“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.8.2 **Policy Guide (PG)**

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	Policy Guide (PG)
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, G. Mavrellis, D. Melas, , 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	V. Akylas, E. Androutsou, P. Karkavitsas, A. Kelesis, G. Mavrellis, M. Pahoula, G. Papadaki, G. Papastergios, E. Pavlidou, I. Pothitaki, I. Savvaidou, P. Symeonidis, P. Tzoumaka, I. Tsikoti, F. Vagena	GET, MoT (& LEVER S.A.),
31-06-2022	V.2	V. Akylas, E. Androutsou, S. Argentini, F. Asta, T. Belalidis, G. Casasanta, F. De' Donato, P. Karkavitsas, A. Kelesis, G. Mavrellis, D. Melas, , 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 will result to the short-term forecasting and future projection of the UHI phenomenon initially in two Mediterranean cities: Thessaloniki (Greece) and Rome (Italy). Also, the city of Heraklion, Pavlos Melas (Greece) and Civitavecchia (Italy) were added during the duration of the project.

The phenomenon of UHI has an impact on human health, which becomes more intense, as the duration of the heat wave episodes is expected to increase due to climate change. The spread of urban areas has become alarming in recent years; almost 73% of Europe's population lives in cities, a rate which is expected to reach 80% by 2050. Extensive urbanization is triggering significant changes to the composition of the atmosphere and the soil, which result in the modification of the thermal climate and the temperature rise in urban areas, compared to neighbouring non-urban ones.

The modelling 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, and assessing the energy needs of buildings. In addition, it guides the Heat Health Warning System 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 Policy Guide (action C.8), 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.

I The LIFE ASTI Project's 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.

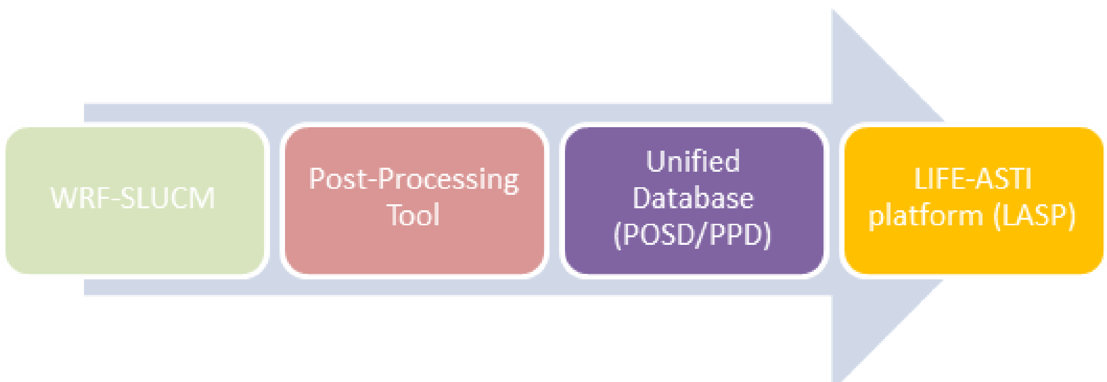

Figure 1: Overview of the operational UHI forecasting system

b. <u>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).</u>

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 neighborhood level. Daily averages or maximum values of selected parameters are used in order to define the magnitude of the UHI. A simple color 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 plan (LARG) that will support the potential of 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 lead 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**
   e. Assessment of the impact of future climate change scenarios on UHI,
   f. 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 northeastern 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:

g. <u>UHI Adaptation Actions Plans Portfolios for each city</u>

h. 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.

II POLICY RECOMMENDATIONS

II.1 Methodology

These recommendations have been prepared within the framework of LIFE ASTI, the goal of which is to develop, pilot operate, and validate of UHI forecasting systems, combined with heat health warning systems. The preparation of recommendations document follows the methodology, which was created based on the experience and results of the project by the project partners. In order to prepare these recommendations, regional and EU policy documents were analysed, such as National and EU Climate Change Adaptation Strategy, National Energy and Climate plan, with the aim to understand policy goals and actions with regard to climate change adaptation and UHI effects and measures. In addition, various quantitative data and indexes were also analysed from both, national and EU level data sources in order to present the state-of-the-art of the climate impact assessment of the UHI effect.

II.2 Potential Implications

The increasing urbanisation trends, which generate structural and land cover changes in metropolitan areas, are blamed for the UHI effect. The UHI effect can be found in practically any sort of urban area, regardless of its size or climate (Stewart & Oke, 2012). It is critical to determine the various sources and drivers of the UHI effect, as well as the hazards and implications for urban populations, in order to combat this phenomenon and develop effective mitigation and adaptation solutions.

Innovation and smart technologies in UHI could greatly contribute and promote the goal of combating UHI effect and impacts (human discomfort, buildings overheating, public health impacts), along with the increase of resilience towards heat waves. The failure of not investing in innovation and smart technologies through the improvement of regional policy documents and the engagement of stakeholders will lead to a gradual degradation of the environment and in particular the urban environment, thus of the local economy, and will have a severe impact on the health of vulnerable population groups.

With an estimation of approximately 166,000 people dying due to extreme temperatures (heat waves) between 1998-2017, as declared by WHO, it is evident how crucial is to invest in the improvement of technologies, planning, infrastructures and where to focus innovation on. Minimisation of the UHI effect, public health safety, improvement of infrastructures, increased quality of services and utilities are expected results that would not be achieved when there is lack of an integrated UHI plan, which focuses on innovation and smart technologies.

Innovation requires also good coordination, which is the first step towards a consolidated planning with the involvement of several stakeholders of the different sectors. If policies would not focus on innovation the effects and impacts of UHI will become more severe, by posing a big threat towards the urban populations, national economies, etc. while monitoring the urban environment and analysing variables and cost-benefit, it is critical to take thorough and effective measures.

UHI may result in several implications in the following areas:

- Energy Impacts
- Infrastructure and Buildings
- Urban environments (pavements, public spaces, etc.)
- Water Quality
- Air Quality
- Flora and Fauna Impacts
- Health and Socio-economic Impacts

To summarise, the UHI sustainability is linked directly to the national sustainability and development. Focused and integrated policies are necessary to achieve the protection of urban population and national economic growth, promoting at the same time respect to the environment.

II.3 Policy Recommendations

In 2016, the National Climate Change Adaptation Strategy for Greece was developed, as a part of the EU's 2009 White Paper "Adapting to climate change: towards a European framework for action". The purpose of this strategic document was to summarise the national strategy that will be pursued over the next years, as well as to propose the first stages in a process for planning and implementing measures to address the impacts of climate change at a national, regional, and local level.

Furthermore, in 2019, the National Energy and Climate plan was developed and was established by the Regulation on the governance of the Energy Union and Climate Action (EU) 2018/1999, as it was implemented in 2019 as part of the Clean Energy for all Europeans. The strategic goal of this Plan is to lay out and specify priorities and policy measures for a wide range of development and economic activities aimed at achieving specified energy and climate goals by 2030.

According to this Plan, in order to lower the UHI effect by 20% by 2030, special measures and incentives are being prepared for the bioclimatic improvement of urban public space. However, no specific measures are being mentioned, thus it is proposed that a more specific strategy should be prepared, by focusing on the needs of tackling the UHI effects. In addition, governments could promote policy coordination by incorporating requirements and guidelines into relevant rules, standards, or ensuring that existing regulations do not present an unjustifiable obstacle to the implementation of strategic measures.

The specialisation of the measures towards facing UHI effects is, as mentioned before, limited, thus policy makers should focus on the reduction of anthropogenic heat emissions, improvement of urban structure and surface, improvement of way of living, etc. The governments need to explore the possibility of creating a single cluster with a view to providing holistic support to the relevant stakeholders, which are responsible of reducing Urban Heat Islands (informing them about funding opportunities, networking, design and implementation of investment plans, synergies with academic and research institutions, etc.).

i. Recommendations on Public Health

During heat waves, overheating of buildings and other infrastructure, as well as the negative consequences for residents, have been recognized as public health hazards. As a result, heat might be regarded a serious hazard - one of the deadliest in Europe, especially for vulnerable demographic groups. It is of high importance to consider Public Health services as a tool to combat heatwaves and their results on human health.

The governments should consider the Urban Health Initiative (WHO, 2022) when forming their Strategy in terms of public health. The Urban Health Initiative is a policy framework aimed at reducing the number of deaths and diseases caused by hazardous urban surroundings. Its goal is to provide data, resources, and capability to the health and other sectors in order to illustrate to the public and decision-makers the entire spectrum of benefits that may be realized by constructing healthy urban settings.

In order to integrate health into policies the following (Figure 2) should be considered:

1. Identifying stakeholders and policies

Before beginning with drafting a policy document all stakeholders involved should be identified, along with every existing policy document that is relevant to the effects that several issues, phenomena, etc. have impacts on health. Following that, all relevant data should be collected in terms of health consequences to properly form the policy document.

2. Ensuring effective participation

After having identified the relevant stakeholders, what needs to be ensured is their participation both in the drafting of the policy document and the policy implementation. What is a very important factor is the cooperation of all during the policy-making processes.

3. Using tools to analyse the current situation

In order to have a clearer idea of the current situation, the relevant stakeholders should possess information on both socio-economic and health implications because of UHI. Thus, existing, or new technologies need to evaluate the health and economic consequences of UHI.

An example of this tool could be the ICT application created in the context of Life ASTI project. This application provides a short-term forecast, by producing high-quality forecasting products, such as bioclimatic indicators, heating, and cooling degree days, assessing the energy needs of buildings. 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 primary target of LIFE ASTI is the development, pilot operation, and validation of UHI forecasting systems, combined with HHWS.

4. Developing a Strategy

After acquiring all information required, stakeholders should focus on developing the Strategy to minimize the impacts of UHI on public health.

Figure 2 Path of Urban transformation (Source: https://www.who.int/initiatives/urban-health-initiative)

In general, what needs to be considered as essential is the education of public on adaptation techniques. Moreover, to avoid the results of a heatwave on human health, it is important to educate the public on adaptation techniques. Education on issues such as how to react through a heatwave or preparedness for such events can be useful not only for the crowd but also for industries, athletes, workers and patients, so as to minimize the significant knowledge gap around excessive thermal events and heat-related issues (Akompab et al., 2012; Hatvani-Kovacs et al., 2016c, 2016d; Pisello et al., 2017; Saman et al., 2013). Heat health knowledge can increase the know-how on the implementation of Public Health measures and the adaptation of techniques to decrease health issues during heat waves.

Additionally, the observation of the UHI provides the opportunity of mapping urban areas that show high-risk levels of heat. These maps can be provided by the Public Health Services to the public with a view to avoiding such areas as much as possible during heatwaves. (Bao et al., 2015; Chow et al., 2012; Huang et al., 2011; Keramitsoglou et al., 2013; Loughnan et al., 2014; Taylor et al., 2015; Tomlinson et al., 2011). This measure can be efficient not only for the public to avoid these high-risk hot spots but also for the

Public Health Services to develop these hot spots in cool refuges, referring to spaces well adapted and constructed in such a way that provide healthy thermal comfort even in case of a heatwave (Hatvani-Kovacs, et al., 2018). Furthermore, there must be an efficient tool to disseminate alerts on heat waves.

Lastly, emphasis should be given to the management of heat-related and safety promotion, through all means of communication. The proper management shall adequately face any unforeseen issues that might arise.

ii. Recommendations on Urban Planning

Urban planning refers to the development of new ways to tackle heatwave hot spots, to combat the UHI effect. Urban areas need to incorporate opportunities related to the heat island reduction. Such measures can help the promotion of the heat island reduction strategies.

The Strategy to be developed should consider both socio-economic factors along with the urban morphology in terms of urban planning. In particular, the following should be considered:

- Building materials and surface elements
- Building and infrastructure-related evaporation
- Population
- Human-caused heat release
- Density of construction
- Water bodies
- Green spaces

Increasing the green surface with tree planting should be one of the measures to be incorporated during the formation of the UHI Strategy. Developing a minimum acceptable ratio of green space in urban areas could promote the adaptation of urban vegetation that helps the absorbance of high temperatures through photosynthesis. Beyond the present open space percentages, local development plans for private properties should include a mandatory minimum green space ratio and intensity.

Figure 3 Transformation of an impervious parking lot in Indiana to a public green space (Source: CityGreen, 2021)

Also, evapotranspiration is responsible for lowering surrounding temperatures as water's being released through leaves (Growing Green Guide: A Guide to Green Roofs, Walls and Facades in Melbourne, Australia, 2014).

Additionally, increased vegetation cover is one of the simplest solutions for urban areas to lessen the UHI effect. Thus, governments should incorporate this method into their plans, strategies, climate actions plan, or any other policy document related. The most important advantage of this method is the shade, which helps certain areas from absorbing and releasing solar energy. Trees are an example of providing shade to the ground and to buildings and infrastructure. However, the form and selected type of vegetation is of great importance as well since each type has a different effect. In this context, it is valuable to consider the opportunity of taking advantage of brownfield investments, such as green roofs. Roof surfaces covered in vegetation can absorb heat, provide passive cooling, and also clean air pollutants thus improving air quality. Green spaces between buildings can contribute to the amelioration of the local microclimate, (Hatch, 2016)

Furthermore, it is important to build and operate cool public spaces, and public refuges, which can be used to encourage public's response to high-risk temperatures. These refuges can be places where people can socialize, exercise, study and do other productive activities inside a building with healthy temperature where citizens can spend their days during heatwaves (Hatvani-Kovacs et. all, 2018). This thermally safe environment can be used for all citizens but mostly for the most vulnerable ones.

Moreover, as mentioned before water bodies are very important for the UHI effects. Water features in a densely populated area serve two purposes: design and ecological. Rainwater is used to fill the enormous water surfaces. The water features help to improve the urban climate by lowering the ambient temperature in the summer, attracting dust particles, and humidifying the air. Thus, a special section should be included in the development of urban planning, as far as water bodies are concerned.

Figure 4 The Water Square (Source Public Space, 2013)

Finally, implementing heatwave vulnerability maps can increase awareness regarding to the characteristics of each area and informing citizens to avoid such areas during a heatwave and providing knowledge for the local councils to decrease the reasons contributing to the heatwave vulnerability.

iii. Recommendations on Building and Construction

Buildings contribute to the UHI because of their increased thermal capacity. They are exposed to solar energy through their roofs and walls, as well as heat lost due to space cooling, electric loads by the residents. In Greece, buildings are responsible for 40% of total energy consumption and for 45% of CO_2 emissions. At the same time, the lack of green areas affects public health, but also burdens residents by intensifying the sense of discomfort (Ministry of Environment & Energy, 2016). However, from 2011 the Hellenic Ministry of the Environment and Energy has issued a Ministerial Decision on "Terms, conditions and process of construction of planted areas on roofs and outdoor areas of buildings". Through this decision, a Special List is created that should be constantly updated by the construction services.

In order to be able and improve/alternate older buildings and set a new basis for the construction of new ones, an accessible guide should be created for all professionals (engineers, architects, etc.) to follow considering all the necessary data for each area (temperature, number of heat waves, materials, etc.). This guide should include techniques to reduce the risk of a building overheating, by taking into consideration not to compromise its energy efficiency.

Furthermore, it is considered important to financially incentivize heat stress resistant design. This measure can increase the efficiency of a building not only the energy efficiency but also the thermal one as using heat stress resistant materials and heat resistant colors in the exterior of buildings can cause the reflection of the excessive heat, decreasing high temperatures and consequently, minimizing the effects of a heatwave. It is important to assure that these heat stress resistant materials can be reliable as many claim that their product is heat resistant when it is proved otherwise. For this, it is recommended to reassure the run of random and tactical tests of these products and the quality of the colors used to paint the building. In particular, paint materials can provide lower temperatures as they are able to reflect the excessive heat with a view to increase cool surfaces as well as cool interiors, resulting into decreasing the use of air-conditioning which is a major contributor to the UHI. Materials used in the construction of buildings should provide insulation in such manner that can reduce the temperature of the surface of the building contributing to lower temperatures in the surrounding areas and conducting less heat into the interior of each building, (Hatch,2016).

In the same context, not only residential buildings but also public buildings can be heat stress resistant, (Pockett,2010). Such buildings can be used as showcases, for example schools. This can be achieved with a certificate provided to buildings which exceed the acceptable energy efficiency. Implementing the Building Energy Performance Certification (EPC) can help the empowerment of knowledge about energy efficiency and heat stress resistance of buildings.

In addition, cool roofs and green roofs can help the decreasing of temperature and owners should be encouraged to develop cool roofs and install roofing materials with high solar reflectance and thermal emittance. There can be many approaches regarding developing cool roofs such as the simplest, which meets the minimum requirements and that is just painting the roof in light colors. Other approaches can be more complex such as insulation and window improvements, which is more efficient and costly as well. Special thought should be given to the development of green walls/vertical gardens. These gardens consist of plants that survive without any soil, only by requiring water and nutrients.

Figure 5 Example of Vertical garden by Patrick Blanc, in Madrid Spain (Source: Ferrovial, n.d.)

iv. Recommendations on Urban Infrastructure, Services and Utilities

Urban growth, infrastructure efficiency, services and utilities performance can be massively affected by the UHI effect. Due to the importance of urban areas in the scope of increasing temperatures, the infrastructure performance of the urban areas can reduce the risks of climate change. Recommendations on urban infrastructure, utilities and services are in order to promote decreasing temperatures in metropolitan areas.

First of all, innovation and technology has provided many approaches that can be helpful in this act to combat rising temperatures. More specifically, the DLC (direct load control) strategy which refers to the capability of using utilities and services remotely, can facilitate controlling air-conditioning, pool pumps, or even photovoltaic panels with the use of a simple Wi-Fi connection. The implementation of such strategies by suppliers of electricity simplifies the struggle of the high peak demand of electricity in urban areas, that can even result to total blackouts of a specific area. During the summer season, this can have major negative impacts due to the high demands on electricity and especially on air-conditioning. The DLC strategy, as it enables the electricity suppliers to remotely operate these specific appliances, promotes cyclic control, decreasing the consumption of electricity only for the use of air conditioners by up to 35%, (Energy Supply Association of Australia,2012). In general, the development of ICT Tools should be encouraged and supported. Governments should investigate viable policy tools to provide incentives for new IT-enhanced products and services, and also award funds for the fast transformation of existing technologies. An emphasis should be given to the conditions for a substantial role for the private sector in assuming part of the risk of the planned ICT investments.

Moreover, it is crucial to adopt measures that facilitate the coolness of infrastructure surfaces. More specifically, regarding transportation, wooden rail sleepers and other heat stress resistant materials can be found useful as they can help decrease temperatures, reflecting excessive heat.

Furthermore, electricity-wise measures can promote the decrease of excessive use of appliances such as white goods, during the peak hours of electricity demand. These measures can help manage and monitor the electricity demand, decreasing excessive heat during a heatwave. This can lead to dynamic pricing, which means setting different price ranges used for the different periods of the day which vary on the amount of demand of electricity, (National Climate Change Adaptation Research Facility, 2015). It is important to note that, effective governance coordination is key to designing and delivering transformative urban infrastructure investments.

In terms of water facilities, water bills reflect the excessive water use during the summer season. Increasing the water use component of the water bill could be helpful for decreasing the excessive water consumption. In the same context, another water-wise measure can be a water consumption target. This measure can result to a major reduction of water consumption. Monitoring water consumption during heatwaves can facilitate the need for water for emergency situations, (Wells, 2016).

Lastly, Green Infrastructure (GI) is increasingly being recommended as a major solution for reducing UHI effects in urban areas. Examples of GI could be parks, gardens, trees, green roofs, pavements, etc. Roofs and pavements cover more than 50% of urban areas. In order for a city to lower urban temperatures, they need to implement a variety of cooling strategies, including GI. Cooling effects could be improved by combining green infrastructure with cool roofs and pavements, as well as using materials or coatings that reflect more sunlight or offer cooling through water evaporation. However, GI adoption is dependent on several criteria, including local conditions and characteristics, space needs, irrigation water availability, materials' availability, economic benefits, durability and maintenance requirements, etc. To comprehend and measure the associated economic, environmental, health, and welfare benefits of green infrastructure, city planners, private sector companies, and individuals require rules and proper decision-making support. Reviewing best practices and methodologies and combining inputs from diverse sources, such as soliciting comments from experts and citizens, as well as the commercial sector, could improve decision-making support.

Figure 6 Examples of Green Infrastructure (Source: Georgetown Climate Center, 2022)

III CONCLUSIONS

Facing the UHI effects is a particularly challenging situation. Thus, UHI is inextricably linked to several socio-economic factors, which need to be considered before drafting a policy document. Therefore, several stakeholders must work together to solve this difficult problem. Governmental agencies should collaborate with relevant municipal departments, and other public services, such as the ones responsible for urban planning, construction laws and transportation, in order to mobilise the broader support. As UHI presents differences depending on the location, proper engagement with local authorities must be maintained, as they need to assist in developing a policy guide.

The policy guide should bear in mind the four (4) factors as described in this deliverable:

1) Public Health
2) Building and Construction
3) Urban Planning
4) Urban Infrastructure, Services and Utilities

Recommendations on Public Health issues include the identification of stakeholders and policies and their effective participation. Also, the use of proper tools for the analysis of the existing situation towards the development of a strategy and education of the public.

Recommendations on Urban Planning to combat the UHI effect include the adaptation of urban morphology concerning building materials and surface elements, urban and population density, evaporation of structures, heat release sources, green park spaces and water bodies.

Recommendations on Building and Construction refer to the decrease of the thermal capacity of buildings by using heat stress resistant building materials and design, including green roofs and walls as well as vertical gardens.

Recommendations for actions on Urban Infrastructure, Services and Utilities to be used for the reduction of urban temperatures include the use of ICT tools for the control of energy consumption in peak hours. Several other electricity-wise measures can be considered such as the dynamic pricing for the decrease of energy consumption, sparing of water during summer, and converting infrastructure into green in order to lower urban temperatures.

Abbreviations

AUTh	Aristotle University of Thessaloniki
CDD	Cooling Degree Days
DLC	Direct Load Control
EPC	Building Energy Performance Certification
EU	European Union
GI	Green Infrastructure
HDD	Heating Degree Days
HHWS	Heat health warning systems
ICT	Information and Communications Technology
PPT	Post-Processing Tools
SLUCM	Single Layer Urban Canopy
UHI	Urban Heat Island
UHI-ASAR	UHI Adaptation Strategies Assessment Report
UHI-FCAR	UHI Future Climate Assessment Report
UHI-OFS	Urban Heat Island Forecasting System
WHO	World Health Organisation
WRF	Weather Research Forest

Table of Figures

References

Akompab, D., Bi, P., Williams, S., Grant, J., Walk. (2012). Awareness of and attitudes towars heat waves within the context of climate change among a cohort of residents in Adelaide, Australia. Retrieved from https://doi.org/10.3390/ijerph10010001

Bao, J., Li, X., Yu, C. (2015). The construction and validation of the heat vulnerability index: a review. *Int. J. Environ. Res. Public Health 12, 7220–7234*. Retrieved from https://doi.org/10.3390/ijerph120707220

Chester Gooden CityGreen. (2021, February 10). Can tree canopies help to offste increases in urban heat? Retrieved from https://citygreen.com/can-tree-canopies-help-to-offset-increases-in-urban-heat/

Chow, W.T.L., Chuang, W.-C., Gober, P. (2012). Vulnerability to extreme heat in metropolitan Phoenix: spatial, temporal, and demographic dimensions. *Prof. Geogr. 64,286–302.* Retrieved from https://doi.org/10.1080/00330124.2011.600225

Energy Supply Association of Australia. (2012). Analysis of initiatives to lower peak demand. Retrieved from http://www.esaa.com.au/Library/PageContentFiles/20071394-e301-4cd1-bc7a-80bfbb352be6/120529_Deloitte_AnalysisodInitiativestolowerPeakDemand.pdf

Georgetown Climate Center. (2022). GREEN INFRASTRUCTURE TOOLKIT. Retrieved from https://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/introduction.html?chapter

Growing Green Guide project Partners. (2014, February). A guide to green roofs, walls and faceds in Melbourne and Vistoria, Australia. doi:ISBN 978-1-74326-715-8

Hatch, P. (2016). Dulux Stung With $400,000 Fine for Claiming Its Paint Would Cool Down Houses. Retrieved from http://www.theage.com.au/business/consumer-affairs/dulux-stung-with-400000-fine-for-claiming-its-paint-would-cool-down-houses-20161102-gsgt0b.html

Hatvani-Kovacs, G., Belusko, M., Skinner, N., Pock. (2016). Heat stress risk and resilience in the urban environment. Sustain. Cities Soc. 26. Retrieved from https://doi.org/10.1016/j.scs.2016.06.019.

Hatvani-Kovacs, G., Bush, J., Sharifi, E. and Bola. (2018). Policy recommendations to increase urban heat stress resilience.

Hatvani-Kovacs, G., Bush, J., Sharifi, E. and Bola. (2018). Policy recommendations to increase urban heat stress resilience.

Huang, G., Zhou, W., Cadenasso, M.L. (2011). Is everyone hot in the city? Spatial pattern of land surface temperatures, land cover and neighborhood socioeconomic. *MD. J. Environ. Manag. 92, 1753–1759*.

I.D. Stewart & T.R. Oke. (2012, December). *Research Gate - Local Climate Zones for Urban Temperature Studies.* doi:10.1175/BAMS-D-11-00019.1

Keramitsoglou, I., Kiranoudis, C., Maiheu, et.al. (2013). Heat wave hazard classification and risk assessment using artificial. *Environ. Monit. Assess. 185, 8239–8258*. Retrieved from https://doi.org/10.1007/s10661-013-3170-y

Loughnan, M., Tapper, N., Phan, T., McInnes, J.A. (2014). Can a spatial index of heat-related vulnerability predict emergency service demand in Australian capital. *Int. J. Emerg. Serv. 3, 6–33.* Retrieved from https://doi.org/10.1108/IJES-10-2012-0044.

Ministry of Environment & Energy. (2016). National Climate Change Adaptation Strategy (Excerpts). Athens. Retrieved from https://www.bankofgreece.gr/RelatedDocuments/National_Adaptation_Strategy_Excerpts.pdf

Ministry of Environment and Energy. (2019, December). National Energy and Climate Plan. Athens. Retrieved from https://ec.europa.eu/energy/sites/ener/files/el_final_necp_main_en.pdf

National Climate Change Adaptation Research Facili. (2015). Managing heatwave impacts under climate change. Retrieved from https://www.nccarf.edu.au/sites/default/files/attached_files_publications/HEATWAVE_A4-Webview.pdf

Pisello, A.L. (2017). State of the art on the development of cool coatings for buildings and cities. *Sol. Energy 144 pp 660-680*. Retrieved from https://doi.org/10.1016/j.solener.2017.01.

Saman, W., Boland, J., Pullen, S., et. al. (2013). A Framework for Adaptation of Australian. *Natl. Clim. Chang. Adapt. Res. Facil*. Retrieved from http://eprints.qut.edu.au/62001/

Taylor, J., Wilkinson, P., Davies, M., et. al. (2015). Mapping the effects of urban. *Urban Clim. 14, 517–528.* Retrieved from https://doi.org/10.1016/j.uclim.2015.08.001.

Tomlinson, C.J., Chapman, L., Thornes, J.E., Baker. (2011). Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham. *Int. J. Health Geogr. 10, 42.* UK.

Wells R. (2016). Heatwave Sparks Record-breaking Water Use in Melbourne Households. Retrieved from http://www.smh.com.au/environment/weather/heatwave-sparks-recordbreaking-water-use-in-melbourne-households-20140128-31l1p.html

WHO. (2022). *World Health Organisation*. Retrieved from Heatwaves: https://www.who.int/health-topics/heatwaves#tab=tab_1

World Health Organisation. (2022). Urban Health Initiative. Retrieved from https://www.who.int/initiatives/urban-health-initiative

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".