forecAsting System for urban heaT Island effect

“Implementation of a forecAsting System for urban heaT Island effect for the development of urban adaptation strategies” (LIFE ASTI)

Action C.8 **Replicability and transferability**

C.8.1 **LIFE ASTI Replication Guide (LARG)**

Athens June 2022

The project Implementation of a forecAsting System for urban heat Island effect for the development of urban adaptation strategies - LIFE ASTI has received funding from the LIFE Programme of the European Union”.

www.lifeasti.eu

Table of contents

Document Information	
Grant agreement number	LIFE17 CCA/GR/OOO108
Project acronym	LIFE ASTI
Project full title	Implementation of a forecAsting System for urban heaT Island effect for the development of urban adaptation strategies
Project's website	www.lifeasti.eu
Project instrument	EUROPEAN COMMISSION - European Climate, Infrastructure and Environment Executive Agency (CINEA)
Project thematic priority	Climate Change Adaptation
Deliverable type	Report
Contractual date of delivery	31/12/2020
Actual date of delivery	31/08/2022
Deliverable title	LIFE ASTI Replication Guide
Action	C.8 Replicability and transferability
Authors	V. Akylas, E. Androutsou, S. Argentini, F. Asta, T. Belalidis, G. Casasanta, F. De' Donato, P. Karkavitsas, A. Kelesis, D. Melas, G. Mavrellis, N. Liora, M. Pahoula, G. Papadaki, G. Papastergios, D. Parliari, E. Pavlidou, I. Pothitaki, I. Savvaidou, P. Symeonidis, P. Tzoumaka, I. Tsikoti, F. Vagena

Version History

Issue Date	Version	Author	Partner
30-02-2022	V.1	G. Mavrellis, M. Pahoula, G. Papadaki, P. Symeonidis	GET
31-06-2022	V.2	V. Akylas, E. Androutsou, S. Argentini, F. Asta, T. Belalidis, G. Casasanta, F. De' Donato, P. Karkavitsas, A. Kelesis, D. Melas, G. Mavrellis, N. Liora, M. Pahoula, G. Papadaki, G. Papastergios, D. Parliari, E. Pavlidou, I. Pothitaki, I. Savvaidou, P. Symeonidis, P. Tzoumaka, I. Tsikoti, F. Vagena	GET, MoT (& LEVER S.A.), AUTh, ISAC-CNR, SYMRAXIS, DEASL

Executive Summary

The LIFE ASTI project focuses on addressing the impact of Urban Heat Island (UHI) effect on human mortality, by developing and evaluating a pilot system of numerical models that results to the short-term forecasting and future projection of the UHI phenomenon initially in two Mediterranean cities: Thessaloniki (Greece) and Rome (Italy). Also, the cities of Heraklion, Pavlos Melas (Greece) and Civitavecchia (Italy) were added during the implementation period of the project.

The UHI phenomenon has an impact on human health, which is intensifying as the duration of the heat wave episodes is expected to increase due to climate change. The rate of urbanisation has become alarming in recent years: almost 73% of Europe's population lives in cities, a figure which is expected to reach 80% by 2050. Extensive urbanisation is triggering significant changes to the composition of the atmosphere and the soil, resulting in the modification of the thermal climate and the temperature rise in urban areas, compared to neighbouring non-urban ones.
The modeling system, which was developed in the framework of the LIFE ASTI project, produces high-quality forecasting products, such as bioclimatic indicators, heating and cooling degree days, assessing the energy needs of buildings. In addition, it guides the Heat Health Warning System to be implemented in both cities and aims at informing the competent authorities, the general population and the scientific community.

LIFE ASTI, as a LIFE funded project maintains an effective and uncomplicated management. The beneficiaries integrate the respective tasks and communication with prompt processes. All procedures are simple and direct on a reasonable level.

This document addresses the LIFE ASTI Replication Guide (LARG) (action C.8), which consolidates the experiences and knowledge gained during the implementation of the project into a step-by-step guide that facilitates the replication of the projects’ products to other urban areas.

The goal of the replicability and transferability guide is to multiply the impact of the Project results and to replicate and transfer its findings after its end, in order to reach a wider audience and implement its results in further cities and regions, other than the Project demo cities.

I Project Overview & Objectives

LIFE ASTI objectives promote the EU policies for "Climate Action" and also have a high impact in many fields of other EU policies. First of all, they contribute directly to the improvement of EU citizen's quality of life, favouring this way the "Regional Policy" for regions and cities in the European Union. Secondly, they help to deliver "Research and Innovation" policy objectives, as one of the primary project's targets is the open access dissemination of scientific results by sharing all available knowledge with regional/local authorities and the general public.

The specific objectives of LIFE ASTI project were:

- To design, implement, pilot and validate a set of UHI forecasting systems in Thessaloniki and Rome, based on state-of-the-art numerical models. These modeling systems provide stakeholders with several UHI-related, high-resolution forecasting products, including thermal bioclimate indices, as well as Heating and Cooling Degree Days to estimate the energy demand of buildings. Furthermore, they drive the Heat Health Warning Systems that were developed and operationally tested in both cities (Thessaloniki & Rome), helping the local authorities to react appropriately to extreme events.
- To establish dissemination tools and allow open access to UHI-related information and products to the end-users with Information and Communication Technology (ICT) applications. These tools help the concerned authorities and the general public to fill the knowledge gap on local climate vulnerabilities and risks
- To assess the impact of future climate change scenarios on UHI for the two selected cities.
- To evaluate the impact of promoting green activities (e.g., green roofs, ventilation areas, etc.) in urban areas to combat the UHI effect using the developed modeling systems for the two selected cities.
- To develop good practice guides and efficient strategic plans for mitigating future UHI effects in the involved cities, as well as in other EU urban areas which face the same UHI adverse impacts.
- To raise awareness and encourage authorities to apply the above urban adaptation strategies and mitigation initiatives. This will contribute and support the Signatories' commitment to "Mayors Adapt" and "Covenant of Mayors"
- To organize events to promote, replicate and transfer the designed modeling systems and the best urban adaptation strategies to other European cities that face the same climate issues arising from UHI effect. As a results of the promotional actions, the cities of Heraklion in Crete, of Pavlos Melas in Central Macedonia and of Civitavecchia in the Lazio Region were areas where the LIFE ASTI forecasting platform was replicated during the implementation period of the project.

The above mentioned objectives lead to a substantial contribution to the overall aim of the EU Adaptation Strategy by developing policies for a better adaptation to UHI impacts, especially during summer heat waves, reducing the heat wave risk in metropolitan areas by introducing heat prevention services, and better-implementing energy efficiency guidelines in European cities.

The combination of socio-economic, environmental indicators, with additional more context-specific considerations allows the replicability and transfer of the results, knowledge and best practices. As a result, other urban as well as rural areas can adapt and implement this project in their local context and increase their resilience to heat waves and other climate-related impacts.

II Project Results

The information provided by LIFE ASTI contains high resolution UHI-related forecasting products, including thermal bioclimatic indices and Heating/Cooling Degree Days (HDD/CDD) to estimate the energy demand of buildings, as well as heat health warnings in each involved city. This kind of information allows environmental protection, the prevention of heat-related deaths and sustainable urban development, in accordance with the LIFE Regulation (Regulation (EU) No. 1293/2013) and the objectives of EU Commission Communication EU Strategy on adaptation to climate change (COM/2013/0216). Furthermore, the distribution of the information mentioned above is provided through open access ICT tools anticipating the implementation of EU Directive 2003/4/EC on public access to environmental information

Therefore, the LIFE ASTI project resulted both in short term and in long term adaptation tools but also contributes significally to the EU adaptation strategy.

A. **Short – Term Adaptation Tools**

   a. <u>Pilot UHI forecasting systems in five cities (Thessaloniki, Rome, Heraklion, Pavlos Melas and Civitavecchia) providing high-resolution (250 m) UHI-related products, including thermal bioclimate indices and Heating/Cooling Degree Days (HDD/CDD).</u>

The Weather Research Forecast (WRF) modeling system, coupled with the Single Layer Urban Canopy (SLUCM) has been running since June 2019 at the Aristotle University of Thessaloniki (AUTh), with a series of shell scripts developed by the AUTh team for the automated download of the initial/boundary conditions and its daily operation. This process' output files contain several meteorological factors, such as temperature, wind speed, precipitation, short-wave radiation etc., which are required for the derivation of the UHI related products, enabling their addition in future versions.

The operational UHI forecasting system (UHI-OFS) has been employed automatically through a structured system of scripts, which operate continuously at AUTh's IT infrastructures. The pilot operational UHI forecasting system consists of two main components: a) the implementation of WRF-SLUCM modeling system and b) the Post-Processing Tools (PPT). The output is retrieved automatically from the LIFE-ASTI platform and the results are available on the project's website and mobile application. An overview of the UHI-OFS is illustrated in Figure 1.

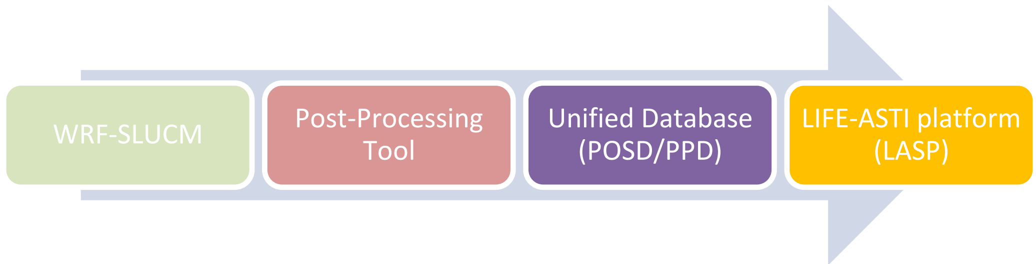


Figure 1. Overview of the operational UHI forecasting system.

b. Heat Health Warning Systems providing differential alerts within each involved city and the potential effects on health at high spatiotemporal resolution (at district level for each city).

Heat health warning systems (HHWS) are one of the core elements of a heat adaptation plans as defined by World Health Organisation (WHO) Guidance. Heat warning systems serve as tool on which prevention and emergency measures should be modulated, based on the severity of risks. Heat warning systems are different from a weather forecast of heatwave event; they identify temperatures that are harmful for the populations' health. In this case, the association of temperatures to increased mortality are considered, during observed times series of temperature and daily mortality data.

Thresholds and warning levels are set based on specific health risk thresholds (increases in daily mortality). HHWW models ran in test mode in 2019 and became operational in the summer of 2020. Forecasts meteorological data produced by AUTh are used to define the Heat Health Watch Warning Systems (HHWWS). Model outputs are shared and made available for AUTh, GET and DEASL. Then they are reported in the LIFE ASTI platform and are made available for anyone via the web and the mobile application.

c. A web-based open access portal and a mobile application to disseminate the above-mentioned forecasting products to authorities, stakeholders and the general public.

The LIFE ASTI system platform is a collection of IT software and applications that provides access to the information produced in the project.

The web application provides access to the information produced by the LIFE ASTI forecasting system (meteorological models and health warning system) for Rome, Thessaloniki, Heraklion, Pavlos Melas and Civitavecchia. The application is available at: https://app.lifeasti.eu/

It provides an overview of the forecast data in city neighbourhood level. Daily averages or maximum values of selected parameters are used in order to define the magnitude of the UHI. A simple colour scale is used for the visualization of the thermal stress. In addition, an expert panel provides maps and graphs of the spatial and temporal variation of UTCI, temperature and humidity

d. A concrete replicability and transferability guide (LARG) that supports the LIFE ASTI results to be utilized by authorities and stakeholders of other regions in Europe.

The integration of UHI and HHW forecasting alerts in extreme heat conditions, identifying UHI hotspots where the application of soft adaptation (e.g. air-conditioned rooms) measures are prioritized. The pilot application of the systems led to the following in Thessaloniki, Rome and Heraklion (first replication city).:

- increase of local/regional adaptation initiatives
- increase resilience to heat
- reduction of heat attributable deaths
- improved quality of life support

B. Long-term adaptation tools and contribution to EU adaptation strategy

a. Assessment of the impact of future climate change scenarios on UHI,
b. Sensitivity studies for assessing the impact of adaptation strategies (e.g., green infrastructure)

The LIFE-ASTI programme focuses on UHI variables such as temperature, heating/cooling degree days and UHI intensity. Action C4 had a two-fold objective: (a) to provide an assessment of the impact of future climate change scenarios on UHI for the two Mediterranean cities (UHI-FCAR) and (b) to assess and quantify the outcome of promoting mitigation measures in the cities to reduce/hinder the UHI effect (UHI-ASAR).

The two initial Mediterranean cities (Thessaloniki and Rome) were selected to provide a representative geographical coverage of the UHI issue, to reflect different environmental conditions and to support one of the EU's most important political priorities for joint effort and transnational cooperation.

For Thessaloniki (domain d03), the annual average temperature for the reference period is around 17.5°C. The expected temperature increase is of 1°C and ~3.5°C for the periods 2046-2050 and 2096-2100 respectively. In the greater area of Thessaloniki, it can be noticed that the south-eastern regions located further from the coastline (>6km) indicate higher temperature increases compared to the north-western regions during summertime.

A comparison is made between three urban and two non-urban reference points, to represent the centre of the city and the ambient rural areas. On average, by the year 2050 (2100) in the five selected points the temperature is expected to increase by 0.8°C (2.7°C), 0.6°C (3.7°C), 1.3°C (4.1°C) and 1.7°C (4.2°C) in winter, spring, summer and autumn, respectively.

Regarding energy consumption, energy demand for heating will decrease in winter and cooling degree days (CDD) will increase in the summer. The winter average heating degree days (HDD) for the reference period is 5-7°C, which is expected to decrease by 0.85°C and 2.6°C by the year 2050 and 2100. However, looking at the summer average CDD during the reference period, this parameter fluctuates between 3-5°C over the urban area of Thessaloniki. The footprint of the city differs by 2°C or more from the areas around it. By 2050, CDD are expected to increase by 1.2-1.5°C, while by the year 2100, this increase will reach 4-4.4°C. It should be highlighted that the eastern regions of the city demonstrate the highest increase.

The apparent temperature (TAPP) is calculated for the typically warmer month of the year (July) for d03 as a function of temperature (T in °C) and dew point temperature (Tdew in °C) to represent the thermal discomfort of local populations.

On average, in d03, TAPP will increase by 2-3°C and 4-5°C by 2050 and 2100 respectively both during early morning and early afternoon in July. However, lower ground areas will have higher TAPP (~+0.5°C) compared to ambient elevated regions.

In Thessaloniki, major increases are expected at the very west and east parts, and especially at the south-eastern parts.

For Rome (domain d04), the annual average temperature for the reference year is around 17°C. The expected temperature increase is 1°C and ~3.4°C for the periods 2046-2050 and 2096-2100 respectively. The largest temperature increases are expected in summer (+1.4 and +4°C) and the lowest during winter (+0.5 and +2°C, respectively). Focusing on the greater area of Rome, it can be noticed that the further the distance from the sea, the higher the future temperature increase is. The temperature increase difference between a western region (by the sea) and east of Rome is on an annual basis approximately 0.3°C and 0.7° for the periods 2046-2050 and 2096-2100, respectively. The largest differences between west and east are observed during summer and autumn (up to 0.7°C), while the lowest ones (0.3°C) are noticed during winter and spring for the period 2046-2050. However, during the period 2096-2100, the temperature increase difference is greater for spring, summer, and autumn (0.7-1°C), while in winter the difference remains low (~0.3°C).

A comparison is made between three urban and two non-urban reference points, to represent the centre of the city and the ambient rural areas. On average, by 2050 (2100), the temperature is expected to increase by 0.5°C (2°C), 0.4°C (3.7°C), 1.2°C (4°C) and 1.4°C (3.6°C) in winter, spring, summer and autumn respectively in the five selected points.

During the reference period in the night and morning, the average UHI intensity is ~2-2.5°C (~1-1.5°C) between urban and west (east) reference points through the entire year. However, in the afternoon, the UHI effect between the urban and the eastern reference points is practically eliminated, whereas between the urban and west remains at ~2°C almost throughout the whole day. Regarding future periods, there are no significant changes in the UHI effect except in spring, when the UHI intensity seems to be slightly enhanced (by 0.2-0.3°C) in the afternoon.

Energy consumption for heating will decrease in winter and CDD will increase in the summer. In particular, the winter average HDD for the reference period is 4-6 degree days, which is expected to decrease by 0.5 and 1.8 degree days by the year 2050 and 2100 in Rome and the surrounding regions. CDD during the reference period is ~3-4 degree days, increasing by 1.1 and 4.1 degree days by 2050 and 2100, respectively.

In the present climate, TAPP presents increased values (24-26°C) close to the sea and lakes early in the morning, while in the afternoon maximum TAPP (~32°C) is observed in low ground regions far from the sea. The central and northeaster parts of the city of Rome exhibit the highest TAPP (24°C and 32°C respectively). Although TAPP for the entire domain will increase on average by 2-3°C and 4-5°C by 2050 and 2100, respectively, in lower ground areas TAPP increase will be more intense (by ~+0.4°Cto +1°C) than in elevated regions. The city of Rome exhibits the largest increases, +2.6°C and +5.6°C by the middle and the end of the century.

These assessments led to the construction of:

c. UHI Adaptation Actions Plans Portfolios for each city
d. Good Practice Guidebook for combating UHI and increasing resilience to heat

The LIFE ASTI project significantly contributes to the overall objective of the EU Adaptation Strategy by developing policies to better adapt to the effects of UHI, especially during the summer heat waves. This is achieved by reducing the risk of heat waves in metropolitan areas, through the introduction of heat prevention services and the improved implementation of energy efficiency guidelines in European cities.

The implementation of operational UHI forecasting systems and the effective dissemination of focused information with the use of ICT tools successfully strengthen cities' adaptive capacity to climate change, and successfully address the issue of the UHI effect and its impacts. Within this context, atmospheric models can be a valuable tool for providing accurate spatiotemporal information with a high level of detail on UHI effect and assisting the application of heat health warning systems (HHWS).

The action plans, and guides further contribute to the development of:

- Sustainable Energy and Climate Action Plans (SECAPs) under the new Covenant of Mayors (2030) in both cities
- Regional Adaptation Actions Plans in both cities
- Actions in the framework of 100 resilient cities initiative in Thessaloniki contributing this way to: **improved thermal bioclimate conditions in the areas applied**
- Actions in the framework **"Thessaloniki – Climate Neutral and Smart Cities by 2030"**

Additionally, communication and dissemination actions:

- raise awareness of the general public,
- increase knowledge, skills and competences of policy makers
- contribute to the research of the scientific community

It is worth mentioning that the system has also been replicated and transferred to the municipalities of Pavlos Melas (Greece) and Civitavecchia (Italy) during the last months of the project. The pilot application of the systems and the long-term adaptation tools for these municipalities will be evaluated during the AFTER LIFE period of the LIFE ASTI project.

III What to Transfer & Replicate

i. LIFE ASTI Replicable Products

Replicability and transferability were and still are one of the primary objectives of LIFE ASTI. From the beginning of the project, the concept, the modeling methodology, the forecasting systems and the dissemination tools were designed as a modular, easily adaptable and implementable solution for any urban area where public heat information is vital.

The ultimate aim of the replicability strategy is broken down into (i) **the short-term aim** which foresees the implementation of the LIFE ASTI UHI Forecasting System to other urban municipalities of the project countries and also the utilization of the tool for increasing resilience to heat at regional/local scale for the cities that already have it and (ii) the **long-term aim** which foresees the expansion of its forecasting models to other domains to include cities from any other country in Europe, but also to utilize the produced UHI Adaptation Actions Plans and Policy Guides through the introduction of heat prevention services and the improved implementation of energy efficiency guidelines in European cities. This kind of information allows environmental protection, the prevention of heat-related deaths and sustainable urban development, in accordance with the LIFE Regulation.

The LIFE ASTI project has a set of four clearly defined outcomes that can be replicated and transferred to other cities, Municipaliteis and Local authorities.

- The first clear outcome that can be replicated is the **UHI Forecasting System** itself providing high-resolution (250 m) UHI-related products, such as thermal bioclimate indices and Heating/Cooling Degree Days, including also the related deliverables that are describing the Methodological Report on UHI Forecasting Systems and the UHI Operation Forecasting Systems Manual (UHI-OFSM). The pilot operational UHI forecasting systems have a very high transferability potential, initially simulating weather conditions in the continental base (Mediterranean) to provide Initial and Boundary Conditions to the regional simulations with higher spatial resolution over Greece, Italy and potentially to other Mediterranean countries.

- The second clear outcome that can be replicated is the **Heat Health Warning Systems** providing differential alerts within each involved city and the potential effects on health at high spatiotemporal resolution, including also the related deliverables such as the Heat Health Warning Systems Manual (HHWSM).

- The third outcome that can be replicated are the **LIFE ASTI System Platform** and **Web Application**. These are a collection of IT software and applications that provide access to the integrated information provided by the UHI Forecasting and the Heat Health Warning Systems. The implemented solution consists of an online application platform that disseminates information to the authorities and the public. The platform is based on Free Open-Source Software and manages information derived from predictive meteorological models, meteorological stations, and satellite data. The information is disseminated through a web application, but also through a mobile application. The goal of the solution is to inform the authorities and citizens about Extreme Heat Phenomena as well as the effects of the Urban Heat Island Effect, providing direct and easy access to the data in the form of interactive maps and graphs. All generated data is accessible via web services and can be leveraged by third-party applications using the provided web services. The application offers an online form to search for metadata of services and how to access them (Catalogue Service for the Web – CSW).

- The fourth outcome that can be replicated and transferred is in fact the bundle of deliverables concerning the Good Practice Guidebook for combating UHI and increasing resilience to heat, the UHI Adaptation Actions Plans Portfolios developed for Thessaloniki and Rome, and the Policy Guide which addresses competent authorities and stakeholders from various sectors (e.g., health, energy, etc.) at the National and EU level where there are urban areas in need of counteracting UHI and preventing the general public from heat-related health problems. They indicate the means, policies, examples of excellence, and financial tools for increasing resilience to heat at regional/local scale, beyond the targeted cities of Thessaloniki and Rome.

Table 1: Replicable Products communicated to targeted audience

Deliverable	Identified audience	Key content
Forecasting and health related products	All audiences	Forecasting of meteorological parameters (T, RH) and UHI related products (UHII, DI, UTCI, Tapp)
Policy Guide (PG)	Local, Regional and National authorities	Policy framework, national and EU directives and legislative, socioeconomic impacts, and the establishment of long-term collaboration between relevant stakeholders.
Good Practice Guidebook (GPG)	Local and Regional authorities, Medical community, Tourism sector	Approaches, technologies and best practices for counteracting the impacts of UHI.
UHI Adaptation Action Plans Portfolio (UHI-AAPP)	Local stakeholders (authorities, medical community, tourism sector, education sector, NGOs, civil society)	(i) Short-term adaptation measures to reduce exposure to heat (e.g. air-conditioned rooms, civil protection announcements, surveillance of susceptible subgroups, etc.). (ii) Long-term adaptation measures (e.g. green roofs, ventilation areas, etc.) based on the assessment of future climate change on UHI effect

		and the impact assessment of selected adaptation scenarios.
LIFE ASTI Replication Guide (LARG)	Replication cities	Very analytical framework that facilitates the replication of the project's outcomes to other urban areas.

ii. Step by Step Replication Protocol

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

In fact, the LIFE ASTI forecasting system can be transferred to all urban municipalities (cities, towns and suburbs) for the development of their adaptation strategies/ Climate action plans following the next steps. The uptake of the solution is however strongly linked to the willingness/interest of the municipalities for developing adaptation strategies.

The following steps describe the work breakdown and also the partners' execution & monitoring responsibilities. Due to the public nature of the document there are not costs include per action.

The **framework for setting the cooperation scheme** with other municipalities consist of the following steps:

Step 1: Identify potential municipalities to implement. Besides the already identified potential replication areas, the identification process will continue even during the AFTER LIFE period through forums, workshops, congress, etc. related to local adaptation to climate change and by direct contact with the environmental technicians of the municipalities.

Step 2: Present the solution and provide information about UHI and facilitate LIFE ASTI's documents (reports, guides, videos, training material)

Step 3: Signature of cooperation agreement or contract.

Once there is an agreement the **Implementation framework** begins. The following steps describe the work breakdown and also the partners' execution & monitoring responsibilities. Due to the public nature of the document there are not costs include per action.

Step 1 : Add a new domain to the forecast meteorological model. For this purpose it is necessary to prepare the input data (AUTH) and then the modification of the business system (AUTH). Adding new domains increases the execution time of the models. Therefore, it may be necessary to increase the computing resources (RAM, CPU) or even to install a parallel system of models in new infrastructure (so that it serves the new areas and can be run in the time available so that the results can be provided. next day. Responsible partner: AUTH. Implementation time 4 months.

Step 2 : Define the new Heat Health Warning Systems based on the profile and temperature-mortality association of each city. Responsible partner: DEASL. Implementation time approximately 2 months for big cities like Athens and Milan. In some cases especially for potential cities in new domani areas it could take up to 3 months since we need to verify feasibility but also retrieve of data especially health data which might not be an immediate matter also due to GDPR.

Step 3 : Modify the web interface to include the new site. Alternatively create a copy that will only apply to the new site (dedicated web app). Responsible partner: GET. Implementation time 1 month.

Step 4 : Creation of a new mobile application only for the new area and / or its integration in the ASTI application. Responsible partner: GET. Implementation time 1 month.

Step 5 : Monitoring the business operation. These are operating costs charged per year. As long as LIFE ASTI provides data to even one customer, these costs do not increase linearly with the areas covered, but certainly, if there are dedicated applications for each municipality, the time required to check the proper operation of the system increases. Responsible partner: mainly AUTH, contribution in parts by GET. Implementation time 1 month / year for each partner.

Step 6 : Integration and valorisation of the LIFE ASTI's everyday feedback of the UHI forecasting system and the heat health warning system into the strategic and operational plans of the hosting cities. Responsible partner: ALL, each partner on his field of expertise. Implementation time: hard to estimate especially since the services are customized to the needs and requirements of each city.

This step includes activities related to:

- training the staff of the involved authorities on the use of the LIFE ASTI forecast systems and tools,
- technology transfer to those that provide technical support and consulting services to municipalities for adaptation and mitigation strategies,
- presenting how MoT and DEASL are valorising the outputs of the project into their Sustainable Energy and Climate Action Plans (SECAPs) under the new Covenant of Mayors, Regional Adaptation Actions Plans, Actions in the framework of 100 resilient cities and Actions in the framework "Climate Neutral and Smart Cities by 2030", as good practice examples

a. Replication Tools

During the project several replication and transferability activities, but also communication and dissemination activities, took place addressing the networks stakeholders, in order to describe, inform and explain the outcomes of the project. Especially communication and dissemination activities contributed fundamentally to the replicability and transferability of the project being transversal to whole actions.

These actions included the following:

Dissemination and training events: several dissemination and training events were organized both at national and international level. The events addressed all stakeholder levels (primary, secondary and third parties) and included capacity building activities in order to provide the involved actors with the necessary expertise to extend the results of the project. Two seminars and two local working tables were organized in each of the 2 original cities (2 in Thessaloniki and 2 in Rome). The events were organized in 2 different periods during the project implementation. The first round of events took place during 2019 (November in Rome & October in Thessaloniki), while the second was towards the end of the project (October 2021 in Rome and March 2022 in Thessaloniki). All four events targeted the policy and decision makers with the primary purpose to provide knowledge to the authorities for the use of the UHI and Heat Health Warning Forecasting Systems developed in the framework of the project. The training activities increased the capacity of the participants for improved governance while they were useful for the project itself since they allowed the authorities' engagement in the continuation of the use of the LIFE ASTI developed systems and tools by the trained participants after the project end. Moreover, the events offered the opportunity to disseminate the project and to interact with the authorities and stakeholders to recognize their experience, needs and requests from the project to better benefit from it. Local media were invited in the working tables.

Information and education materials: different type of information and education materials have been produced during the project including manuals, videos and broadcasts which are expected to enhance the transferability of the project. All these products are available via the website of the project.

Scientific publications: 8 scientific publications were published. The results were also presented in 18 conferences, workshops and events.

Networking: a great importance has been given also to networking activities to ensure the dissemination but also sustainability, transferability and replicability of the project results. Networking activities will include national and international events and are addressed to the different categories of stakeholders to facilitate cooperation, to transfer knowledge and to share data. They are expected to function as catalyser for the data and knowledge transfer and for the replication of the obtained results within new cities and projects.

III Identification of Replication Areas

Urban Heat Island (UHI) effect is relevant to virtually all big EU cities, especially in the greater area of the Mediterranean. The combined effect of climate change and rapid urbanization is expected to exacerbate the problems arising from UHI effect. Therefore, there is the imperative need for cities and regions, that face the adverse impacts of UHI effect, to monitor and analyse the UHI phenomenon in order to build and to apply proper adaptation and mitigation strategies for increasing resilience to heat at regional/local scale.

It is worth mentioning that the provided forecasts, at the three Mediterranean forecasting domains implemented during the project (see action C.1), provide the capability to identify potential cities that are vulnerable to heat wave events and UHI effect. In the following images you can see the extend of each one of the three forecasting domains. Originally, there were 2 domains (Thessaloniki and Rome) but since the 1st replication city – Heraklion – was added quite early during the project lifetime, there are 3 domains currently.

Figure 1: Domain in Rome

Figure 2: Domain in Thessaloniki

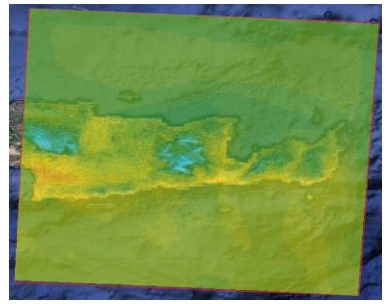


Figure 3: Domain in Heraklion

Businesswise, it is in the interest of all partners to maintain the operational modeling systems of UHI forecasting and the operational heat health warning systems created during the project's duration for the 3 different domains.

Each city situated within these extends, which also faces high temperatures and extensive heat waves, is a possible replication city with minimum effort with minimum effort concerning at least the preparation of input data (AUTH) and then the modification of the operational system, which leads to decreased costs for the provision of the service.

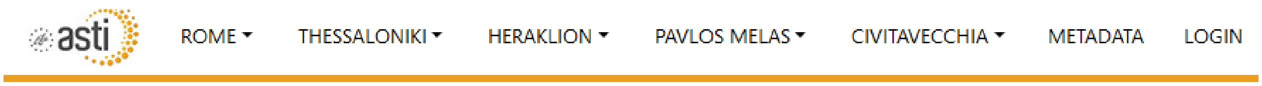
It is important to emphasize that the whole implementation routine, including initialization of the models, operation, and post-processing procedures, as well as management and visualization of the UHI forecasting products and heat health warnings, is fully automated and will be employed in the same – existing and purchased – computational and storage infrastructure as during the LIFE ASTI project for the replication sites.

Moreover, the scalable ntier and modular modeling architecture ensures easy expandability of the system by expansion of the infrastructural computational and storage resources. The implemented system architecture allows the easy expandability of the system to be able to support additional areas all over Europe. Thus, any urban area in the two countries can be added with relatively small cost in the pilot operational forecast mode, but this is also possible for any other location in Europe.

During the lifetime of the project there were 4 Italian cities investigated as possible replicability sites for the AFTER LIFE period of the project: Catania and Palermo, both in the province of Sicily (population of 310,247 and 658,403 respectively), Civitavecchia in Lazio region (52,650 inhabitants) and Perugia in Umbria with 166,676 inhabitants. Also, several cities in Greece had been approached as possible replication cases (e.g. Kalamaria, Pavlos Melas, Evosmos-Kordelio).

It was decided to add 2 more replication cities before the end on the project. The city of **Pavlos Melas** (Greece) was added during March of 2022 and the city of **Civitavecchia** (Italy) was added during end of

May of 2022. The final decision among them was made based on the availability of data and the commitment of the local stakeholders to uptake the outcomes of the project.



Moreover, the consortium made targeted contacts with specific cities phasing severe impacts of climate change and the UHI phenomenon and the LIFE ASTI's outputs were presented. These cities included the city of Athens and Larissa in Greece, but also the city of Nicosia in Cyprus. All 3 cities are considered potential future clients and the communication with them is still ongoing.

The case study for implementing the LIFE ASTI in Athens, which is considered a flag city for potential replication cases, is presented hereunder

i. Case Study in Greece – City of Athens

Athens is the capital city of Greece. It is the largest city in Greece, and the 7th largest city in the European Union. Athens dominates and is the capital of the Attica region and is one of the world's oldest cities, with its recorded history spanning over 3,400 years and its earliest human presence beginning somewhere between the 11th and 7th millennia BC.

The Municipality of Athens (also City of Athens), actually constitutes a small administrative unit of the entire city, with a population of 664,046 (in 2011) within its official limits, and a land area of 38.96 km^2 .

The climate of Athens is characterized as subtropical, Mediterranean, with prolonged hot and dry summers and mild winters, with moderate rainfall. The average annual temperature is 17.7ºC, based on the weather station of Thisio. The last years have been measured in the center of the Municipality quite elevated temperatures in the summer season (maximum 42.8^{o}C in July), while in the months of December - March the temperature can drop below 0^{o}C. The middle rainfall is relatively low (378mm per year - Figure 23), as well as the wind speed (around 2m/s annual average wind intensity).

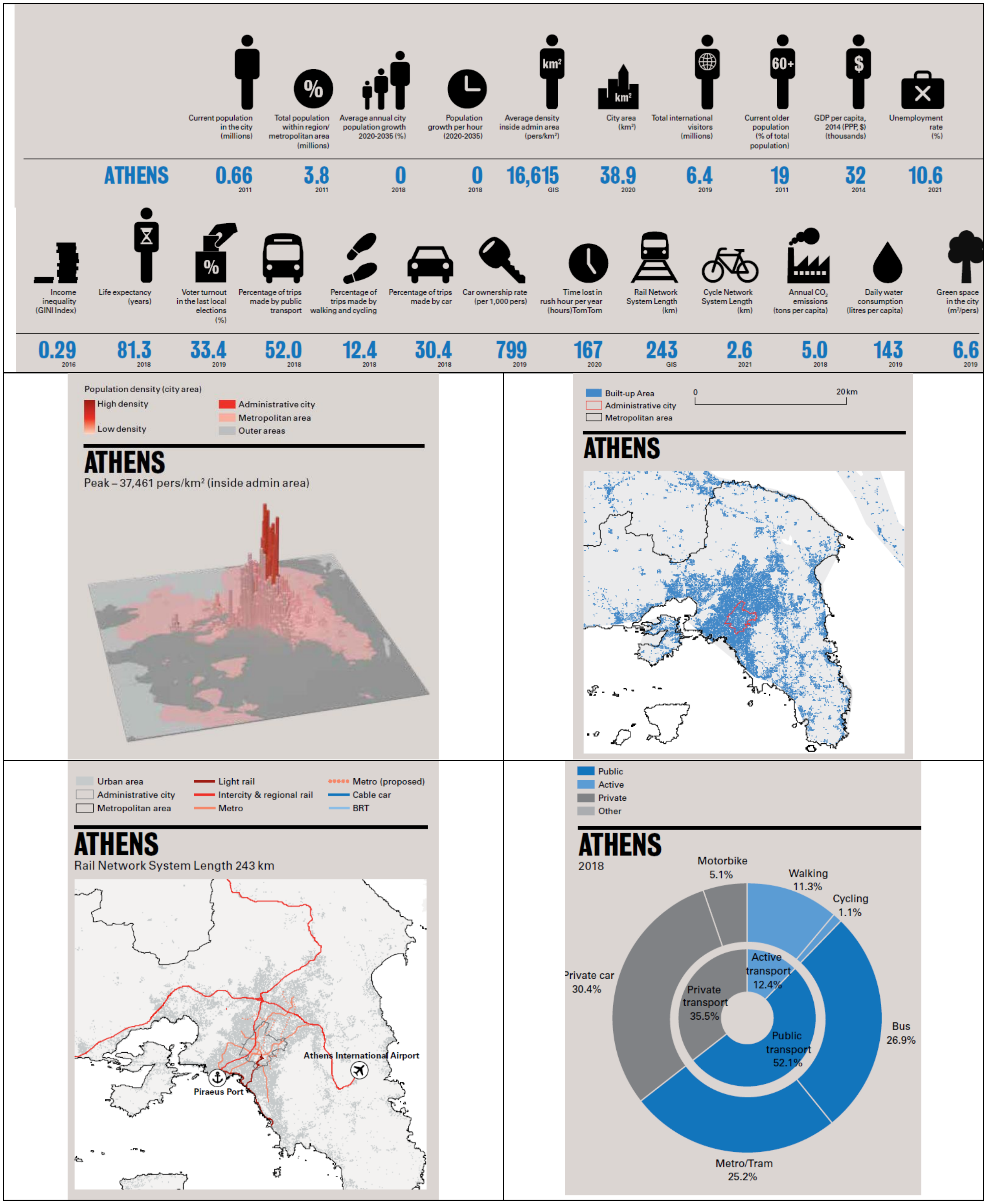


Figure 4: The City of Athens in numbers (source: https://www.lse.ac.uk/Cities/Assets/Documents/Urban-Age/Athens-Urban-Age-Task-Force-Spatial-Compendium.pdf?utm_source=substack&utm_medium=email)

Climate change scenarios indicate that extreme heat events are expected to typify the city's future. Between 2021 and 2050, average summer temperatures in Athens are projected to increase by 2°C; between 2071 and 2100 the projected increase goes up to 4°C. We are already observing a gradual increase in the length and level of high temperatures as well as the frequency and intensity of heat waves and other related phenomena such as flash floods and bad air quality. The Athenian Urban Heat Island, intensified by the rising heat, exhibits severe temperature differences reaching 6°C, 7°C even 10°C between the city center and its suburbs. The density, anarchy and bad quality of our built urban fabric, as well as the lack of green open spaces are the main culprits.

The Athens July 21st, 1987, and a lethal heatwave

- Lasting almost **10 days**,
- **2,000** heat related deaths.
- Tdaily,max= **41-44°C**, Tnight,min>28°C (for 10 days long)
- **2960** heat-related admissions recorded in hospitals
- **31%** fatalities among admitted cases

Figure 5: The Athens lethal heatwave in the 21st of July 1987 in numbers (source: https://resilientcitiesnetwork.org/downloadable_resources/Network/Athens-Resilience-Strategy-English.pdf)

It is worth mentioning that a recent analysis of 571 European of cities of Newcastle Polytechnic assessed Athens as the European city facing the greatest impact from heat waves[1]. Meanwhile, a report by Moody's[2] that assessed the credit risks of 30 European cities from climate change, ranked Athens first in relation to its exposure to extreme heat and drought and among the first 3 large cities threatened by forest risk fires. According to the report, the growing tension and frequency of extreme heat means that the credit capacity of Athens will be vulnerable to climate change, especially if the heatwaves lead to a recession in tourism activity and have a negative impact on the overall economic development of the city.

[1] Selma B Guerreiro et al, 2018, "Future heat-waves, droughts and floods in 571 European cities," Environ. Res. Lett. 13 034009

[2] Moody's Public Sector Europe Report #1098303, 12.Dec.2017 under the title "Climate Change will pose increasing credit challenges for cities"

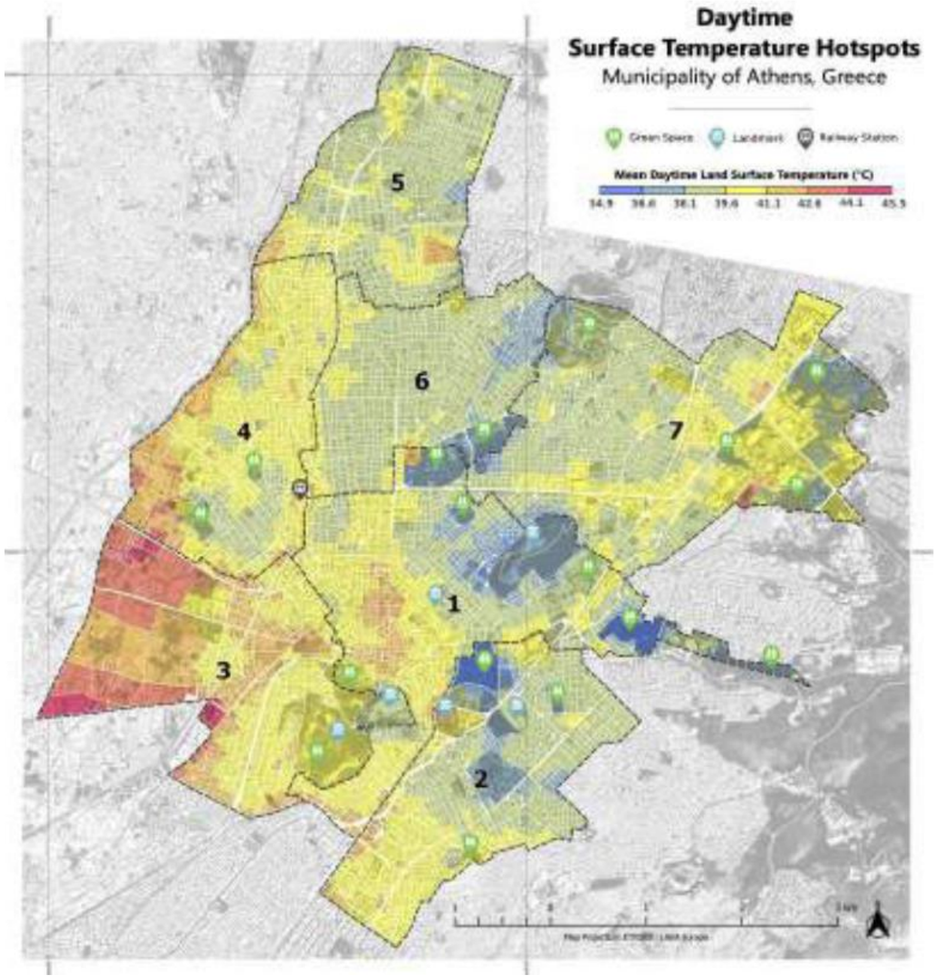


Figure 6: Variability of soil temperatures in the months of June-August during the 3-year time period (2018-2020) in the Municipality of Athens (ARTi Analytics BV, as part of the services of EXTREMA Global)

Considering the above, the municipality of Athens has proceeded to measures aiming at reducing the intensity of phenomena related to heat as well as protection of the most vulnerable groups of the population. Recently, the Municipality of Athens has proceeded with a special collaboration with the Arsht-Rockefeller Resilience Center and with support of the Extreme Heat Resilience Alliance (EHRA) of this center, Athens will receive expertise but also the appropriate resources so that it can better defend itself against rising temperatures.

Mayor Kostas Bakoyannis established a specific responsible position that will coordinate strategies and measures for the city's preparedness during the hot season, the protection of the most vulnerable, but also the design from now on of a cooler one city. Athens is the first city in Europe to have adopted this responsibility and Mrs Eleni Myrivili, who is acting as Chief Heat Officer of Athens, has already assumed her role responsible for Combating Urban Overheating.

The consortium of LIFE ASTI is in contact with the Municipality of Athens already since May of 2021 presenting the LIFE ASTI forecasting system and outcomes but also the contribution of the LIFE ASTI to the Resilience of Athens.

If Athens adopted LIFE ASTI it would have

1. A daily UHI forecasting system providing high-resolution (250 m) UHI-related products at district, including thermal bioclimate indices and Heating/Cooling Degree Days (HDD/CDD).
2. A Heat Health Warning System providing differential alerts within the city (and the potential effects on health at high spatiotemporal resolution (at district level)
3. A web-based open access portal and a mobile application to disseminate the above-mentioned forecasting products to authorities, stakeholders and the general public 0.66 millions current population based on the census of 2011)
4. A tool to assess the adaptation and mitigation actions taken towards the resilience of the city against heat waves and the urban heat island effects.

The discussions with the Municipality of Athens are ongoing and it is worth mentioning that Mrs Eleni Myrivili the Chief Heat Officer of Athens also participated in LIFE ASTI's Final Conference in May of 2022, while through her the consortium has established a network connection with the Resilient Cities Network[3].

As mentioned above Athens is considered as a potential customers and based on the replication step-by step protocol the 2 first steps of **the framework for setting the cooperation scheme** have been completed, while we are in discussions for and we are in discussions for signing a cooperation agreement or contract. Therefore, and due to the public character of this document, costs are excluded.

ii. Case Study in Italy – Municipality of Milan

One of the biggest metropolises of Italy located in the region of Lombardy with more than 1 million inhabitants. The city is mostly exposed to pluvial flooding, extreme wind and heatwaves. Milan has a city Masterplan with a vision towards 2030, which introduces a resilience approach in built context and public spaces, emphasizing increasing green areas to reduce the impact of climate change. The city has also drafted the first integrated Air & Climate Action Plan to identify priority measures for air quality and climate change mitigation and adaptation.

Milan's climate is continental, with damp, chilly winters and hot, humid summers. Snow falls between December and February, and springtime is generally rainy. In winter temperatures range between 30 and 50 °F (−1 and 10 °C) and in summer between 68 and 86 °F (20 and 30 °C). Characteristic of the Po Basin, fog often shrouds the city in winter. The removal of rice fields from the southern neighbourhoods and the closure of most of the city's heavy industry have reduced the phenomenon. However, this has been offset somewhat by the growth of an almost uninterrupted built-up area around the city, which reduces local air circulation, and by the grey smog, or traffic-related air pollution, that often covers the city.

[3] https://resilientcitiesnetwork.org/

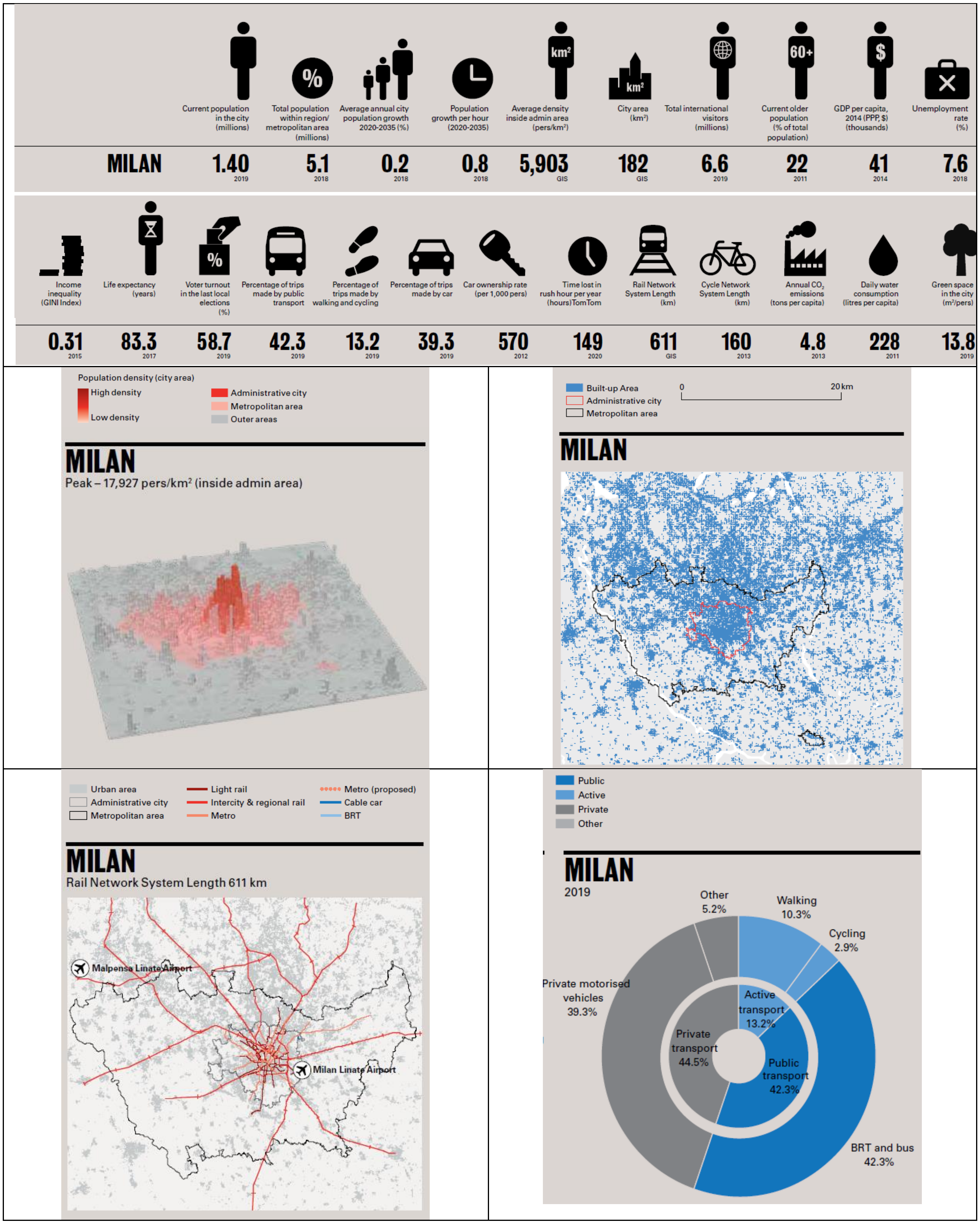


Figure 7: The City of Milan in numbers (source: https://www.lse.ac.uk/Cities/Assets/Documents/Urban-Age/Athens-Urban-Age-Task-Force-Spatial-Compendium.pdf?utm_source=substack&utm_medium=email)

The municipality of Milan has been working on adaptation for years. Main climate threats are heat stress and floods. Two projects that the municipality is working on currently are the implementation of their Air and Climate Plan (ACP) and the application for funding from the National Government. The ACP is a climate action plan and targets adaptation, mitigation and resilience and sustainability. The plan is connected to various other strategies and plans such as the City Masterplan and the Resilience strategy. With the ACP, Milan is moving from a planning phase towards as phase of implementation. The objectives include becoming a 1) healthy and inclusive Milan, 2) connected and accessible Milan, 3) sustainable energy Milan, 4) resilient and climate adaptive Milan, and 5) participatory Milan. Additionally, an important aspect for Milan is to mitigate gentrification effects of climate adaptive developments.

Both the implementation of the ACP and application for funding, create a demand for systems and capacity to monitor and evaluate adaptation actions and policies and to perform risk assessments for new developments. While climate information and various climate services are available for Milan, there is no clear overview present of all information and potential knowledge and information gaps. Potential directions for improving the knowledge base include generating urban heat island maps and understanding social vulnerability.[4]

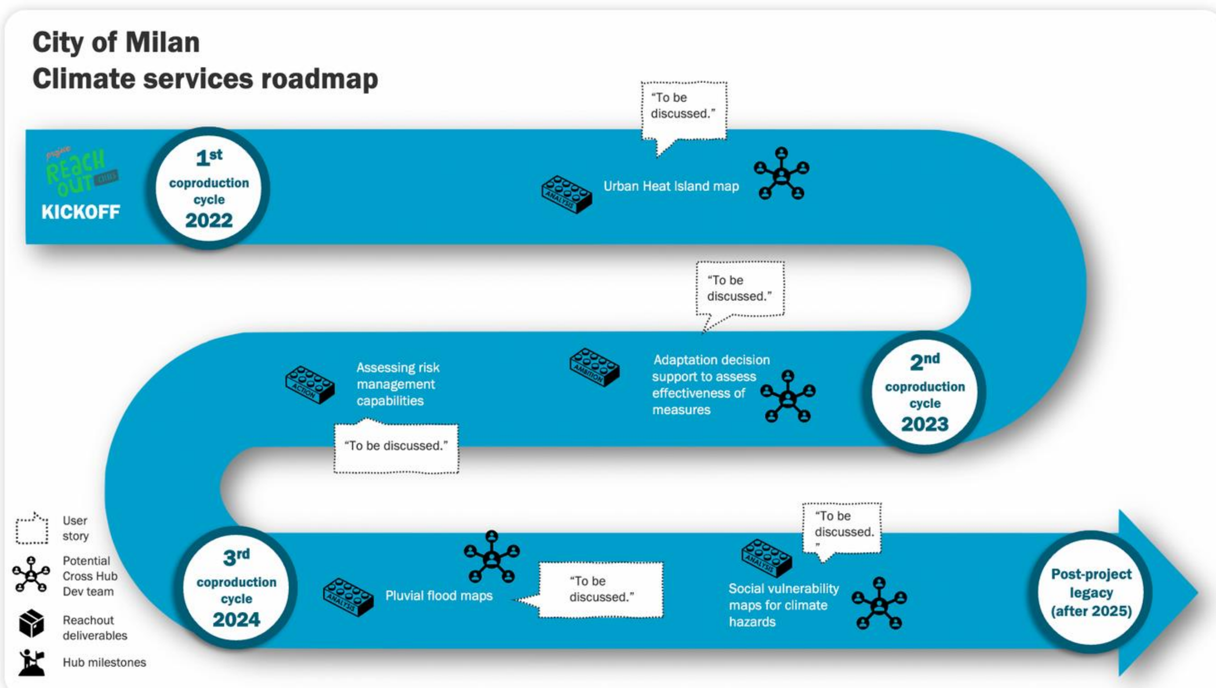


Figure 8: City of Milan's Climate Service Roadmap (source: https://reachout-cities.eu/post_type_city/milano/)

Considering all the above, Milan has been targeted by our consortium as the next flag city for potential replication case in Italy. Through connection established to the Resilient City Network, via Mrs Myrivili,

[4] Source https://reachout-cities.eu/post_type_city/milano/

the consortium has planned to approach Milan's Chief Resilience Officer Mr. Piero Pelizzaro in order to present the LIFE ASTI solution. The approach and the further development of this potential business case will take place during the AFTER LIFE period of the project.

IV Replication Actions during the AFTER LIFE period

In addition to the foreseen After-LIFE actions, the following replication activities are also expected during the AFTER-LIFE period and:

1. Submission of new proposals, related to LIFE ASTI, for funding from EC financial instruments (Horizon, LIFE, Interreg etc.) and national funds. In particular, scientific partners intend to include in future relevant proposals the expansion and upgrading of the LIFE ASTI outcomes so as to incorporate information for more UHI related indexes, more countries and/or higher analysis resolution. Partners involved: Potentially ALL depending on the proposal
2. Sign contracts with municipalities for the development of their forecasting System for urban heaT Island effect for the development of urban adaptation strategies. Partners involved: ALL
3. Demonstration of the LIFEASTI platform and project's outcomes to events organized by the project partners, 3rd parties in the project and other countries. All partners will continue to promote the use of the outcomes to relevant occasions. Partners involved: ALL
4. Technology transfer to those that provide technical support and consulting services to municipalities for the development of their SECAPs (on demand). This could involve the knowledge transfer for all of the outcomes of the project, or just the knowledge transfer of individual components such is the platform, the polices and guidelines etc. 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 LIFE ASTI forecasting System for urban heaT Island effect (on demand).
6. UHI forecasting systems and Heat Health Warning Systems demonstration and training for higher education students.
7. Promotion of the LIFE ASTI forecasting System for urban heaT Island as a business solution to the network of the consortium and investigate their willingness for uptake.

VII Conclusions

The project team has placed particularly high emphasis in the replication potential of the LIFE ASTI outcomes. To this end, a great load of work was directed to maximizing this potential for all urban municipalities especially of Greece and Italy - instead of only the respective ones for the 2 project municipalities as foreseen in the proposal. As a result, the LIFES ASTI forecasting system is already replicated to 2 more cities (Pavlos Melas and Civitavecchia without having to insert any new data or infrastructure costs.

The implementation of the Replicability and Transferability guide is expected to promote the development of future joint action and cooperation opportunities and to extend the results of the project.

forecAsting
System
for urban
heaT Island
effect

The project Implementation of a forecAsting System for urban heat Island effect for the development of urban adaptation strategies- LIFE ASTI has received funding from the LIFE Programme of the European Union".