

In fact, the UrbanProof toolkit (except Stage 1) can be **readily used by all urban municipalities (cities, towns and suburbs) of Cyprus, Greece and Italy (~3000)** for the development of their adaptation strategies/ Climate action plans. The uptake of the toolkit is however strongly linked to the willingness/interest of the municipalities for developing adaptation strategies.

The adaptation strategies are important policy instruments according to the EU Strategy on Adaptation to Climate Change (2013), while the new EU Adaptation strategy (2021) places greater emphasis on them and intends to further improve them. Although their development at local level is not obligatory, the EU Covenant of Mayors, which has as signatories the majority of urban municipalities in Europe, foresees the development of Climate Action Plans (CAP) by the municipalities.

Therefore, the project replication efforts were focused on creating links with the Covenant of Mayors and its representatives in Europe (i.e. the Covenant Supporters and Coordinators[3]), as it is believed that the

[3] ***Covenant Supporters**: not-for-profit organisations (associations of local and regional authorities, networks, local and regional energy agencies…) with the capacity to promote the Covenant of Mayors and to mobilise and support their members and/or local governments to reach the Covenant of Mayors' objectives.*

***Covenant Coordinators** can commit to support signatories within their geographical scope in many different ways including promotion of the Covenant of Mayors, technical and/or financial support to develop and implement Sustainable Energy and Climate Action Plans, networking activities involving the Covenant*

urban municipalities may be significantly supported for the development of well-informed, science-based Climate Action Plans with the use of the UrbanProof toolkit. In specific, critical geospatial information enabling spatially differentiated results at municipal level may be exploited through the toolkit.

2.1 Creation of links with the Covenant of Mayors

To create solid links with the Covenant of Mayors, the following activities were implemented:

- **Ensuring consistency and compatibility with the EC standards.** The UrbanProof toolkit process was structured from the beginning upon the Urban adaptation process indicated by the Urban Adaptation Support Tool of the Covenant of Mayors –Europe Office and the European Environment Agency. The UrbanProof toolkit is also consistent with the JRC Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP), part 1 and 2" (Bertodi et al., 2018)[4]. In particular, the UrbanProof toolkit methodology for elaborating a Climate action plan is fully in line with the respective guidance provided in Part 1 of the JRC Guidebook. In addition, the UrbanProof toolkit is also in line with the methodological approach suggested by the JRC Guidebook – Part 2, for conducting a Risk and Vulnerability Assessment (RVA) for a SECAP.

- **Guidelines were developed** for supporting municipalities in the development of their Climate Action Plans with the use of the UrbanProof toolkit. The guidance is in accordance with the Reporting guidelines of the EU Covenant of Mayors (2020). See Annex II of the replication and transfer plan (current document).

- **Demonstration of the UrbanProof toolkit and of the relevant supportive material (guide, user manual, tutorial video, etc.).** All urban municipalities in the 3 project countries and especially the associations of municipalities and other relevant networks of local authorities that collaborate with the municipalities, e.g. in the framework of the Covenant of Mayors, were invited to participate to the demonstration events of the UrbanProof toolkit and to the final project conference.

- **Direct investigation of the willingness/interest of stakeholders for using the UrbanProof toolkit** through specialized polls and questionnaires. Follow-up actions were undertaken in the case of positive feedback.

- **Dissemination of the UrbanProof toolkit through the Covenant of Mayors (CoM).** The UrbanProof toolkit was communicated to the CoM personnel, who stated that they find the

[4] Bertoldi P. (editor), *Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 1 - The SECAP process, step-by-step towards low carbon and climate resilient cities by 2030,* EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96847-1

Bertoldi P. (editor), *Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 2 - Baseline Emission Inventory (BEI) and Risk and Vulnerability Assessment (RVA)*, EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96929-4

UrbanProof toolkit very relevant and useful for the local authorities and that they would be glad to promote it through their communication channels. So far, the UrbanProof toolkit and the Guide for the development of CAPs was published in a relevant blog article of the CoM, and the project final conference was announced under the events section of the CoM, while more promotional activities will take place in the future, as stated by them.

- **Dissemination of the UrbanProof toolkit through the** Climate-ADAPT platform of the European Environment Agency.

- **Direct communication with selected Covenant supporters and coordinators** in the three countries took place in order to promote the UrbanProof toolkit within their geographical scope and/or to their members/local governments. So far, the Climate-KIC in Cyprus, the Central Union of Municipalities of Greece, the Region of Central Macedonia and the Technical Chamber of Greece, have stated their willingness for promoting their tool through their network, have published information on the toolkit at their websites and stated their intention in inviting the project team to events that will be organized by them in the future in order to demonstrate the toolkit to its network.

- The toolkit was **used by postgraduate students** for conducting impact assessments and developing adaptation strategies for the municipalities of Alimos and Metamorphosis, in the framework of two master theses in NTUA.

2.2 Creation of links with other relevant initiatives/organizations

The UrbanProof toolkit was also promoted through other links and communication channels in the three project countries.

2.2.1 Greece

The project established links for replication and transfer with other relevant initiatives and stakeholder organizations/authorities in Greece.

1. In the framework of the LIFE IP "AdaptInGR" the following activities for the replication of the UrbanProof toolkit are foreseen:

- The project team of Green Fund is willing to organize an event for the demonstration of the UrbanProof toolkit to the five partner municipalities of AdaptInGR (Agioi Anargiroi-Kamatero, Katerini, Komotini, Larisa, Rodos), where the partner municipalities of the project Circular Greece could also participate.

- The UrbanProof toolkit will be demonstrated in one of the Regional Thematic Workshops to be organized.

- The toolkit will also be included in the Hub for climate change adaptation in Greece that will be implemented by the Natural Environment & Climate Change Agency.

2. The UrbanProof toolkit results will also be exploited by LIFE ASTI. In the framework of Action C.7 "Local Pilot Actions", the UrbanProof tool will be used to visualise the impact of the adaptation strategies to the urban microclimate of Thessaloniki. For such purpose, a downscaling algorithm will refine the resolution of the outcome from the climate models used under the LIFE-ASTI project. The results will refer to at least the present climate exhibiting the microclimate of regions of the city before and after the adaptation strategies.

3. The department of Environmental Inspection of the Ministry of Environment and Energy has also expressed its interested to explore the potential for exploiting the UrbanProof toolkit features and has invited the project team to present it. Other departments of the Ministry will also be invited to attend as it is believed that they would also be interested in the toolkit.

4. The toolkit is promoted through the Climate-KIC in Greece, while its use in the municipalities of its network in Northern Greece is under examination.

2.2.2 Cyprus

1. The Cyprus Energy Agency which is a Supporter of the "Covenant of Mayors" and has undertaken the SECAPs for 40 local authorities in Cyprus, is interested in using the toolkit for the preparation of the Climate Action Plans. To this end, raining seminars were

More contacts and meetings were made to promote this and to provide support where necessary.

2. The UrbanProof toolkit has provided valuable data, in order for the municipalities of Strovolos, Lakatamia and Nicosia to proceed with the drafting of a masterplan for Pediaios River and its linear park.

3. The Municipality of Strovolos, along with Cyprus Energy Agency, is working on another Project of Nature Based Solutions at the linear park, where output from the UrbanProof Project will be utilized.

4. MADRE will suggest the use of the toolkit for the development of local adaptation strategies to the other urban municipalities of Cyprus as well, through a relevant provision that will be included in the annual revision of the National Action Plan for Adaptation (in 2022).

2.2.3 Italy

Thanks to the UrbanProof project, a new LIFE project has been developed with Reggio Emilia involved as partner: the LIFE CITYAdap3 project. The project represents the logical continuation of UrbanProof as it is aimed at implementing the Local Adaptation Strategy through partnerships with local businesses. Thanks to the CITYAdap3 project, 18 local companies have been already involved and the Municipality is launching a pilot action on adaptive parks based on the analyzes and studies conducted within the UrbanProof framework. The UrbanProof project and toolkit will be presented to the municipalities of the LIFE project Cityadap3. The strategy and the project results will be employed during the project. During the events of Cityadap3 the project will be illustrated also to the local stakeholder group which will be involved in the Adaptation Strategy of Reggio Emilia.

2.3 After LIFE activities

In addition to the above indicated activities for the replication and transfer plan that took place in the course of the Urban Proof project, a number of additional replication and transfer activities is foreseen to take place after the project end, i.e. After-LIFE. These are presented following:

1. Submission of proposals for project funding from EC financial instruments (Horizon, LIFE, Interreg etc.) and national funds. In particular, NTUA and NOA intend to include in future relevant proposals the upgrading of the UrbanProof toolkit so as to incorporate information for more indicators, more emission scenarios, more countries and/or higher analysis climatic resolution.

2. Sign contracts with municipalities of the 3 countries for the development of their Climate Action Plans with the use of the UrbanProof toolkit. NTUA, NOA and IUAV through the contacts and collaboration they have with municipalities, may undertake the development of their Climate Action Plans.

3. Demonstration of the UrbanProof toolkit and project to events organized by the project partners and 3rd parties in the project and other countries. All partners will continue to promote the use of the toolkit to relevant occasions.

4. Technology transfer to those that provide technical support and consulting services to municipalities for the development of their SECAPs (on demand). This involves the transfer of the toolkit server to another server, or, the provision of access to other entities, in order to enable third parties to edit the toolkit databases and features. The terms of transfer may be defined based on the interests of individual parties.

5. Technical assistance and training seminars to potential users of the URBANPROOF tool (on demand). The assistance and seminars will be provided by NTUA and NOA in Greece and Cyprus and IUAV in Italy.

6. Tool demonstration and training for higher education students. NTUA and IUAV will present the UrbanProof toolkit through lectures and will also assign master thesis on the use of the toolkit.

7. Promotion of the toolkit to the network of the project consortium and investigation of their willingness for uptake.

Annex I – Feedback on evaluation questionnaires

In this Annex, the statistical analysis provided by google forms for each question of the three UrbanProof toolkit evaluation questionnaires (Greek, English, Italian) is presented.

D.X.X: TITLE

Beneficiary Responsible:
Authors:

Annex II – Guidance for developing Climate Action Plans with the use of the UrbanProof toolkit