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URBAN OVERHEATING & ADAPTATION MEASURES

An analysis at EU, national, and local level

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LIST OF ABBREVIATIONS

CCP	Climate Change Plan
EC	European Commission
ECA	Europe and Central Asia
EEA	European Environment Agency
EU	European Union
GCP	Global Challenges Program
UHI	Urban Heat Islands
UO	Urban Overheating
WB	World Bank

ABSTRACT

In the context of escalating climate challenges, urban heat islands are reshaping the thermal landscapes of Europe's cities and communities. As we navigate their increasing incidence and severity, a cohesive and informed response is required to addresses immediate impacts and lay down the foundations for resilient urban development.

This report on **Urban Overheating & Adaptation Measures** explores the adaptation strategies employed across the European Union (EU) to mitigate the impacts of urban heat.

This analysis has two objectives: to clarify the challenges posed by urban overheating within the EU and to study the adaptation efforts spanning various governance levels. Through the examination of policies, initiatives, and practices at the EU, national, and city levels, this analysis provides an assessment of the current state of play, highlights exemplary cases of innovation and resilience, and identifies pathways for enhancement and collaboration.

Urban overheating not only exacerbate environmental and health risks but also pose significant socioeconomic challenges. In response, the European Commission, its member states, and cities have mobilized a diverse array of adaptation strategies, ranging from green infrastructure development to policy reforms and community engagement initiatives. This report delves into these measures, offering insights into their effectiveness, scalability, and potential for replication.

EXECUTIVE SUMMARY

The initial purpose of this report was to try to identify the financing gap for addressing urban overheating challenges in EU cities. To achieve this, analytical efforts have initially focused on EU level and national level strategies, policies, and plans, to determine whether financing needs are adequately identified. These first analytical forays have shown that while for Mitigation efforts, needs are fairly well identified (both at the national level, and increasingly at the local level, through Local Action Plans for Transition to Climate Neutrality), for Adaptation efforts the task is more difficult to achieve. For one, there are no clear goals or easily measurable performance indicators for Climate Adaptation. In the case of Mitigation, the goal is clear: reduce greenhouse gas emissions to, or close to zero. Without clear goals and measurable performance indicators, it is difficult to define whether an adaptation measure is successful and/or impactful. Consequently, a more ambitious uptake of adaptation efforts requires also the elaboration of a framework for what constitutes adaptation success.

Given that national-level estimates of adaptation needs are limited (although the World Bank report "Climate Adaptation Costing in a Changing World" does provide EU-wide estimates), the **next analytical step taken was to conduct a survey with EU cities, to better understand Adaptation and Urban Overheating needs**. The survey focused on the roughly 300 cities that have applied for the "100 Climate Neutral and Smart Cities by 2030" Mission, as it was assumed that cities that have the ambition to become climate neutral by 2030, would also be committed to addressing adaptation and urban overheating challenges. And indeed, 42% of surveyed cities said they have experienced heatwaves in the past 5 years, 48% said they have conducted urban heat island studies, and 59% already have some consideration of urban heat in city strategies. However, when asked to provide estimates of the budget allocated to address urban overheating challenges, all respondent cities provided figures that were disproportionately low compared to budgets allocated for mitigation challenges. **Without clear Adaptation targets, it is also difficult for these cities to properly assess Adaptation needs.** Even for Mitigation, EU cities have only recently started to prepare detailed Action Plans for Transition to Climate Neutrality, which include detailed estimates of what it would cost to achieve climate neutrality. Thus, for example, Stockholm (Sweden) estimates that it will require €15 billion to achieve the transition to climate neutrality by 2030, while Cluj-Napoca (Romania) estimates a total cost of around €5 billion. Other cities have estimated lower costs – e.g. €3.5 billion in Marseilles (France), €1.3 billion in Sønderborg (Denmark), €1.2 billion in Mannheim (Germany), or €0.5 billion in Klagenfurt (Austria).

Given that all EU Member Countries are committed to achieving the Mitigation goals set out in the European Green Deal, it is important that the next cohesion policy have a stronger focus on Adaptation Measures, and a first step in this direction is the elaboration of a Framework for what is Adaptation success. For the current cohesion policy, it would be possible to achieve scale in Adaptation and Urban Overheating measures, by coupling adaptation measures to planned mitigation measures (e.g. the installation of solar panels on a building could be doubled by the painting of the rooftop with sub-absorbent materials). Such joint mitigation-adaptation interventions could be implemented with limited additional costs required. Annex 5 includes a detailed list of possible joint mitigation-adaptation interventions.

INTRODUCTION

Are European cities adequately equipped to address the challenges posed by Urban Overheating? The hypothesis informing this work builds on the fact that while climate mitigation objectives today significantly shape urban development strategies, adaptation measures, particularly those addressing urban heat, are not receiving adequate attention or resources. This report aims to shed light on current efforts at different levels of government, assessing their effectiveness and identifying areas for improvement. By examining these measures, the analysis aims to contribute to the ongoing dialogue and action on climate change resilience and sustainability.

The reality of climate change presents significant challenges across the globe, with the EU being no exception. The region faces a variety of impacts, including increased incidence of heatwaves, severe storms, flooding, and droughts. These events not only pose threats to human health and safety but also have far-reaching effects on ecosystems, agriculture, infrastructure, and economies. The World Bank's flagship "Thriving" report has developed a composite climate change-related hazard exposure index (covering the following hazards: floods, heat stress, tropical cyclones, sea-level rise, water stress, and wildfires), and the results for ECA cities (1,344 cities out of a global sample of 10,000 cities) indicate that many ECA cities will face higher risk of drought and heat stress by 2040. The "European Climate Risk Assessment" prepared by the European Environment Agency indicates that the record hot summer of 2022 was responsible for around 60,000 to 70,000 premature deaths. The European Commissions "Ninth report on economic social and territorial cohesion", (April 2024), indicates that the impact of climate change will be profound in Europe (see maps below). Moreover, most of Europe is heating twice as fast as the global average, with southern and south-eastern regions projected to be hotspot regions facing maximum potential impacts from extreme heat and other climate-related events. With three quarters of Europe's population living in urban areas, the impacts of climate change and extreme heat are increasing, affecting lives, livelihoods, and infrastructure. Timely adaptation measures can help offset these negative impacts.

This report covers several key aspects of climate change adaptation, with a specific focus on UHIs in European cities:

State of play in the EU: This includes an exploration of the overarching EU policies and directives related to climate change adaptation, such as the EU Adaptation Strategy and the European Green Deal. It also examines how these policies are translated into action at

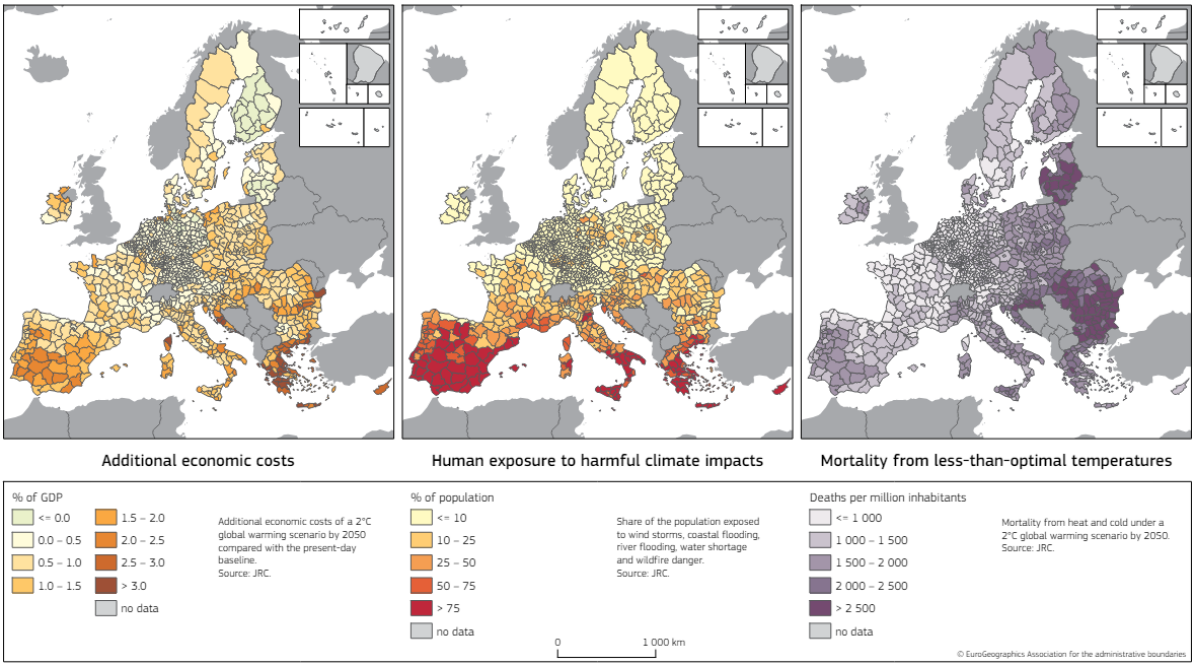


Figure 1. The impact of climate change under a 2°C global warming scenario in NUTS 3 regions, 2050

the national level in EU countries and at the local level in EU cities.

Best practices in EU cities: A look at best practices adopted by cities across the EU in implementing climate adaptation measures. This includes innovative solutions, successful projects, and strategies that have effectively enhanced local resilience against climate change impacts.

Results from a questionnaire for local administrations: A questionnaire gathering insights from local administrations across the EU collected data on their needs, challenges, and opportunities in implementing climate change adaptation measures. The questionnaire targeted close to 300 cities that have formally applied for the EC's "100 Climate Neutral and Smart Cities by 2030" and are committed to combat climate change. Of the 64 cities that responded, 83% indicated that they have a formal strategy/plan in place focused on addressing climate change, along with a comprehensive package of measures. 89% of cities that responded also participate formally in climate related networks of pilot projects.

OVERVIEW OF URBAN OVERHEATING

Urban overheating (UO) is an environmental phenomenon where urban areas experience significantly higher temperatures compared to their rural surroundings, with some studies estimating urban temperatures almost 10°C higher than rural temperatures.[1] This effect is primarily due to the absorption and re-emission of solar energy by buildings, roads, and other urban infrastructure. Urban Overheating is characterized by increased surface temperatures during the day and elevated ambient temperatures at night. The intensity of the Urban Overheating effect can vary based on city size, urban design, and geographical location.

The European Commission (EC) estimates that regions, such as Constanța (Romania), may lose over 3% of their GDP, yearly, because of climate change, with up to a quarter of the county population being impacted by exposure to growing temperatures, and up to 1,600 deaths yearly being caused by this exposure. **46% of the cities that responded to the survey on urban heat management (see relevant chapter) indicated that they experienced a dramatic, climate-related event (not just heat related) in the past 5 years which resulted in local loss and damage, which includes heatwaves.**

At the EU level, up to 0.9% of GDP may be lost yearly due to climate change, with over 25% of the EU population affected[2]. The current number of preventable deaths caused by excess heat or cold are estimated at 334,000 people per year, for all the EU. Overall mortality is projected to increase to 438,000, if climate change dynamics continue, with a larger proportion of deaths caused by heat than in the present. Elevated urban temperatures and heatwaves can also lead to increased energy consumption for cooling, exacerbate air pollution and greenhouse gas emissions, and pose significant health risks.

As urban populations continue to grow, the impact of urban overheating becomes increasingly relevant. Approximately 75% of the EU population lives in urban areas, making the study of urban overheating particularly relevant for EU policy and urban planning. The EU's diverse range of urban environments presents unique challenges and opportunities in understanding and addressing urban overheating. **59% of cities survey respondents indicated that the impact of urban heat islands is treated directly in their climate change strategies/plans.** Many European cities are characterized by high-density urban areas with historical architecture, which can influence local microclimates. And the diversity of European climate from Mediterranean to Continental necessitates tailored approaches in urban planning and locally-led adaptation strategies to combat the UO phenomenon.

[1] Copernicus Climate Change Service, "Demonstrating heat stress in European Cities" https://climate.copernicus.eu/demonstrating-heat-stress-european-cities

[2] European Commission. 2004. Ninth report on economic social and territorial cohesion

On an editorial note, it is important to note here that this work initially explored the impact of Urban Heat Islands (UHI), and some of the tools used in the preparation of this report reflect that. For example, the questions in the survey focus specifically on the impact of UHIs. While the term Urban Heat Islands is still extensively used in work on climate adaptation, to describe "excess" heat that negatively impacts cities, recent literature[3] indicates that urban heat islands do not always have negative effects. In some cities (for example Nordic cities), the negative impact of UHIs is limited and is often outweighed by positive impacts (e.g. lower energy costs and lower GHG emissions from heating). Consequently, Urban Overheating (UO) is used throughout the report, although the term Urban Heat Islands (UHIs) is kept when referencing some of the tools used in the preparation of this report.

THE EUROPEAN UNION ADAPTATION CONTEXT

The European Union has been proactive in addressing climate change, with a significant focus on mitigation to reduce GHG emissions and transition to renewable energy sources. **Adaptation to climate change is equally vital but received somewhat less public and policy attention in the policy discussion space to date.** The EU's adaptation strategy recognizes the importance of addressing urban overheating as part of creating resilient urban spaces and EU initiatives aim to guide member states and local governments in integrating UO mitigation and adaptation into broader climate action plans.

Part of the reason that mitigation receives more attention relates to the capacity to clearly measure the impact of mitigation measures (i.e. reduction of GHG emissions). The ability to have a clear target for mitigation measures, also means that it is much easier to prepare comprehensive action and investment plans. In fact, this is what is required from the cities accepted in the "100 Climate Neutral and Smart Cities by 2030". They must prepare comprehensive action and investment plans that detail how they will achieve climate neutrality by 2030, and how much they estimate this will cost. For example, Stockholm (Sweden) estimates that it will require €15 billion to achieve the transition to climate neutrality by 2030, while Cluj-Napoca (Romania) estimates a total cost of around €5 billion. Other Mission cities have estimated lower costs – e.g. €3.5 billion in Marseilles (France), €1.3 billion in Sonderborg (Denmark), €1.2 billion in Mannheim (Germany), or €0.5 billion in Klagenfurt (Austria).

Achieving the same level of precision for Adaptation Plans (i.e. identifying overall adaptation needs) requires the identification of precise goals or performance indicators. For example, and Adaptation Plan could aim that by a certain date the number of preventable deaths caused by excess heat or cold be reduced by a certain percentage. Similarly, a plan focused on reducing the impact of urban overheating, could propose that temperature difference between different parts of the city does not vary by more than 2°C. Measuring the achievement of these objectives poses a significant technical challenge and will require the allocation of additional resources.

Another possible option for having more ambitious adaptation measures is the coupling of adaptation and mitigation measures. For instance, installing solar panels (a mitigation measure) reduces reliance on fossil fuels and related emissions. Combined with adaptation measures like painting roofs white or establishing rooftop gardens, these initiatives not only contribute to reducing greenhouse gas emissions but also help in building resilience in urban environments to UO. This dual approach provides a holistic solution to both causes and effects of climate change. **Encouragingly, 67% of survey**

[3] See for example: Martilli, Alberto, et al. 2004. *Is the Urban Heat Island intensity relevant for heat mitigation studies?* Urban Climate, Volume 31, March 2020.

respondents have thought of coupling adaptation measures to planned mitigation measures, for higher overall impact at a reasonable cost.

With the 2021-2027 Programming Period well underway, this coupling of adaptation measures to planned mitigation measures can be one of the most efficient ways to achieve adaptation impact at scale. The added cost for integrating adaptation considerations in a mitigation project/program are usually marginal. For example, the design of a new pedestrian area, or a bike path, could include provisions for the use of materials that are sun and water absorbent. Annex 5 includes a comprehensive list of adaptation, mitigation, and joint adaptation-mitigations measures, which can serve as inspiration for local administrations.

It is also important to keep in mind that effective adaptation requires an integrated policy approach across different levels of government. EU-level strategies and targets provide a framework and support, but adaptation strategies must be tailored at national and city levels to build resilience against local climate risks and vulnerabilities. This multi-level approach ensures that adaptation measures are relevant, locally-led, effective, and sustainable.

GLOBAL NETWORKS AND TOOLS FOCUSED ON URBAN HEAT

Taking lessons from the World Bank's new Global Challenges Programs (GCPs) approach can be helpful in thinking about addressing pressing multi-actor and multi-sectoral challenges such as climate adaptation broadly and UO specifically. As example the GCP focusing on water security and adaptation will focus on improving access to safe drinking water, sanitation, and climate-resilient irrigation services, and enhancing water security through shifting to integrated, multisectoral approaches, requiring strong political leadership and new strategic partnerships. The GCPs also emphasizes the necessity of private sector involvement and financing to address the water crisis and meet Sustainable Development Goals.

Networks and platforms to support stakeholders in climate action has proliferated, and several such resources exists with a focus on UO specifically. A few key networks are listed here:

The **Heat Action Platform** (https://heatactionplatform.onebillionresilient.org/) is an interactive tool designed by the Adrienne Arsht-Rockefeller Foundation Resilience Centre for city officials, practitioners, and financial institutions. It provides guidance and solutions for mitigating the impacts of extreme heat at regional or municipal levels. This platform enables users to develop heat action plans, project or policy interventions focused on heat resilience, integrate heat resilience strategies into existing plans, and advocate for community heat resilience investments. It targets urban planners, climate and resilience officers, government officials, policymakers, and development finance institutions.

For practitioners, the platform offers a framework, technical resources, and case studies for creating actionable heat resilience plans or projects. This includes best practices, local solution inventories, and evaluation frameworks. Policymakers are supported with information on heat risks and opportunities, best practices for heat-risk reduction, and evaluation frameworks for setting and demonstrating impactful targets. Development finance institutions can use the platform as a resource for guiding government partners in developing effective heat action plans or projects.

Cooling is essential for maintaining health, food nutrition, stable energy, and productive economies, especially in a warming world. Inefficient and polluting cooling methods also pose dangers, with cooling-related emissions set to double by 2030 and triple by 2100 due to factors like heat waves, population growth, urbanization, and rising middle-class demands. Cooling is predicted to become a major driver of global electricity demand in the next thirty years, with space cooling alone consuming as

much electricity as China and India combined by 2050.

The **Cool Coalition** (https://coolcoalition.org/), formed by UNEP and various global leaders, aims to address this challenge. Launched at a global conference, it promotes efficient and climate-friendly cooling solutions. This coalition, now comprising over 100 partners including 23 countries, focuses on reducing the need for mechanical cooling, shifting to renewable energy sources, improving conventional cooling methods, and protecting vulnerable populations from extreme heat. It emphasizes a collaborative approach, uniting governments, cities, businesses, academia, and civil society in achieving sustainable cooling solutions that align with the Sustainable Development Goals, the Kigali Amendment to the Montreal Protocol, and the Paris Climate Agreement.

The coalition's actions centre around three pillars: advocacy for efficient cooling, mobilizing action and commitments from various leaders, and facilitating knowledge exchange across sectors. Its work is propelled by member-led working groups focusing on key areas in the cooling sector since September 2019.

CITIES4BIODIVERSITY - C4B (thegpsc.org/c4b), launched in September 2021, is a World Bank partnership initiative to help cities integrate green and climate solutions into their planning and project design. It focuses on developing a network of cities to advance urban green infrastructure, address biodiversity loss and climate change, incorporate ecosystem services in land-use planning, use nature-based solutions for urban investment, and explore financial models for investing in nature.C4B offers support through deep-dive learning, knowledge sharing, and targeted technical assistance to participating cities. This work is led by the Global Platform for Sustainable Cities (GPSC) and the Global Program on Nature-Based Solutions for Climate Resilience, under the World Bank's Urban, Disaster Risk Management, Resilience and Land Global Practice (GPURL), alongside various partner organizations.

The initiative includes cities from both developing and developed countries, prioritizing those with existing relevant projects and ambitious commitments to ecosystem integrity and climate resilience, aiming for nature-positive, carbon-neutral urban environments. The initiative facilitates global knowledge creation and capacity-building for sustainable urban development.

UNDERSTANDING URBAN OVERHEATING

DEFINING URBAN OVERHEATING

UO occurs when urban regions experience higher temperatures than their surrounding rural areas, a condition primarily caused by the modification of land surfaces and human activities. This effect is most pronounced during the night and is attributable to various anthropogenic and structural factors in urban environments.

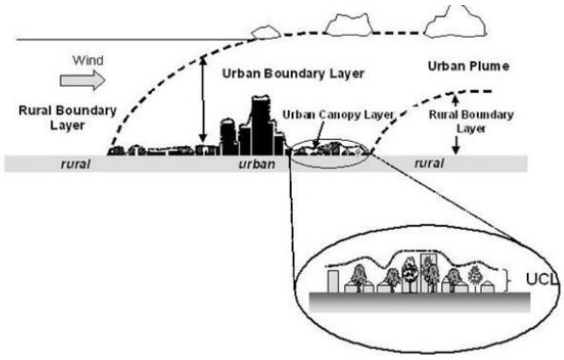
The concept of UO is not just limited to 'hotter cities' but encompasses a range of climatic alterations caused by urbanization. UO can broadly be categorized into:

i) surface overheating, observable at the ground or rooftop level and measured using various platforms such as meteorological stations, aircraft and satellite date which measures the temperature of the surface as seen from above; and
ii) atmospheric urban overheating, which occur near the surface or at the urban canopy level primarily observed through air temperature measurement

Both air and surface UO result from multiple factors, including solar radiation absorption, building materials, and low vegetation cover. Understanding their distribution is key for informed urban planning decisions, considering factors like building orientation and urban green spaces. The intensity of UO varies diurnally and seasonally, typically showing higher intensities during the evening and night-time due to the slow release of heat from urban materials.

Urban overheating can be further categorized into different types based on the urban atmosphere layers they affect, including surfaces and subsurface. It's crucial to distinguish these types as they stem from different mechanisms. Generally, UO refers to the heightened warmth in urban atmospheres compared to rural surroundings, particularly noticeable at night under calm, clear conditions. As identified by Oke et al., (2017) and Bechtel, B. et al., (2019), there are four main types of UHIs: Surface Urban Heat Island, Sub-Surface, Canopy layer, and Boundary Layer, each resulting from unique physical processes and exhibiting specific temporal and spatial patterns, primarily driven by urbanization's alteration of natural landscapes. As indicated earlier, not all UHIs have a net-negative impact in cities, which is why in the report we focus primarily on Urban Overheating.

Figure 2. Schematic description of the four types of urban heat islands



Source: Grow Green - Final Report. Available at: https://growgreenproject.eu/wp-content/uploads/2021/05/GrowGreen_WP3_UHI_method_Tec_140720.pdf

CAUSES AND CONTRIBUTING FACTORS

The development of UO is attributed to a combination of factors, including urban design, materials, and human activities. Urban areas, with their high concentration of buildings and roads, absorb and store heat more than rural areas, primarily from concrete and asphalt, which have high heat capacity and thermal conductivity, leading to significant absorption and slow release of heat. Additionally, the low albedo (reflectivity) of these surfaces results in higher absorption of solar radiation, further contributing to increased surface temperatures.

Another critical factor in the formation of UHIs is the reduction of vegetation in urban areas. Vegetation plays a crucial role in urban cooling through evapotranspiration, a natural process that provides cooling effects. The decrease in natural land cover and green spaces in urban areas leads to lower evapotranspiration rates, diminishing these natural cooling effects.

The design and layout of cities also significantly influence urban overheating. The arrangement and density of buildings in urban areas affect airflow and heat distribution. For instance, narrow streets flanked by tall buildings, often referred to as "street canyons," can trap heat and reduce wind flow, thereby exacerbating UO effects.

The "*How Urban Growth Changes the Heat Island Effect and Human Thermal Sensations Over the Last 100 Years and Towards the Future in a European City*" presents a study on the impact of urbanization on surface air temperatures and human thermal comfort in Sofia, Bulgaria. Using the Weather Research and Forecasting model, the study analyses the changes in urban heat island effect and thermal comfort levels from 1878 to 2050. It reveals that urbanization increased surface air temperatures by approximately 4.0°C from 1878 to 2012 and predicts a further 0.4°C rise by 2050. The study also evaluates the discomfort levels using the Temperature-Humidity Index, suggesting that future urban changes may not significantly alter Sofia's temperature climate. The findings contribute to understanding urban warming and its implications for urban planning and human health.

The study's findings align with research on cities like Paris and Tokyo, indicating that well-developed cities with limited expansion potential will not see major urbanization-driven temperature increases. The study also explores the urban heat island effect, differentiating Sofia's situation from cities where urban expansion and distinct topography play a larger role in temperature changes. Future work will focus on urban-mountain interactions in the context of global warming.

IMPACT OF CLIMATE CHANGE ON URBAN OVERHEATING

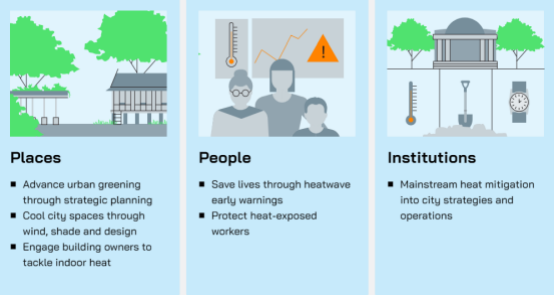
Climate change significantly exacerbates the UO effect, creating a feedback loop where increased urban temperatures contribute to global warming, which in turn intensifies UO effects. This synergy between UO and climate change is particularly concerning as it leads to more frequent and intense heatwaves, which amplify UO effects, especially in densely populated urban areas. These conditions pose serious risks to public health, including heat stress, respiratory problems, and increased mortality rates, particularly among vulnerable populations.

Research from various EU cities demonstrates the growing impact of climate change on UHIs. For instance, the European Environment Agency's data shows increased temperature differentials between urban and rural areas, confirming the escalating UO effect.

The intensification of UO poses significant public health risks, including heat stress and air quality deterioration. Studies by the World Health Organization have linked these changes to increased morbidity and mortality in urban populations. The EC's "Ninth report on economic social and territorial cohesion" indicates that preventable deaths from cold and heat amount to 334,000 people per year, with mortality estimated to grow to 438,000 people by 2050, due to climate change.

The environmental consequences of UO extend beyond public health. They include changes in local weather patterns, such as altered wind patterns and precipitation rates, and can exacerbate air quality issues. The impact on urban ecosystems is also significant, affecting biodiversity and the health of urban green spaces. The World Bank's "Unlivable" reports provides a framework for strengthening urban heat resilience (see below).

Figure 3. Framework for Urban Heat Resilience



Source: World Bank. 2023. Unlivable: What the Urban Heat Island Effect Means for East Asia's Cities

MEASUREMENT AND MONITORING OF URBAN OVERHEATING

Understanding and addressing UHIs require effective measurement and monitoring strategies. Advances in technology have enabled more precise and comprehensive monitoring of UO. Remote sensing and satellite data play a pivotal role in mapping and analyzing UO effects from a broader perspective. These technologies provide detailed thermal images that help in identifying hotspots and understanding the spatial distribution of UHIs.

Ground-based observations, including weather stations and temperature sensors, complement satellite data by providing localized measurements of UHI intensities. These observations are crucial for validating and calibrating remote sensing data. Additionally, urban climate monitoring networks contribute to a more nuanced understanding of UO dynamics over time.

Computer modelling and simulation have also become indispensable tools in UO research. They allow for the prediction of UO effects under various urban development scenarios and the assessment of potential mitigation strategies. These models help urban planners and policymakers in making informed decisions to combat UO effectively.

Data and mapping: urban heat mapping requires comprehensive data on temperature, land use, and urban infrastructure. This process involves sophisticated tools and expertise in geographic information systems (GIS), remote sensing, and environmental science.

Cost and support: mapping urban heat islands can be expensive due to the need for advanced technology and expertise. Universities often play a crucial role in supporting this process through research and collaborations, utilizing academic resources and expertise in environmental studies and geospatial technologies.

Adaptation planning: urban heat mapping is vital for adaptation planning, allowing cities to identify heat-vulnerable areas and implement targeted cooling strategies. It involves stakeholders like local governments, urban planners, researchers, and community organizations. Accessing data may involve partnerships with satellite data providers, weather stations, and research institutions.

The World Bank report on "*Urban Heat in South Asia: Integrating People and Places*" addresses the rising issue of urban heat in South Asian cities. It emphasizes the need for understanding and managing the urban heat island effect, which disproportionately affects vulnerable groups such as children, informal workers, and residents of informal settlements. The key recommendations include improving data collection and analysis to understand urban microclimates, integrating people and place in urban heat management by addressing both social and spatial vulnerabilities, and managing the long-term impacts of urban heat, particularly on human capital, social welfare, and economic development. The document underscores the importance of integrating urban heat resilience into city planning and policy-making processes.

The World Bank report “Analysis of Heat Waves and Urban Island Effects in Central European Cities and implications for Urban Planning”, discusses in more detail the implications of urban overheating in Central European Cities, and provides a framework for addressing impacts in an integrated manner (see figure below).

Figure 4. Framework for dealing with urban overheating

Source: World Bank. 2020. Analysis of Heat Waves and Urban Island Effects in Central European Cities and implications for Urban Planning.

A study in Hannover, Germany (Kabisch, N., Remahne, F., Ilsemann, C. et al, 2023), analysed the urban heat island effect during extreme heat conditions, comparing data from 2017 (a non-heat year) with 2018–2020 (heat years). It found a greater UHI intensity during night-time in heat years, contrasting with lower UHI intensity during daytime. Inner-city urban areas exhibited the strongest UHI effects, with significant temperature differences compared to rural areas. The research highlights the importance of urban green spaces as local cooling zones to mitigate heat effects, especially under increasing global warming and extreme heat events.

The analysis of Urban Heat Islands using Land Surface Temperature (LST) data, especially from Landsat satellites, is vital for urban heat studies, climate monitoring, and thermal mapping. LST, indicating the Earth's surface temperature, is derived from solar radiation and is essential for understanding energy distribution between land and atmosphere. Recent advancements have led to the development of methods for retrieving LST from thermal infrared data, enhancing the accuracy of environmental assessments. This analysis is crucial for mapping urban climates, managing water resources, and evaluating vegetation health, with Landsat satellites being particularly useful for high-resolution LST data in local studies.

The analysis of UHIs involves several key processes:

- Spatial analysis: utilizing GIS software for identifying and mapping UHI patterns using techniques like zonal statistics and hotspot analysis.
- Statistical analysis: applying statistical methods to explore the relationship between LST and urban factors such as land use, vegetation cover, and building density.
- Temporal analysis: investigating the dynamics of UHIs over time through long-term trends, seasonal variations, and daily patterns.

The accuracy of UHI analysis depends on the quality of satellite imagery, calibration, atmospheric correction methods, and assumptions in LST retrieval. It is important to use both LST data and auxiliary data (like climate and land use) for robust analysis and to use average LST values from all available data for a specific season and year to minimize errors and deviations.

A brief Methodology for Urban Heat Islands analysis based on Land Surface Temperature is available as part of Annex 4. The Methodology has been developed as part of the *Functional Areas in the EU* project, by the World Bank, and presents a quick example on how to generate urban heat maps. It is important to note here that while satellite imagery is very useful in helping design urban heat responses, there are various shortcomings and biases with this method, and more longstanding measurement approaches should be used.[4]

[4] For a more detailed treatment on these issues see: Stewart I.D. and Mills G. 2021. The Urban Heat Island: A Guidebook. Elsevier.

STATE OF PLAY IN THE EUROPEAN UNION

POLICY FRAMEWORK

The 2003 European heatwave, which is estimated to have caused 70,000 preventable deaths, has been a catalyst for a number of Adaptation policies in the EU. The World Health Organization Regional Office for Europe has played an important role in drafting guidance and heat-health action planning that served as a foundation for subsequent EU-wide policies. Currently, the European Union's approach to climate change adaptation is encapsulated in the **EU Adaptation Strategy**. It focuses on three primary objectives:

- promoting action by Member States: the strategy encourages all Member States to adopt comprehensive adaptation strategies and provides funding and resources to help them build their adaptation capacities.
- climate-proofing action at the EU level: this involves integrating climate resilience into all major EU policies and initiatives, ensuring that Europe's infrastructure and ecosystems are robust against the changing climate.
- promoting adaptation globally: the EU strives to increase its support for international climate resilience, especially in developing countries most affected by climate change.

Moreover, the **European Green Deal** represents an ambitious package of measures that includes a roadmap for making the EU's economy sustainable by turning climate and environmental challenges into opportunities. It introduces initiatives such as the "Renovation Wave" for energy-efficient building upgrades and the "Mission on Climate-Neutral and Smart Cities," which directly addresses urban challenges like UHIs. While there are clear allocations for mitigation measures (i.e. a minimum of 37% from the Cohesion Fund, and a minimum of 30% from the ERDF have to be earmarked for climate mitigation interventions), amounting to around **€118 billion for the 2021-2027 Programming Period**, there are no clear allocations for adaptation measures. Since Member States have to prove and measure mitigation earmarks, the cohesion policy includes a comprehensive list of 143 interventions (see Annex 6), with indication of the extent to which that intervention responds to addressing climate change goals. **Of this list of 143 interventions, only 6 directly address adaptation goals, and only 4 addresses directly Urban Overheating**. Another 12 interventions could potentially accommodate joint mitigation-adaptation approaches.

To see a more ambitious uptake of adaptation measures, it would help if **the next cohesion policy would propose clear earmarks for adaptation measures**, as it does for mitigation measures. For the current Programming Period, an efficient solution would be to propose the adoption of joint mitigation-adaptation approaches, wherever this is possible.

Beyond the cohesion policy, the **Climate Law** sets the legal framework for achieving the EU's goal of climate neutrality by 2050. Climate change adaptation is integrated into various EU policies, including agriculture, forestry, water management, and regional development, ensuring a holistic approach to tackling climate change impacts.

GOVERNANCE AND NETWORKS

The **EU Annual Report on the State of Regions and Cities** highlights the vital role of local and regional leaders in implementing green and digital transitions. This includes advocating for cohesion policies to ensure a sustainable future. The report underlines the importance of involving local and regional governments in policy-making processes to achieve a more inclusive and sustainable future for European

regions and cities. It also emphasizes empowering local actors to address social, economic, and environmental challenges effectively. It further includes challenges and opportunities faced by European regions and cities: the impact of the Russian war on Ukraine, the energy crisis, climate change, food safety, the European Green Deal, digital transitions, cohesion policy, and rural development.

The EU report on "**Cohesion in Europe towards 2050**" outlines long-term strategies for ensuring that all regions in the EU can adapt to climate change effectively, emphasizing the importance of cohesion policy in building a resilient Europe, and with clear references made also to UHI.

The report “Climate Adaptation Costing in a Changing World”, financed by the European Commission, and prepared by the World Bank, estimated in 2024 that annual climate adaptation costs in the EU to be around €21 billion, through 2030 – with a lower bound annual cost of around €15 billion, and an upper bound cost of around €64 billion.

The **Taxonomy Regulation and its Delegated Acts**, including those specifically related to climate change mitigation and adaptation, are crucial legal frameworks. They set clear criteria for what constitutes a sustainable economic activity, guiding investment, and policy decisions towards climate-resilient development.

The **European Environment Agency's report on assessing the costs and benefits of climate change adaptation** offers insights into the economic rationale for investing in adaptation measures, including UHI, guiding strategic decisions at both EU and national levels. The EEA’s “European Climate Risk Assessment” identifies heat stress as the major climate change risk in coming years, and notes that the exceptionally hot year 2022 was responsible for around 60,000 to 70,000 premature deaths.

The **Eurostat report on climate change losses** provides vital data on the economic impacts of climate change in the EU. This data is critical for understanding where adaptation strategies are most needed and how they can be cost-effective.

The **ESPON Climate Data Set** offers detailed insights into how climate change is affecting different regions of Europe. This information is crucial for tailoring adaptation strategies to specific regional needs.

The **Committee of the Regions** plays a crucial role in shaping the EU's adaptation policies. It is responsible for voicing the opinions of regions and cities on EU law that may impact them. Committee of the Regions' legislative work is carried out through six thematic commissions, covering a broad range of areas relevant to local and regional authorities. This includes the Commission for the Environment, Climate Change and Energy, which coordinates the Committee's work in fields related to the European Green Deal. The **Committee of Regions' Regional and Local Barometer 2023** further provides an analysis of how regions and localities are responding to climate challenges, highlighting the variances and similarities in adaptation approaches across the EU.

The **EU's Resilience Dashboards**, part of the strategic foresight reports, are innovative tools for assessing the resilience of various sectors and systems in the EU to climate change. They serve as a guide for prioritizing areas for adaptation action.

The **Covenant of Mayors for Climate and Energy** represents a network of local and regional authorities committed to implementing sustainable energy policies.

The **European Climate Adaptation Platform** (Climate-ADAPT) is a platform to support Europe in adapting to climate change, providing information on expected climate change, current and future vulnerability, and best practices.

INITIATIVES AND FUNDING

Several EU-wide initiatives, programs, and financial support for UO and adaptation measures aim to enhance climate resilience across member states. This includes significant funding for climate change adaptation through various financial instruments.

The **European Structural and Investment Funds** (ESIF), particularly the European Regional Development Fund (ERDF) and the Cohesion Fund are significant financial tools supporting urban adaptation projects, including those aimed at mitigating UHIs in EU regions. The **LIFE Programme** is the EU's funding instrument for the environment and climate action, which supports climate change adaptation, biodiversity, and environmental governance and information projects. Moreover, the **Horizon 2020** program has funded research and innovation projects focused on urban climate adaptation, providing valuable insights into UHI mitigation strategies. These projects encompass various approaches, from green infrastructure to innovative cooling technologies.

Special attention is given to regions that are most vulnerable to climate change, such as coastal areas, flood-prone regions, and areas with a high risk of droughts and forest fires.

NATIONAL ADAPTATION EFFORTS IN EU COUNTRIES

NATIONAL ADAPTATION POLICIES

The European Union's overarching climate adaptation framework is implemented variably across its member states, each tailoring their approach to address specific national and local challenges, including Urban Heat Islands.

EU countries are encouraged to develop and implement their own national adaptation strategies in line with EU directives. These strategies focus on assessing vulnerabilities to climate change and developing appropriate adaptation responses.

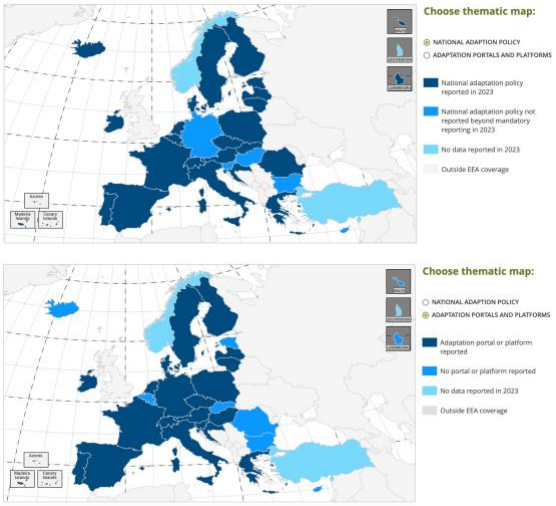
EU Member States have developed a range of national strategies and policies to address climate change adaptation, with varying degrees of focus and methodologies. In 2023, EU Member States complied with their second mandatory reporting of national adaptation actions under the Regulation on the Governance of the Energy Union and Climate Action.

While all EU countries have acknowledged the importance of adaptation to climate change, the approaches vary significantly. Some common elements across most strategies include the recognition of climate change impacts on various sectors such as agriculture, water management, and forestry, and the need for a holistic approach to adaptation.

For example, Southern European countries are more focused on addressing water scarcity and drought management, given their geographical predisposition to these challenges. Northern European countries, on the other hand, often emphasize flood management and coastal protection due to their proximity to sea-level rise threats.

The strategies generally include a mix of short-term actions and long-term planning, reflecting the urgent need to address immediate climate impacts and the requirement for sustainable adaptation measures. However, the depth and breadth of these strategies vary, with some countries having more comprehensive plans that integrate climate adaptation into various aspects of governance and policymaking.

Figure 5. National adaptation policy and adaptation portals and platforms in the EU



Source: European Commission and the European Environment Agency Climate-ADAPT, https://climate-adapt.eea.europa.eu/en/countries-regions/countries

The World Bank report "Climate Adaptation Costing in a Changing World" undertakes a detailed assessment of the needed adaptation costs in different EU countries, and as such it draws extensively on existing strategies and plans. The report indicates that properly quantifying adaptation needs is difficult, as there are no quantified global or EU objectives. An analysis of existing country studies indicates that adaptation costs per capita can range from around €34 per person in France to €64 in Austria, €110 in Slovakia, €143 in Romania, and €174 in the UK.

Annex 7 includes a number of case studies with national adaptation approaches from EU countries, which highlight the diversity of approaches used. Clearly, adaptation needs vary from country to country, and this is also reflected in the variety of approaches used. At the same time, the lack of a common adaptation framework, well defined goals, and measurable performance indicators, also makes it difficult to define, assess, and monitor progress in climate adaptation from country to

country. Some of the key takeaways from the analysis of national adaptation approaches, especially as they are related to Urban Overheating, are discussed in more detail below.

For starters, there are significant challenges in the implementation of UO adaptation policies at the national level. One primary challenge is the integration of these strategies into existing urban development and planning processes. There is often a gap between national policy frameworks and their translation into actionable local plans.

Another challenge lies in the financing of adaptation projects. While EU funding supports many initiatives, the allocation and efficient use of these funds at the national and local levels can be complex, sometimes leading to delays or suboptimal utilization of resources.

Further, there is a need for enhanced cooperation and knowledge exchange between EU member states. Sharing successful strategies and lessons learned can significantly improve the effectiveness of UO adaptation efforts across the Union.

While a majority of EU countries identify climate adaptation as a priority, and have dedicated strategies/plans, **the lack of clear earmarks from the cohesion policy for adaptation interventions, also influence the weight adaptation measures has in national priorities.**

The fact that there are no internationally agreed adaptation targets (nor are there, from the analysis done for this report, comprehensive national adaptation targets), also means it is difficult to adequately assess adaptation needs. Rather, interventions seem to be done ad-hoc.

With respect to UO interventions, most national strategies/plans do not treat the issue in detail, although most documents note the need to reduce the impact of UO. In the case of Denmark, the responsibility to prepare adaptation plans is passed on to the local level (with Danish local administrations having a strong mandate), which also implies a dedicated treatment of UO issues. In Poland, the Ministry of Environment has prepared adaptation plans for 44 cities. In Romania, the dedicated climate strategies mention the need to reduce the impact of UHIs, but UHIs are treated in detail (along with urban heat maps for all the municipalities in the country) in the National Urban Policy.

Local administrations are best placed to map urban overheating in detail, and to identify the best solutions for addressing the impact of UO. Their efforts would be aided if clear performance indicators would be proposed at the global or European level. Moreover, establishing regional or global peer-to-peer networks, focused on addressing the impact of UO, could enable a faster dissemination and scale-up of best-practices and innovative UO approaches.

The sections below discuss in more detail a number of relevant national adaptation approaches, which may serve as inspiration for other national governments.

Croatia: Program for the development of green infrastructure

The Republic of Croatia's Government has adopted the Green Infrastructure Development Program in Urban Areas. This initiative, aligned with the Construction Law, supports the implementation of Croatia's Spatial Development Strategy—a key state document guiding spatial development and pursuing the strategic objective of Ecological and energy transition for climate neutrality within the green and digital transition framework of the National Development Strategy until 2030. The program aims to enhance living standards, promote health, and contribute to sustainable social, economic, and spatial development.

Compliance with national, sectoral and multisectoral strategies

The Green Infrastructure Development Program aligns with the National Development Strategy of the Republic of Croatia until 2030 (NRS 2030), a comprehensive strategic document outlining the country's

development vision, strategic objectives, and priority areas for public policies.

The Integrated National Energy and Climate Plan for Croatia from 2021 to 2030, focusing on reducing greenhouse gas emissions and energy consumption, serves as a crucial benchmark for national policy in the medium term. The Green Infrastructure Development Program's goals and priorities align with this plan, contributing to the enhancement of urban sustainability by promoting the development of green spaces.

In April 2020, the Croatian Parliament adopted the Climate Change Adaptation Strategy for the Republic of Croatia until 2040. This strategy emphasizes incorporating adaptation to climate change into existing and new policies, focusing on green infrastructure's role in achieving adaptation goals and strengthening resilience through nature-based solutions.

The Green Infrastructure Development Program plays a role in reducing energy consumption in buildings by implementing green roofs, walls, and tall greenery for shading.

The Long-term Strategy for the Restoration of the National Building Fund until 2050 emphasizes energy efficiency in construction areas, including Nearly Zero Energy Neighborhoods (nZEN) with zero energy consumption. The strategy recognizes the significance of green infrastructure development, integrating green and blue areas into the built urban fabric to reduce temperatures, urban heat islands, and energy needs for heating and cooling.

In June 2021, the Croatian Parliament adopted the Low-carbon development strategy of the Republic of Croatia until 2030 with a view to 2050 for sustainable development based on a low-carbon economy and efficient resource use. The ZI Development Program's goals align with this strategy, contributing to the sustainability of urban areas and addressing challenges such as climate change and resource efficiency.

The Green Infrastructure Development Program is in harmony with the Strategic Spatial Development Document (SPRRH), adopted by the Croatian Parliament. The SPRRH guides spatial planning at national, regional, and local levels, emphasizing the importance of strengthening natural capital through the development of green infrastructure to create pleasant and orderly cities.

Priorities of the Program

The key priorities in the Green Infrastructure Development Program's public policy include:

1. Enhancing the management of green infrastructure development by establishing standards, planning methodologies, recording mechanisms, and monitoring processes for the state and progress of green infrastructure. This involves creating a typology and spatial database to monitor and evaluate development implementation. Efforts focus on refining the legal framework and promoting the creation of strategic documents for green infrastructure development.
2. Promoting widespread and easily accessible green infrastructure in urban areas by initiating pilot projects and subsequently encouraging the construction of green infrastructure across the entire Republic of Croatia.
3. Advancing knowledge and fostering social awareness regarding the sustainable development of urban areas through green infrastructure.

Proposed projects

Some of the projects proposed in the Program include:

- Construction of green roofs - which can be part of the energy renovation of a public or multi-residential building or as a separate activity.
- Transforming the existing non-functional green area into a functional element of green infrastructure - the objective of the project is to promote the revitalization of the current

underutilized green space in the urban area, which currently lacks a distinct purpose and fails to contribute to enhancing social, economic, and environmental benefits for the local community.

- Revitalization of cultural and industrial heritage sites - revitalization of spaces and structures of historical significance while incorporating new facilities as contemporary attractions for residing in green infrastructure zones. The project aims to transform the location into a new functional space, generating economic benefits. It will be integrated into the urban network of green infrastructure, using renewable energy sources and sustainable materials.
- Developing urban gardens on buildings - establishing urban gardens on flat roofs, terraces, balconies, and loggias of public or multi-apartment buildings. These gardens serve various purposes, such as producing food for personal consumption, facilitating educational activities in schools and kindergartens.

Outcomes of the Program

The anticipated outcomes of the Program include:

- Stimulating green investments.
- Generating employment opportunities and establishing new enterprises for the construction and maintenance of green infrastructure, as well as the production and sale of building and biological materials.
- Achieving energy savings and reducing citizens' energy expenditures.
- Mitigating heat islands and temperature effects in cities.
- Adapting to and mitigating the consequences of climate change.
- Lowering greenhouse gas emissions and preserving/restoring air, water, and soil quality.
- Enhancing urban areas by revitalizing abandoned underused, and neglected land.
- Improving the quality of life and living conditions in cities.
- Enhancing public health and reducing healthcare expenses.
- Facilitating food production through urban gardens, greenhouses, and conservatories.
- Improving the condition and market value of real estate.
- Elevating the quality of space and social standard in buildings.
- Raising awareness about the significance of green infrastructure.

Funding for Program implementation will be financed through the European Structural and Investment Funds during the 2021-2027 financial period and the Mechanism for Recovery and Resilience via the National Recovery and Resilience Plan 2021-2026.

Poland: Climate Change Adaptation Plans in 44 Polish cities

Figure 6. Main climatic hazards for Polish cities

Source: Polish Ministry of the Environment

The Polish Ministry of the Environment completed an innovative project to prepare cities for climate change. This initiative involved 44 major cities and resulted in comprehensive adaptation plans. These plans assessed each city's specific vulnerabilities to climate threats and outlined solutions for challenges like floods, heat waves, and water shortages.

The project stands out in Europe for its scale, with a national government directly supporting so many cities in climate adaptation.

Developed through collaboration between city officials, residents, and experts, the plans prioritized cities due to their high population density and greater vulnerability to climate change compared to rural areas.

It serves as a successful model for future climate change adaptation efforts across Poland.

Project partners

The following institutions were involved in the project:

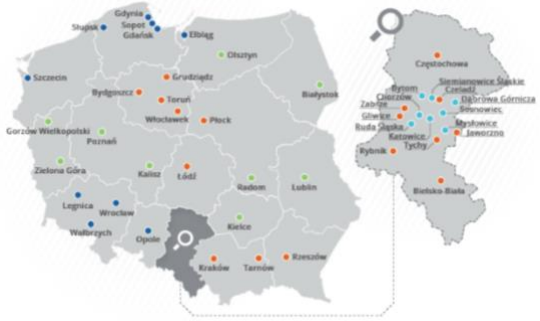
- Environmental Protection Institute
- Institute of Meteorology and Water Management
- Institute for the Ecology of Industrial Areas
- Arcadis Sp. z.o.o. - international consulting and engineering firm
- Deloitte - subcontractor for the promotional and organizational aspects.

Partner cities

44 cities were involved in the project: 37 cities with a population of 100,000 inhabitants; three cities with populations ranging between 90,000 and 100,000, and four cities with populations less than 90,000. In total, the population of these 44 cities represent 30% of the country's population.

Project implementation

The project was implemented between January 2017 - January 2019, starting with the development of an Urban Adaptation Plan.



In the next phase, each city's exposure to climate phenomena was evaluated. The assessment identified the most vulnerable sectors and social groups, along with the city's inherent capacity to adapt. Additionally, the project identified the city components most at risk from climate changes.

Following the vulnerability assessment, a risk analysis was conducted (see results below). This analysis projected future climate hazards and the associated risks for the most vulnerable components. However, it wasn't all negative; the analysis also explored potential opportunities a city could leverage in the face of climate change. By considering these factors, priorities for adaptation measures were established.

Urban adaptation measures selected for the Polish cities

Bydgoszcz: "Rain is profit" project - modernization of rainwater sewers

The construction and modernization of rainwater sewers spanning 14 km and 90 km respectively, alongside the establishment of 81 rainwater management facilities such as reservoirs, pre-treatment plants, and watering installations, will enable the utilization of approximately 37,000 m3 of captured water. Over the past few years, initiatives have been undertaken in Bydgoszcz to prepare the city for climate change impacts. The city authorities aim to diminish rainwater disposal via sewers and restructure urban spaces to function as sponges, collecting rainwater for use during drought periods. This initiative, undertaken by Miejskie Wodociągi i Kanalizacja (Municipal Water Supply and Sewerage System), received European funds from the Operational Programme Infrastructure and Environment. Commencing in 2017.

The project constructed approximately 14 km of new rainwater sewers, with 6 reservoirs, 22 rainwater treatment plants, 11 outlets to bodies of water, and modifications to existing rainwater sewers. This was followed by the cleaning and renovation of the existing rainwater sewer network, spanning approximately 90 km. Upon completion, the project is expected to capture approximately 37,000 m3 of rainwater for watering green areas or discharge into ponds after pre-treatment. These measures are anticipated to mitigate flooding risks to buildings and streets while reducing reliance on municipal water for green area irrigation.

Gdańsk: drainage system

Gdańsk's flood protection system relies on an intricate network of over 50 reservoirs, totaling around 700,000 m3 in capacity, strategically constructed on cascading streams—a unique approach among Polish cities. There are plans to expand this reservoir network further. Additionally, the drainage infrastructure includes over 20,000 wells, 18,000 street inlets, 317 km of streams and ditches, 751 km of rainwater sewers, 15 km of levees, and 3 rainwater gardens.

Between 2001 and 2015, Gdańsk invested PLN 380 million in drainage and anti-flood infrastructure, resulting in a more than fivefold increase in water capture capacity. Comparing the outcomes of two severe rain events, losses due to heavy rainfall decreased from PLN 130 million in 2001 to PLN 10 million in 2016. Furthermore, flood warning systems were extended, enhancing resident safety.

Gdańsk's Hydrological Monitoring System, undergoing modernization since 2000, is one of Poland's most advanced. It comprises 25 rainwater stations, 75 water level measurement stations across reservoirs, natural and artificial streams, as well as monitoring stations for the Gdańsk Bay and the Martwa Wisła river, alongside two weather stations.

Construction projects in Gdańsk must adhere to rainwater management regulations outlined in the "Landscape Planning Conditions and Directions for the City of Gdańsk" document. A crucial aspect of Gdańsk's comprehensive rainwater management strategy involves educating and supporting residents to construct small-scale water retention facilities independently.

Katowice: Black to Green project

In Katowice, the integration of culture and new technologies into post-industrial zones has reshaped the city's social fabric and cultivated a fresh urban identity. Leveraging the potential of these areas could bolster the city's resilience against climate change impacts, provided that adaptation measures are seamlessly woven into the entire transformation process—from cleaning up and reclaiming land to introducing novel functionalities.

The Katowice Culture Zone, situated on the former Katowice coal mine grounds at the city's core, stands out as a prime example. Notably, the green roof of the International Congress Centre MCK, adjacent to the Spodek arena, serves as both an aesthetically pleasing space and a biologically active environment.

This innovative design facilitates water drainage and capture, blending seamlessly with the surroundings. Adjacent to the International Congress Centre MCK, a lush "green valley" leads to the state-of-the-art Polish National Radio Symphony Orchestra building, integrating gardens, fountains, and recreational spaces.

Further emphasizing the fusion of nature and architecture, vegetation adorns the underground Silesian Museum building, with a meticulously curated geometrical garden atop the museum roof. Comprising resilient grasses and shrubs, selected to withstand harsh weather conditions. The adjacent Bogucki Park, currently undergoing revitalization, will soon feature redesigned plant arrangements, alongside activity zones for various age groups and an underground rainwater reservoir.

Other developments on post-industrial sites, such as the GPP Business Park and the Euro-Centrum Science and Technology Park, epitomize a holistic approach by incorporating climate protection and adaptation strategies. Following land reclamation, these areas boast biologically diverse landscapes and energy-efficient office buildings equipped with cutting-edge technologies, ensuring minimal environmental impact while maximizing sustainability.

ADAPTATION POLICIES, INITIATIVES AND INNOVATION IN EUROPEAN CITIES

EU AND GLOBAL INITIATIVES AT CITY LEVEL

EU Missions represent an innovative approach under the Horizon Europe program (2021-2027) to address major challenges through research and innovation. Focusing on climate-neutral and smart cities, they aim to drive significant changes by 2030, with cities being crucial in achieving the European Green Deal's climate neutrality goal by 2050. Cities are at the forefront of energy consumption and CO2 emissions, making urban action essential for climate mitigation.

The Cities Mission seeks to transform 100 European cities into climate-neutral and smart cities by 2030, serving as models for others by 2050. This initiative involves a cross-sectoral approach and collaboration among local authorities, citizens, businesses, and national authorities. Funding opportunities are provided to support these goals, with a focus on areas like zero-emission mobility and urban greening.

Annex 2 presents the 100 EU selected for the EU mission of climate-neutral and smart cities by 2030. 12 cities were selected from countries associated to Horizon Europe, and there are cities from every Member State, including capital cities, small, medium, and large cities, as well as frontrunners and less prepared cities

The EBRD Green Cities program, with over EUR 5 billion funding, addresses urban challenges like insufficient infrastructure, environmental issues, and climate change impacts in regions spanning central Europe to Central Asia and the Mediterranean. It focuses on creating market-oriented economies, promoting private initiatives, and ensuring sustainable urban development.

The program comprises three key elements: Green City Action Plans for environmental assessment and planning, investments in sustainable infrastructure, and capacity-building for effective implementation and monitoring of urban projects. Its goals include preserving environmental assets, mitigating climate change risks, and enhancing residents' socio-economic well-being.

EU cities participating in the EBRD Green Cities Program include Bucharest, Craiova, Iași, Mediaș, Timișoara (Romania), Karlovac, Split (Croatia), Sofia, Varna (Bulgaria), Warsaw, Wałbrzych (Poland).

Chief Heat Officers

In response to the escalating climate crisis and soaring global temperatures, a new role, Chief Heat Officer (CHO), has emerged. With less than ten CHOs worldwide, these individuals are tasked with combating extreme urban heat. UN Secretary-General António Guterres has described the current situation as an "era of global boiling," with record-breaking temperatures affecting vast regions globally.

Chief Heat Officers are appointed to specifically address the challenges posed by rising temperatures due to climate change. Their mission is to increase awareness of the dangers of extreme heat and to protect vulnerable communities. This initiative was pioneered by the Adrienne Arsht-Rockefeller Foundation Resilience Centre (Arsht-Rock) and the Extreme Heat Resilience Alliance. CHOs are responsible for planning and implementing strategies to cool urban areas and reduce heat risks, including projects like tree planting.

CHOs are typically appointed by local officials prioritizing heat action. Creating such a position and allocating resources signifies a commitment to a more climate-resilient future and reducing losses in lives and livelihoods due to the climate crisis.

These officers also focus on reducing social inequalities, as poorer communities often suffer the most from extreme heat. Currently, cities like Miami, Los Angeles, and Phoenix in the United States, Athens in Greece, Freetown in Sierra Leone, Santiago in Chile, Monterrey in Mexico, and Melbourne in Australia, as well as Bangladesh, have appointed CHOs.

For example, David Hondula, Phoenix's CHO, has been actively coordinating responses to the city's prolonged high temperatures. This includes public awareness campaigns and tree

planting initiatives. In Miami, Jane Gilbert, the world's first CHO, emphasizes the importance of educating the public about the risk period and implementing measures like installing efficient air conditioning in public housing and increasing tree canopy coverage, especially in low-income areas. These efforts highlight the proactive steps being taken by cities around the world to mitigate the impact of extreme heat and protect their citizens.

In July 2022, at the World Urban Forum, UN-Habitat, and the Atlantic Council's Adrienne Arsht-Rockefeller Foundation Resilience Centre (Arsht-Rock) formed a partnership, sealed with a Memorandum of Understanding, to tackle the impact of extreme urban heat. This collaboration will integrate heat-related strategies across UN-Habitat's work and other UN agencies. A Global Chief Heat Officer (CHO) to lead this initiative, focusing on enhancing heat response and resilience in cities worldwide.

PUBLIC AWARENESS IN URBAN HEAT ADAPTATION

Importance of community involvement

Community engagement plays a crucial role in the adaptation and mitigation of Urban Overheating. The effectiveness of UHI strategies often depends on the active participation and support of local communities. This chapter explores the various dimensions of community involvement in urban overheating adaptation, emphasizing its importance in creating sustainable and resilient urban environments.

Public awareness and understanding of UHIs are fundamental to fostering community engagement. Educating residents about the causes and impacts of overheating, as well as the benefits of adaptation strategies, can encourage community-led initiatives and support for policy measures. For instance, community-driven green space projects not only provide direct cooling benefits but also foster a sense of ownership and responsibility towards the local environment.

Strategies for enhancing public awareness

Effective communication and outreach strategies are key to enhancing public awareness of urban overheating. These strategies can include educational campaigns, workshops, and the use of media to disseminate information about urban overheating effects and adaptation measures.

The EU's Covenant of Mayors for Climate and Energy is an example of an initiative that promotes local action and awareness on climate change issues, including urban overheating, by providing a platform for cities to share knowledge and best practices.

Local governments can also leverage social media and digital platforms to reach a broader audience. The use of interactive tools, such as mobile apps that provide real-time information on heatwaves and cooling centers, can enhance public engagement and response during extreme heat events.

Examples of community-led initiatives

Numerous European cities have implemented successful community-led initiatives to combat urban overheating. In Berlin, community gardens and green rooftops have been established through local resident associations, contributing to urban cooling and biodiversity.

Similarly, in Madrid, neighborhood associations have played a significant role in advocating for and participating in urban greening projects, demonstrating the power of community action in urban climate adaptation.

CITY LEVEL ACTIONS AND INITIATIVES

The adaptation to urban overheating at the local level involves a range of strategies tailored to the unique characteristics of individual European cities. These strategies are

crucial as they address the immediate and specific impacts of urban overheating on urban residents. Key approaches include enhancing urban greenery, improving building materials and design, and developing heatwave response plans.

Urban greenery, such as parks, green roofs, and street trees, plays a vital role in mitigating urban overheating by providing shade and facilitating evaporative cooling. Cities like **Barcelona** and **Milan** have implemented extensive tree-planting initiatives and green infrastructure development as part of their urban planning.

Building design and materials also significantly influence urban overheating intensity. For example, cities like **Frankfurt** and **Vienna** have adopted regulations to promote the use of reflective materials in roofing and pavement, effectively reducing heat absorption in urban areas.

Several European cities have emerged as frontrunners in urban overheating adaptation through innovative initiatives. **London's** "Cool Streets" project focuses on retrofitting streets with materials that reflect more sunlight and absorb less heat. **Paris**, in response to its 2003 heatwave, developed an extensive Heatwave Preparedness Plan, including public awareness campaigns and establishment of 'cool spaces' accessible during extreme heat periods.

Amsterdam's approach to urban overheating involves integrating water management with urban cooling strategies. The city utilizes its extensive canal system to moderate temperatures in urban areas, showcasing a unique adaptation strategy that leverages existing natural features.

In the battle against urban overheating, technology and innovation play pivotal roles. Advancements in various fields have provided new tools and methodologies to better understand, monitor, and address the impacts of urban overheating. Remote sensing technologies, for example, have revolutionized the way overheating is monitored. Satellites equipped with thermal cameras can accurately map urban temperature variations, providing valuable data for urban planners and policy makers (Voogt & Oke, 2003).

In addition to remote sensing, Geographic Information Systems (GIS) are extensively used to analyze urban overheating effects. GIS tools enable the integration of various data sets, including land use, population density, and green space distribution, offering a comprehensive view of the urban thermal environment, and helping in identifying areas most affected by UHIs.

Smart urban planning and sustainable design

The concept of smart urban planning and sustainable design is at the forefront of urban overheating adaptation. These approaches emphasize the creation of urban spaces that are not only resilient to climate change but also contribute to mitigating its effects. One key aspect is the design of 'cool roofs' that reflect more sunlight and absorb less heat. Such innovative roofing materials can significantly lower indoor temperatures and reduce the need for air conditioning.

Another sustainable design strategy is the implementation of green building standards. These standards encourage the use of energy-efficient materials and technologies, which not only reduce greenhouse gas emissions but also enhance the thermal comfort of buildings. The EU's Energy Performance of Buildings Directive is an example of a policy driving such changes, mandating energy performance certificates, and setting energy performance requirements for buildings.

Role of green infrastructure and nature-based solutions

Green infrastructure and nature-based solutions are increasingly recognized for their effectiveness in combating urban overheating. Urban green spaces, such as parks, gardens, and green corridors, provide cooling through shading and evapotranspiration. Moreover, they offer co-benefits including biodiversity conservation, improved air quality, and enhanced psychological well-being of residents.

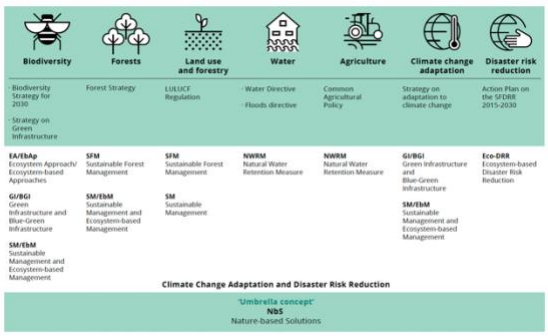
Innovative solutions like green walls and green roofs are also gaining popularity. These living

systems not only help in reducing urban overheating effects but also contribute to stormwater management and create habitats for urban wildlife. The EU's Biodiversity Strategy for 2030 supports the development of green infrastructure, aligning with broader environmental and climate objectives (European Commission, 2020).

According to the European Environment Agency, nature-based solutions for climate change adaptation and disaster risk reduction are holistic approaches integrating natural ecosystem restoration and protection. They aim to mitigate climate impacts and slow global warming while offering environmental, social, and economic benefits. This concept encompasses various methods like sustainable ecosystem management, green infrastructure, and natural water retention measures. While increasingly recognized in global and EU policies, further coherence and prioritization are needed. Stakeholder involvement and the development of standards, targets, and evaluation tools are crucial for effectiveness. However, the vulnerability of ecosystems to climate change poses challenges to their potential in addressing climate-related risks.

The figure below presents an overview of nature-based concepts to climate change adaptation and disaster risk reduction and their related EU policy sectors.

Figure 7. Nature-based concepts to climate change adaptation and disaster risk reduction



Source: European Environment Agency, Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction

"Sponge cities" refer to urban areas designed to absorb rainwater and prevent flooding through natural spaces like parks, lakes, and innovative urban designs. As climate change increases flood risks, these cities utilize "nature-based solutions" to handle climate shocks more effectively. Studies have shown that natural absorption methods are more cost-effective and efficient than man-made solutions.

Major cities worldwide are increasingly adopting measures to enhance their resilience against floods and droughts, such as through inner-city gardens, improved river drainage and plant-edged sidewalks. Measuring "sponginess" involves analyzing the balance between natural and concrete spaces in cities to determine their water absorption capacity.

The latest report from the Intergovernmental Panel on Climate Change (IPCC) highlights that 700 million people are living in regions with increasing rainfall extremes, a situation expected to escalate with rising global temperatures. Additionally, the concept of sponge cities offers the advantage of retaining more water in natural environments like rivers and green spaces, enhancing their drought resilience by reducing water loss through evaporation.

Arup's research evaluated the "sponginess" of seven major cities by measuring their blue and green infrastructure, such as parks and water bodies, versus grey infrastructure like concrete. They also analyzed urban soil's water retention ability. Auckland led with a 35% sponge rating, followed by Nairobi (34%) and New York, Mumbai, and Singapore (30%). Shanghai scored 28%, while London was at the bottom with 22%, due to its high concrete concentration and poor soil absorbency. Cities with higher ratings are more capable of absorbing rainwater.

Challenges and opportunities

While technology and innovative design offer great potential in urban overheating adaptation, several challenges remain. The integration of these technologies into existing urban landscapes can be complex and costly. Moreover, there is a need for continuous research and development to enhance the efficiency and effectiveness of these solutions.

The opportunities, however, are immense. Leveraging technology and innovation can not only help in addressing urban overheating but also contribute to broader goals of sustainable urban development. As European cities continue to grow and evolve, the adoption of smart, sustainable, and nature-based solutions will be key to ensuring a resilient and livable urban future.

This section focuses on some of the best published and promoted initiatives at the city level (identified through desktop review), including local government actions and community-based projects.

GREEN ROOFS IN COPENHAGEN

In 2008, the City of Copenhagen initiated a shift towards alternative rainwater management methods, and this objective was reflected in the Wastewater Plan 2008 as the first document incorporating such approaches. The following year, Denmark played a key role in the UN Climate Change Conference COP15, where strategies were outlined to address the challenges posed by climate change. This period witnessed an increased emphasis on green roofs, culminating in the inclusion of a target for urban design with green roofs in the Climate Plan of the City of Copenhagen.

Subsequently, green roofs became an integral part of various guidelines, including those for Sustainability in constructions and Civil works, which made it mandatory for all Municipal buildings to incorporate green roofs. Furthermore, green roofs were incorporated into the city's Biodiversity Strategy. Since 2010, the inclusion of green roofs has been mandated in most new local plans. A calculation based on the approved new local plans stipulating green roofs indicates a total area of 200,000 m2 earmarked for green roof installations. As of now, the City of Copenhagen has more than 40 green roofs.

Benefits of green roofs

Green roofs are a distinctive opportunity to convert numerous conventional roof surfaces into vibrant and life-sustaining green havens. They contribute to biodiversity by fostering diverse ecosystems. These roofs facilitate the sustainable absorption of increased amounts of rainwater and concurrently mitigate temperature rises.

Consequently, green roofs form an integral component of both the City of Copenhagen's Climate Plan and Climate Adaptation Plan. Serving as habitats for various animals and plants, green roofs play a crucial role in supporting biodiversity, leading to their incorporation into the City of Copenhagen's Biodiversity Strategy.

Residential building: Birkegade Penthouses

The Elmegade district, located in inner Nørrebro, Copenhagen, is likely one of the most densely populated areas, particularly the triangular block bordered by Birkegade, Egegade, and Elmegade, characterized by narrow courtyards due to its high density. The primary aim is to establish this garden in conjunction with three new penthouses, ensuring all residents have access to a genuine outdoor space.

To enhance the envisioned rooftop garden, JDSA drew inspiration from Copenhagen gardens known for their functional aspects. Consequently, the rooftop garden is designed to serve various functions, incorporating elements such as a playground with a shock-absorbing surface and a playful suspension bridge, a green hill featuring diverse seating backed by real grass and robust vegetation.

The BIR concept strives to optimize the site's potential fully, not only accommodating the three new apartments but also creating a practical roof garden and a visually appealing landscape for the cooperative's neighbours and city residents at large. Unlike conventional roofs that signify the conclusion of a construction, the Birkegade roof is poised to transform into an open and versatile space for diverse activities and experiences in the near future.

Commercial building: The New National Archives

The rooftop terrace at the Danish State Archives is an integral part of a forthcoming elevated pedestrian passage, accessible to the

public, connecting two areas in the center of Copenhagen. Spanning approximately 220 x 30 m, the terrace is defined by expansive record storage buildings on one side and the façade of an older structure housing offices for the Danish National Railway (DSB) on the other. This rooftop terrace marks the initial phase of implementation among at least four sections of the planned passage. Over the next few years, the entire elevated passage is anticipated to stretch approximately 900 m.

The primary aim of the rooftop garden is to establish a pedestrian passage for public use while simultaneously creating a serene garden in a central Copenhagen location, in proximity to the Port of Copenhagen and the Central Station. The project's goals include developing a sustainable urban park that optimizes environmental conditions. These objectives influenced the visual design, emphasizing minimal hard surfaces and incorporating a diverse array of plant species. Technically, the rooftop garden's construction ensures that precipitation water passes through the growth media and reservoir plates before reaching the drainage system. This approach enhances the reservoir effect, retaining up to 70% of water annually and promoting natural evaporation.

The addition of greenways introduces a recreational and landscape space between the area's imposing buildings. The rooftop garden contributes to increased biodiversity, rainwater collection, and stabilization of the temperature in the archive buildings.

The project introduces landscape elements and publicly accessible spaces to an area dominated by large, industrially characterized buildings.

Public building: Tagensbo Skole, Multifunctional Hall

The key motivation behind this initiative was to establish an engaging recreational space for children in a densely populated section of Copenhagen, aligning with various planning strategies of Copenhagen City, including the "Strategy for biological diversity," "Copenhagen Climate plan 2025," "Climate adaptation plan," and "A greener Copenhagen."

The advantages of implementing a multifunctional roof include the provision of additional outdoor facilities for both the school and the local community to use and appreciate. Functioning as a bio-agent, the roof serves as a reservoir for surface water.

The multifunctional green roof serves as a communal gathering space for neighbors and school users, fostering a sense of community. The creation of new green areas supports the ongoing development of a greener and more sustainable cityscape, benefiting the residents. In anticipation of future climate changes, the green roof area acts as a reservoir for surface water, alleviating stress on the City's drainage system.

More information about the green roofs: https://storymaps.arcgis.com/stories/820e7c6d7a5f4faf81c8d75346f81848.

PARIS COOL ISLANDS

During the summer of 2019, Paris experienced an unprecedented heatwave with temperatures reaching a record 42.6°C, resulting in an estimated 1,500 fatalities across France. In response to the escalating climate crisis, which brings more frequent and intense heatwaves compounded by the urban heat island effect, Paris is proactively addressing the heat-related risks for its residents. The city is creating a network of easily accessible cool spaces throughout its urban landscape.

Comprising over 800 locations, including parks, forests, swimming pools, and museums, this network forms a series of cool 'islands' where both residents and visitors can seek refuge from the summer heat. These islands are connected by naturally cool walkways. Aligned with the city's climate adaptation strategy, Paris aims to ensure that every resident can reach a cool island or walkway within a seven-minute walk.

To facilitate this initiative, Paris has developed the EXTREMA mapping app, which guides residents to these cool islands. In its inaugural year, the app was downloaded 6,000 times, allowing users to provide feedback on the cool islands.

Benefits of the cool islands

Socially, this initiative aims to provide information about heat risks and cooling options to over 7,000 vulnerable Parisians during extreme heat conditions.

From a *health* perspective, the project addresses a critical issue for Paris officials, particularly after the 2019 heatwave that resulted in approximately 1,500 deaths in France. The establishment of cool islands is seen as a measure to diminish the risk of heat-related illnesses among the population, enhancing resilience to such events.

Economically, the initiative acknowledges that heatwaves can substantially diminish productivity, sometimes by almost a third. Paris is taking proactive steps to build resilience to summer heat, thereby mitigating potential economic damage caused by heatwaves.

Environmentally, the creation of additional green and blue spaces in the city contributes to enhanced biodiversity, reduces the impacts of air pollution, and sequesters carbon.

NICOSIA URBAN BIODIVERSITY

In Nicosia, the SUSHI (SUStainable Development of Historic Areas) project introduced urban furniture with plant canopies to provide shade and counter the Urban Heat Island effect.

This initiative aimed to make public spaces more comfortable during hot months. However, it highlighted the crucial role of local municipality maintenance for the success of such projects. Additionally, the city implemented initiatives to enhance urban biodiversity, including pollinator gardens in parks and educational guides for residents and local authorities.

The "Guide for Nature-Based Solutions in the Historic Centre of Nicosia" focuses on addressing climate challenges in Nicosia's historic center using nature-based solutions. It outlines various NBS approaches, such as green roofs, rain gardens, and permeable materials, to mitigate urban heat islands and improve biodiversity and water management.

The guide emphasizes the importance of adapting these solutions to local climatic, environmental, and social needs. It aims to enhance urban resilience to climate change while providing significant benefits for human well-being and biodiversity.

The Go Green project, currently in design and procurement phase, focuses on installing green roofs and solar panels. These projects, along with the Transform4Climate project, exemplify efforts to transform energy agencies to address climate challenges.

INITIATIVES FOR A #COOLATHENS

The Municipality of Athens launched a messaging service that provide information on summer weather conditions prevailing in Athens, along with necessary protective measures for citizens' safety.

The "heat alert" system categorizes heat waves into four levels, advising citizens on how to effectively safeguard themselves from extreme weather conditions. This categorization relied on an algorithm developed specifically for Athens, which predicted the health impacts of high temperatures on the city's residents. The algorithm was created by analyzing historical weather data spanning two decades and mortality statistics.

The categories are defined as follows:

- Category 0: Elevated temperatures pose a danger to vulnerable individuals' health.
- Category 1: Very high temperatures prompt adherence to instructions and avoidance of prolonged heat exposure, with special attention to informing vulnerable populations.
- Category 2: Very high temperatures pose a significant health risk,

necessitating precautionary measures and readiness to assist vulnerable individuals.

- Category 3: Extreme temperatures present a substantial health hazard, demanding maximum precautions be taken.

The municipality also launched a series of other initiatives for a #CoolAthens:

- Training for Staff: The Hellenic Red Cross is training city workers to help residents during heatwaves. This includes staff from the Health Department, Friendship Clubs, and the "Help at Home+" program for seniors.
- Heatwave Helpline: A dedicated helpline (210-3638049) is available from 8:00 AM to 8:00 PM offering information and support during heatwaves.
- New City Website: The Municipality of Athens launched a new website with heatwave tips, early warnings, and information on city services available during hot weather.
- EXTREMA Global App: app with personalized heat risk information, including locations of Cool Centers, coolest walking routes, and air quality updates.
- Cool Centers: Seven Cool Centers located at Friendship Clubs are open extended hours (8:00 AM to 8:00 PM) to provide relief to all residents during heatwaves.
- Help at Home+ Expansion: The "Help at Home+" program for seniors is offering additional support to help them stay cool at home. The program now includes volunteers from the Hellenic Red Cross.

CLIMATE SHELTERS IN BARCELONA

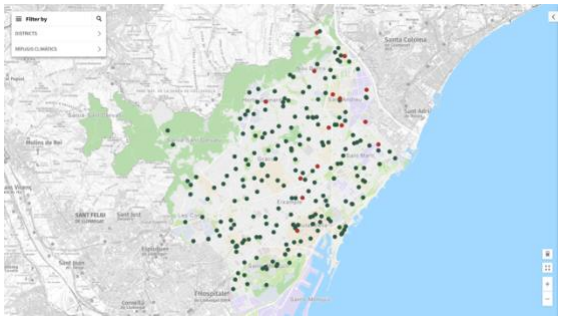
Heatwaves are becoming more frequent and intense due to climate change, especially harming vulnerable populations like the elderly and those with lower income. Similarly, cold weather also poses health risks.

To address these issues, Barcelona has created a network of free climate shelters. These spaces have specific characteristics:

- They can be either indoor or outdoor.
- Indoor spaces operate throughout the year, catering to both heat and cold conditions.
- Outdoor spaces are activated during heatwave prevention periods, typically from June 15th to September 15th.
- They offer thermal comfort to the public while accommodating other functions.
- Indoor spaces aim to maintain temperatures at 27ºC in summer and 19ºC in winter.
- They are tailored for individuals vulnerable to extreme temperatures, including babies, the elderly, those with chronic illnesses, and individuals facing financial hardship.
- They are not intended for individuals requiring medical attention, who should seek care at appropriate healthcare facilities.
- Accessibility and safety are prioritized, along with the provision of comfortable resting areas and free water.
- Urban parks included in the network boast ample greenery, an NDVI index indicating good vegetation quality, accessibility features for people with reduced mobility, and amenities such as fountains and seating.
- Designated climate shelter areas are accessible to the public free of charge.

During the summer, the city facilitates approximately 200 climate shelters, while in the winter around 130. These shelters are available at a maximum 10-minute walk for around 97% of Barcelona's population.

Figure 8. Location of the climate shelters in the city: green represents the summer shelters, red the winter shelters



In addition to the network of climate shelters, the city's diverse social services are ready to assist individuals facing vulnerability due to excessive heat within the urban environment. These services are overseen by the Barcelona Social Emergency and Urgent Care Centre (CUESB).

Preventive protocols are designed to address varying levels of risk based on temperature thresholds. The Barcelona Public Health Agency monitors cases of heat-related illnesses, while the CUESB serves as a pivotal resource during transitions from the preventive stage to alert or emergency stages, wherein the risk to individuals escalates.

During periods of extreme risk, the CUESB may facilitate the relocation of vulnerable individuals to climate shelters as needed. Additionally, the center can serve as overnight accommodations for those who are frail or highly vulnerable.

The city boasts over 1,700 drinking fountains, providing accessible hydration points for residents and visitors alike. The municipal app Fonts BCN enables users to locate these fountains conveniently.

Shade coverage is abundant throughout the city, with nearly twenty pergolas featuring solar panels and social spaces beneath them. Moreover, 183 children's play areas offer ample shade during summer months, with ongoing efforts to introduce seasonal shades that can be installed and removed elsewhere.

VENTILATION CORRIDORS AND GREEN-BLUE INFRASTRUCTURE IN STUTTGART

Stuttgart's geographical location within a valley basin, coupled with its mild climate, low wind speeds, industrial activities, and heavy traffic, have led to significant challenges in maintaining good air quality within the city. Development along the slopes of the valley has hindered air circulation, exacerbated air pollution and exacerbating the urban heat island effect. To address these issues, a Climate Atlas was created for the Stuttgart region, illustrating temperature distribution and airflow patterns based on the city's topography and land use. This data informed various planning and zoning regulations aimed at preserving and expanding open spaces in densely populated areas.

The Climate Atlas for the Stuttgart region, first published in 2008, builds upon decades of prior work initiated by the City of Stuttgart since the 1980s, alongside the continuous efforts of its in-house urban climatology department established as early as 1938.

The Climate Atlas furnishes standardized climatic evaluations tailored to the towns and municipalities across the Stuttgart region. It comprises maps delineating regional wind patterns, cold air flows, air pollution levels, and other pertinent data essential for guiding planners in enhancing climatic conditions for both new projects and retrofitting initiatives. Urban areas are categorized within the Atlas based on their role in facilitating air exchange and cool airflow within the Stuttgart region, considering factors such as topography, development density, green space provision, among others. These areas are classified into eight distinct categories, each accompanied by specific planning measures and recommendations.

In addition to aligning with local climate characteristics, planning recommendations outlined in the "Climate Booklet for Urban Development Online – Städtebauliche Klimafibel Online" adhere to the following guiding principles:

- Surrounding developments with vegetation and establishing larger, interconnected green spaces to facilitate air exchange.
- Preserving valleys as corridors for air delivery and avoiding their development.
- Maintaining undeveloped hillsides, particularly when valleys are developed, as they facilitate the transport of cold and fresh air.
- Avoiding development in saddle-like topographies, which serve as air induction corridors.
- Steering clear of urban sprawl.
- Enforcing protection orders for trees with a trunk circumference exceeding 80 cm at a height of 1m.

The Office for Urban Planning and Urban Renewal, in collaboration with the Office for Environmental Protection, oversees the implementation of recommendations from the Climate Atlas and Climate Booklet. Notable outcomes include the protection of over 39% of Stuttgart's surface area to conserve natural elements, with greenery now covering more than 60% of the city. Initiatives such as greening rooftops, planting tram tracks with grasses, and preserving greenfield land underscore Stuttgart's commitment to enhancing its green infrastructure.

Furthermore, ongoing efforts to expand green infrastructure and improve urban blue infrastructure, including the installation of drinking fountains and water features, aim to bolster Stuttgart's resilience to hotter summers. Projects like "INTERESS-I" focus on testing climate-effective and resilient elements of blue-green infrastructure to develop integrated strategies prioritizing water availability, water quality, climate resilience, social equity, and quality of life considerations.

Stakeholder engagement

The development of the Climate Atlas 2008 was a collaborative effort between the Verband Region Stuttgart, representing regional cities and municipalities, and the City of Stuttgart. Expertise from the Section of Urban Climatology within the Office for Environmental Protection of the City of Stuttgart significantly contributed to this project.

The City of Stuttgart highlights the importance of public involvement in greening initiatives aimed at enhancing air quality and alleviating the heat island effect. Various strategies have been implemented to achieve this goal, including:

- Since 1986, the City of Stuttgart has provided financial assistance to residents for the installation of green roofs. Recognizing the potential of green roofs to counteract overheating and poor ventilation in valley areas, the city encourages their widespread adoption. In 2016, a municipal greening program targeting courtyards, roofs, and facades was reinstated to expedite greening efforts in existing buildings.

Since 1992, Stuttgart residents have had the opportunity to adopt trees or green areas through a dedicated program. Currently, caretakers have adopted over 900 trees and are responsible for tasks such as watering, pest management, debris removal, and protecting trees from dog fouling.

RECOMMENDATIONS

Through a process of reviewing global network and platform guides and recommendations for combating O as well as existing city level actions a series of recommendations and actions have been aggregated. These can be divided into several themes or focus areas for action and can either

be actioned by city administrators or communities at large. Annex 5 includes a more comprehensive list of measures for adaptation and mitigation.

RECOMMENDATIONS FOR IMPROVING BUILDING AND PAVEMENTS

Recommendations for administrations

- Introduce requirements for the materials and colors of the facades. For example, using high albedo materials as highly reflective roofs, vegetation, light-colored buildings, etc., as well as rooftop renewable energy installations.
- Develop more permeable street, sidewalk, and yard surfaces - all new projects, both private and public, to achieve a certain minimum level of permeability.
- Thermally insulate the buildings.
- Create restricted areas in the city to reduce car traffic.
- Create a financial and regulatory framework that creates conditions for the use of alternative sources of energy and energy-efficient technologies.
- Create "climatic oases", i.e. experimental cool spots around the city with a focus on squares and other public spaces. Such oases are realized through transformation of the environment - vegetation, fountains, small water bodies, reflective surfaces, etc. This can be combined with the construction of pilot zero-emission buildings in these areas.
- Implement night ventilation of the premises, which will reduce the need for cooling during the working day.
- Encourage the use of better materials and roof landscaping in the construction of office and multi-family residential buildings.
- Create a parametric planning model. This means being able to assess in real time how planned changes in the environment - constructions and other investments - would affect its parameters. By including in such a model, the volume, location, height and shape of the buildings, the qualities of their facades, the area and the qualities of the pavements, the **thermal effect can also be evaluated.**
- Pilot introduction of ecosystem payments, including financial incentives for green roofs and facades, unsealed courtyards, and tall vegetation.

Recommendations for the community / individuals

- Insulate the house and install windows with good heat transfer coefficients to improve thermal comfort and reduce energy consumption. This is mostly achieved by a third pane of glass, filling between the panes with an inert gas and selectively coating one of the panes.
- Place shading devices, which are better to be outside and must be such that they do not shade in winter.
- When renovating or building a new building, choose materials with a high reflectance or albedo. Materials with a high albedo can both reduce the temperature of the building envelope (direct effect) and lower the temperature of the urban air near the building (indirect effect). Painting surfaces such as roofs and pavements white or adding a reflective coating can be an effective way to increase the albedo of urban areas.
- Do not pave the patio. If it is paved / asphalted, remove the decking and replace it with a grass joint or increase the vegetation.
- Plant trees if in the yard.
- When choosing a home, be interested in what energy class the building is and what energy-efficient solutions are implemented in it.

RECOMMENDATIONS FOR IMPROVING TRANSPORTATION IN THE CITY

Recommendations for administrations

- Create restricted areas in the city to reduce car traffic.
- Introduce restrictions on the use of cars in critical situations (for example, a heat wave), or in certain parts of the city where the construction is densest (the center).

- Renew the public transport with efficient, preferably electric vehicles.
- Add charging points for electric cars with energy from RES.
- Connect, renew, improve, and expand the bicycle network with a focus on security and avoiding conflict situations.
- Repair and widen sidewalks, improvement of intersections.
- Introduce incentives for shared mobility.
- Expand, support, and promote the rail transport for intra-city and suburban travel.

Recommendations for the community / individuals

- Avoid unnecessary driving.
- Use bike / scooter sharing programs.
- Take public transport whenever possible.
- Join carpooling programs.

RECOMMENDATIONS FOR DEVELOPMENT OF GREEN SPACES

Recommendations for administrations

- Develop and evaluate the so-called ecosystem services – i.e. investors to pay more for construction, which limits the ability of ecosystems to keep us warm.
- Plan the city according to the local natural features. For example, properties falling close to rivers should be tailored and oriented to ensure the conductivity of the river and wide public access to the adjacent banks and green areas.
- Develop more parks, including linear parks along rivers. Possibilities for parks on private properties should be analyzed; Connect the green system.
- Use a variety of sustainable, native species that cope better with the heat and the dust and dirty air in the city.
- Use permeable pavements so that the trees can better use the groundwater. To stimulate the laying of pavements with a "grass joint" ensuring permeability.
- Stimulate vertical and rooftop greening in densely built-up central city areas through financial incentives, policies, and regulations.
- Promote the role of parks and stimulate civic initiative in maintaining greenery around the blocks.
- Promote corporate responsibility in greening initiatives and the inclusion of non-governmental organizations in the field of ecology in the development of the green system.

Recommendations for the community / individuals

- Maintain and protect inter-block and pre-block spaces and local gardens in residential neighborhoods.
- Pay more attention to landscaping terraces, balconies and yards with perennial herbaceous vegetation and small tree species and large tree species where possible.
- When buying a home, prioritize those that comply with the landscaping regulation.
- Do not park in green areas, because this permanently destroys and turns them into muddy spots.

RECOMMENDATIONS FOR DEVELOPMENT OF WATER RESOURCES IN THE CITY

Recommendations for administrations

- Provide more long-lasting vegetation in the municipality, including green roofs that retain rainwater.
- Create or restore and maintain artificial and natural water features in the city - mist systems, fountains,

pools, water mirrors, rain gardens, lakes, wetlands.

- Develop more establishments to offer free tap water, including outside.
- Create a network of fountains throughout the city, focusing on the hottest spots. During heat waves, install additional portable water fountains in pre-identified areas.
- Explore the possibilities of using rainwater as an additional water resource.
- Create permeable flooring.
- Explore the possibilities and start applying the sponge city principles.
- Reduce water losses in the aqueduct network and reform the water management system to be able to take advantage of this resource in an optimal way.

Recommendations for the community / individuals

- Save water and thus reduce the problem of possible shortages. For example, fixing leaking faucets, change the shower head, change the toilet cistern to a two-stage one and fixing the leaks.
- Create an own rain garden in the yard / inter-block space, which will provide both the slow assimilation of rainwater and water purification or to install a rainwater collection tank.

RECOMMENDATIONS FOR DEALING WITH HEAT WAVES

Recommendations for administrations

- Develop a municipal early warning system in anticipation of heat waves linked to national weather forecasts.
- Discuss the topic, informing citizens and organizations and promote the implementation of prevention and adaptation measures through various platforms - mobile phones, billboards at bus stops, radio and television, urban advertising.
- Develop and implement an action plan to protect the population from extreme heat. Some elements to be included are:
  - Analysis of priority areas – where are the places most affected by the heat island and concentration of vulnerable groups without access to cooling.
  - A concrete plan and relevant centers for alternative shelter during the hottest hours during heat waves for the vulnerable population. For example, an air-conditioned room in the administration buildings, which is primarily accessible to vulnerable groups. Or shady shelters in the most affected points in the city, where there is no opportunity to plant trees.
  - Steps to involve NGOs, health and social workers and the media to reach more people and especially the marginalized people and communities.
  - Interventions in the basic systems of the city (transportation, administrative services, etc.) so that to minimize heat risks. For example, measures to avoid outdoor queues or mechanisms to know more in time when the bus will arrive to save waiting in the heat.
  - Concrete directions for phasing in stricter regulation and control on ensuring healthy working conditions for outdoor workers (Ordinance on the microclimate of workplaces) and inclusion of new ones at the local level (for construction sites - provision of shade, water, etc.)

- Maintain a register of isolated, elderly, or sick people to be contacted during extreme heat.
- Create a toll-free phone line for information and help.
- Maintain an interactive map of the "islands of coolness" in the city, showing all the possibilities to cool down - from the working water fountains and air-conditioned public buildings to the pools, parks, fountains, cooling jets and green spots offering enough coolness, but also the routes to choose to protect ourselves from the heat.

Recommendations for the community / individuals

- Find out when and where it will be hot.
- When it's hot, know how to handle the heat. E.g., stay cool, drink water regularly and limit heavy food and alcohol intake, wear light and loose clothing made of natural materials such as cotton, wear a hat and sunglasses outside.
- Find out what heat stroke looks like and what the symptoms are – headache, muscle cramps, strong thirst, vomiting, high fever.
- Avoid physical activity in the hotter hours, especially outdoors.
- Keep closed spaces cool and not exposed to sunlight (open blinds, curtains, and close windows exposed to the sun). Ventilate only early in the morning and late in the evening.
- Cool the home, especially if there are elderly people: for example, wet towels or sheets that absorbs heat from the air; use diffusers, not turn on the oven.
- Avoid the hottest areas in the city – open spaces without enough shade or green spaces, public transportation that stops in "hot spots". Choose routes that pass-through fountains, shades, cool space

SURVEY OF EUROPEAN CITIES

To get a better understanding of some of the key issues cities face with respect to adaptation to climate change, and adaptation to urban heat islands in particular, a comprehensive survey was undertaken. The full survey is included in Annex 1 of the report, and it was targeted at 295 cities that have formally applied for the European Commission's "100 Climate Neutral and Smart Cities by 2030" Mission. Given that the application for the "100 Climate Neutral and Smart Cities by 2030" Mission is very thorough (i.e. it requires that cities already have a lot of data related to climate change) and is predicated on cities' willingness to reduce GHG emissions by at least 80% over a 2018 baseline, it was estimated that this selection of cities would be in a good position to provide substantive answers to survey questions.

Of the 295 cities that received the survey, a total of 64, from 23 countries, responded.[5] The table below indicates the countries where city surveys were received from. Annex 3 includes a full list of cities that have submitted completed surveys. Among respondents, a majority (65%) were large cities with a population above 100,000, 27% were medium sized between 50,000 to 100,000, and 8% of respondents were small cities (population beneath 50,000).

Figure 9. Distribution of survey respondents by country and city size

Country	Large	Medium	Small
Belgium	1		
Bulgaria		1	
Croatia	2	1	
Cyprus		1	
Czech Republic	1		
Estonia		1	
Finland	1	1	
France	1		
Germany	1		
Greece	3	2	1
Hungary	2		
Ireland		1	1
Italy	3		
Latvia	1		
Lithuania	1		
Netherlands	2		
Poland	4		
Portugal	5	1	
Romania	7	6	
Slovakia	2		3
Slovenia	1		1
Spain	1		
Sweden	2	2	
Grand Total	**41**	**17**	**6**

[5] The primary target of the survey where the city hall experts, or units, in charge of the climate change agenda in the specific city.

In what follows, we will discuss some of the key insights that emerged from this survey.

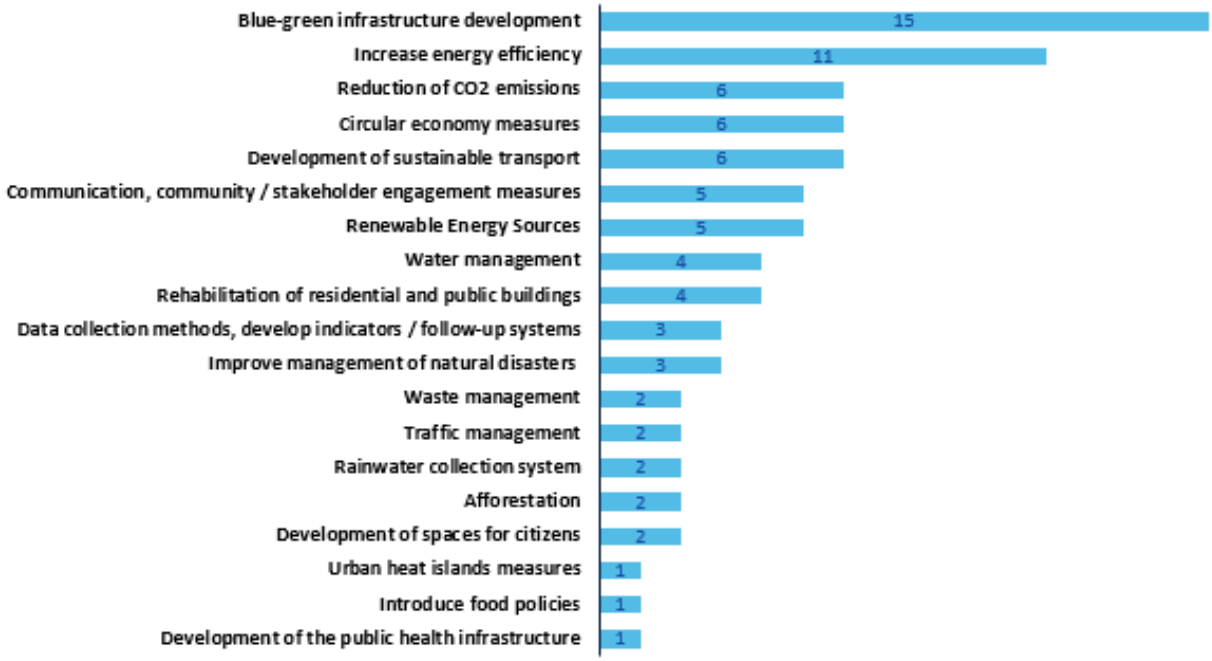
The majority of cities that responded - 83% of the total - have a strategic plan or integrated development document that references climate change.

Around 45% indicated that they have a dedicated Climate Change / Adaptation / Energy Plan in place. Another 22% have dedicated Sustainable Energy and Climate Action Plan (SECAP) or a resilience plans.

The other 33% covered climate change issues in their general local development strategies. The main climate change impacts identified in these strategies/plans included extreme weather events (including heat waves), CO2 emissions, and Urban Heat Islands.

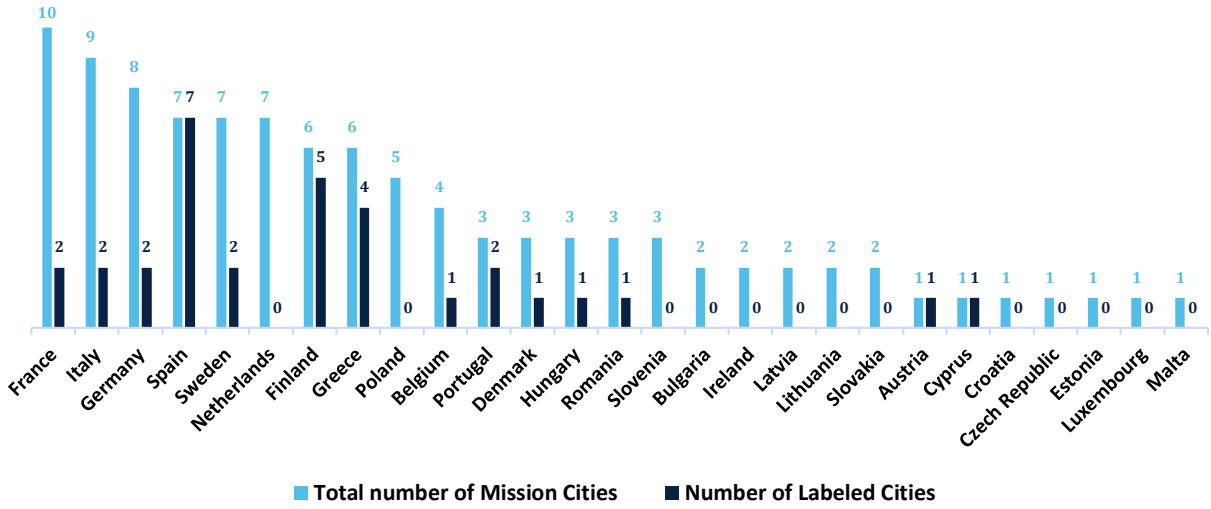
The figure below shows the specific climate change actions identified by respondent cities in their strategies/plans. Significantly, only one respondent identified urban heat island measures in their city strategies and plans.

Figure 10. Main climate changes response actions identified by respondent cities in their strategies/plans



79% of cities that responded indicated that they have prepared a climate-specific action plan or strategy, focused on mitigation, adaptation, climate neutrality, or clean energy. Of these, 40% indicated that they have a Sustainable Energy and Climate Action Plan in place. The SECAP is a pre-condition for accessing EU funds focused on energy efficiency and may be a reason why it has a higher prevalence among surveyed cities. Encouragingly, 24% of cities with a climate-specific action plan indicated that they have an Adaptation Plan in place, although there are no dedicated EU funds for adaptation interventions. Only 3% of respondent cities have a Carbon Neutrality Plan in place. When the survey was submitted to cities, only 10 cities in the EU had managed to finalize their Action Plans for Transition to Climate Neutrality and have their Plan approved by the European Commission (i.e. they received the Mission Label). By end-March 2024, another 23 cities finalized their plans and received the Mission Label. The figure below indicates the distribution of Labeled Cities by EU country.

Figure 11. Number of Mission Cities and Mission Labeled Cities in EU countries, in April 2024



The cities that have climate-specific action plans or strategies, have also identified several responses to the key climate challenges identified. Actions implemented by cities in response to heat waves include de-sealing, development of blue-green infrastructure, green climate axes, public awareness, installation of drinking fountains, planting of urban forests, improving thermal comfort in urban spaces, improving building's energy performance, developing heat stress maps, adapting sensitive operations to a warmer climate, emergency protocols against heat waves, design of climate-adapted urban furniture.

Most cities indicated that they also have climate-specific interventions in other sectoral strategies or plans.

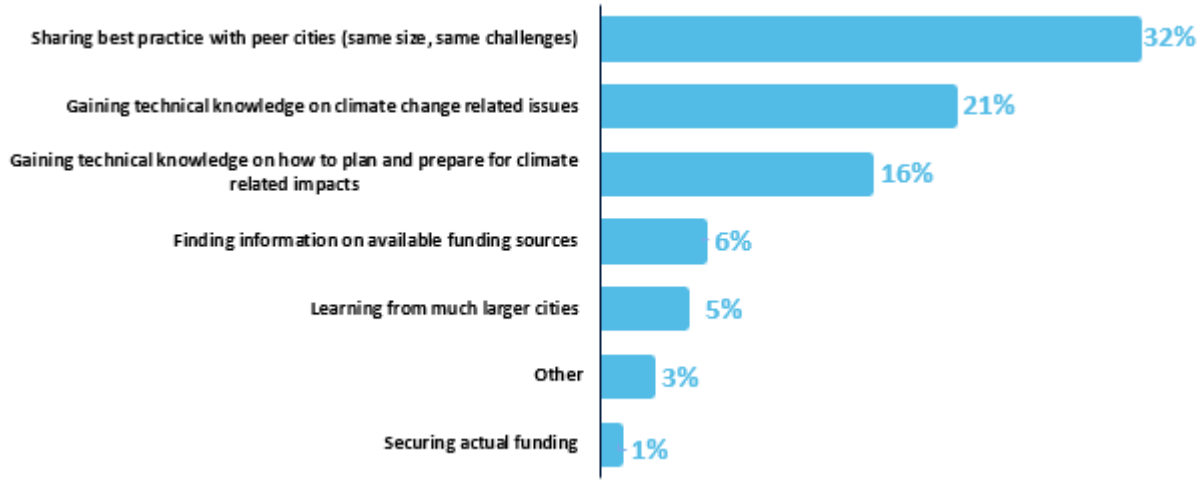
The comprehensive list of adaption measures undertaken by individual cities is a potential treasure trove and inspiration for others interested in climate adaptation. This also indicates the validity of the "100 Climate Neutral and Smart Cities by 2030" Mission approach, which supports several cities to develop their own unique pathways to climate neutrality, and then have these cities serve as inspiration for other cities, in Europe and globally, that commit to pursue a similar pathway.

Encouragingly, 59% of cities indicated that their city has a dedicated unit or department focused on climate change.

A total of 37 of 64 cities have a climate change unit, 13 of which are from Central and Easter Europe. These units are either stand-alone (e.g. Climate Office/Unit, Resilience Office/Unit, Department of Environment and Climate Action), or part of a larger department (e.g. City Planning Office, Department of Environment, Department of Sustainability). Even without a dedicated climate unit in place, 67% of the cities indicated that they had dedicated staff covering climate change. Most of those that had dedicated staff members, had less than 5 experts dedicated to the topic (65%); 25% had between 5 and 10 staff members, and only 10% had more than 10 staff members. Generally, larger Western European cities had larger climate teams in place.

89% of respondents indicated that their city is participating in climate related networks or pilot projects. The most popular networks included: the Covenant of Mayors; the "100 Climate Neutral and Smart Cities by 2030" Mission; and the EuroCities Environment Forum. Other popular networks included: the Carbon Neutral Cities Alliance, Climate-KIC, the Polis Network, Metrex, Net Zero Cities Twining Program, the Resilient Cities Network. When asked what the greatest value was in participating in these networks, the cities responded the following:

Figure 12. What cities value most about being part of climate-related networks



Only 48% of cities surveyed had dedicated budget allocations for climate investments identified in climate plans, strategies, or sectoral plans. Of those with dedicated budgets, only 40% had allocated more than EUR 10 million for such interventions. This is surprising, as all these cities are "100 Climate Neutral and Smart Cities by 2030" Mission cities, which requires both that cities have a track record of climate-related investments, and a clear and ambitious commitment to continue such investments in the future.

Maybe not as surprising, 46% of respondent cities indicated that they have experienced a dramatic, climate-related event in the past 5 years (not just heat related), which resulted in damage and losses at the local level. This clearly indicates that adaptation concerns are not only the purview of developed cities, but a critical development need for cities around the World. The climate-related events with the largest impact on cities included floods (affecting 54% of cities in this cohort), heatwaves (42%), droughts (23%), and wild-fires (15%).

Moving on to the issue of the impact of urban heat islands, 59% of respondents indicate that the impact of urban heat islands is considered in dedicated urban heat action plans or in climate plans, strategies, or sectoral plans. Moreover, 48% of all respondents indicated that dedicated urban heat island studies have been carried out in their city, which is quite a large number considering the technical complexity of carrying out such analyses. The figure below includes some examples of such strategies or plans.

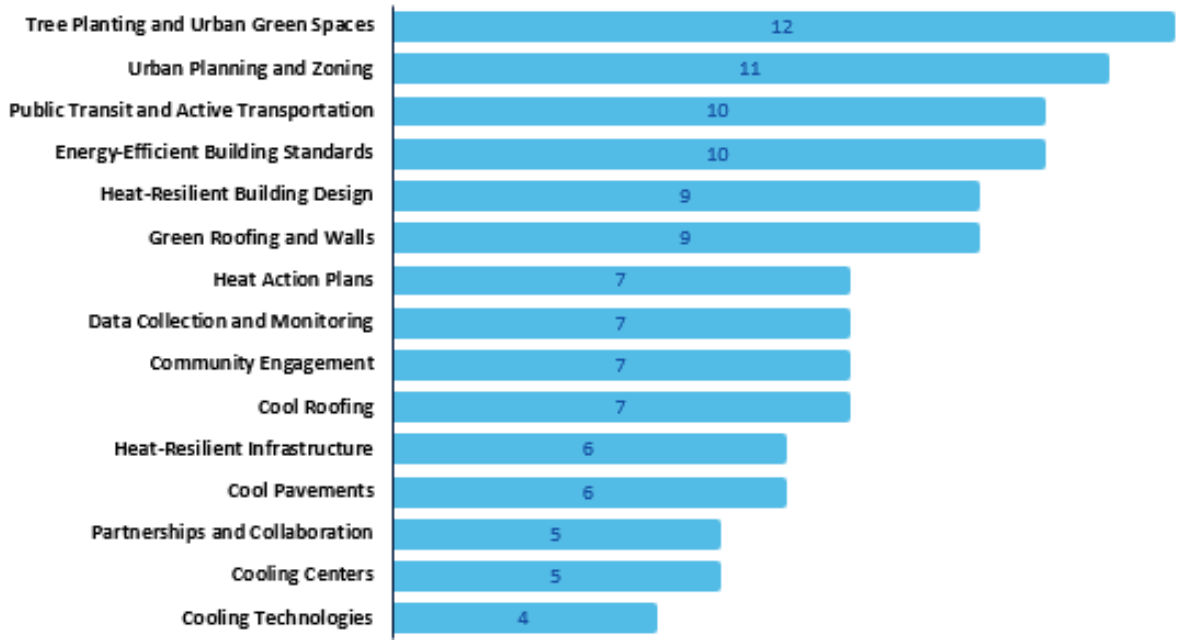
Figure 13. Examples of strategies/plans, from respondent cities, that focus on the impact of urban heat islands

The urban heat island studies carried out by respondent cities identified different types of findings, indicating heterogeneity both in impact and areas of interest. Some examples of findings include:

- Bistrița (Romania): UHI primarily affects the North East area of the city, in the night time
- Genova (Italy): several small heat islands in the city impact different types of urban landscapes
- Ghent (Belgium): 3 to 8°C temperature difference between the inner city and the outskirts
- Helsinki (Finland), Liberec (Czechia), Warsaw (Poland): several UHI zones identified
- Ljubljana (Slovenia): mapped the urban heat islands in the urban area
- Mannheim (Germany): Only 37.8% of the sealed urban area has a favorable bioclimatic situation, with 19,5% being unfavorable and 42.7% having an average bioclimatic situation
- Thessaloniki (Greece): average summer temperature daily range is projected to increase from 25-31 °C in 2022 to 29-35°C by 2100; Estimated of increased mortality risk go up to 130% (depending on conditions), and by the end of the century more than 200 days with T > 20°C are expected
- West Athens (Greece): exhibits a strong heat island effect especially at night; differences in surface temperatures can be as high as 8-10 °C from impervious built-up areas to nearby green or blue areas
- Wroclaw (Poland): 5% of the city's area is affected by UHI.

When asked which intervention measures are most urgently in the city, the following were listed:

Figure 14. Measures identified by respondents as being most urgently needed for dealing with the impact of urban heat islands



Half of the cities indicated specific budget allocations for investments aimed at combating the impact of urban heat islands in the current fiscal year, or for future fiscal years. Allocated budgets varied from smaller sums in cities like Jarfalla (Finland), Nove Zamky (Slovakia), Pula (Croatia), Groningen (the Netherlands), or Pecs (Hungary), to larger sums in cities like Stockholm (Sweden), Brasov (Romania), Thessaloniki (Greece), or Rotterdam (the Netherlands).

All cities had financed heat adaptation measures included in their respective national programs, either EU-funded or State-budget funded, and 70% of cities that responded have taken advantage of such programs. This highlights the importance of having adaption as an EU and a national priority, as even when cities do not have a clear Climate Adaptation Plan in place, the availability of funds for such interventions mobilizes higher uptake for resilience building activities. With an Adaption Plan in place cities are however in a better position to finance their most stringent adaption needs with better planning and consultation.

Only 35% of cities have partnerships or collaborations in place with external stakeholders, such as employers, neighborhood associations, or botanical gardens, to support the design and upkeep of green assets and cool buildings. However, those that do have such partnerships in place are quite creative:

- Vaasa, Finland: Kvarken Archipelago acts as an impartial platform for cooperation and facilitator of all forms of transnational cooperation in the Kvarken region. The city of Vaasa has strong cooperation with 6 universities in the city. The cooperation is also strong with VASEK which is a local actor in the project and assists with business development.
- Braga, Portugal:
  - Employers and Business Associations - Partnering with employers and business associations to implement green building standards, promote sustainable transportation options for employees, and support initiatives that improve the energy efficiency of commercial buildings.
  - Neighborhood Associations - Collaborating with neighborhood associations to identify and prioritize green infrastructure projects, such as community gardens, tree planting initiatives, and the establishment of green corridors to enhance neighborhood resilience and connectivity.
  - Botanical Gardens and Environmental Organizations - Working with botanical gardens, environmental organizations, and conservation groups to provide expertise on plant selection, ecosystem restoration, and sustainable landscaping practices. These partnerships often involve joint educational programs, volunteer opportunities, and demonstration projects to showcase best practices in urban greening.
  - Research Institutions and Universities - Collaborating with research institutions and universities to conduct studies on the effectiveness of green infrastructure interventions, monitor urban heat island effects, and evaluate the social and environmental benefits of cool building technologies. These partnerships help inform evidence-based decision-making and foster innovation in urban sustainability.
- Järfälla, Sweden: participating in the project IoTak - smart roofs for a faster climate transition. The purpose of the project is to produce an evaluation model for what the municipality's roof is best suited for, which also shows the socio-economic and climate-related values of the ecosystem services that the roofs could generate. Through the project, Järfälla municipality will establish a new way of working where planning, optimization and evaluation of green roofs takes place with the help of data. In this way, the municipality can maximize the effect of these efforts for a faster climate transition, while investments can be

- justified by demonstrating the benefit achieved.

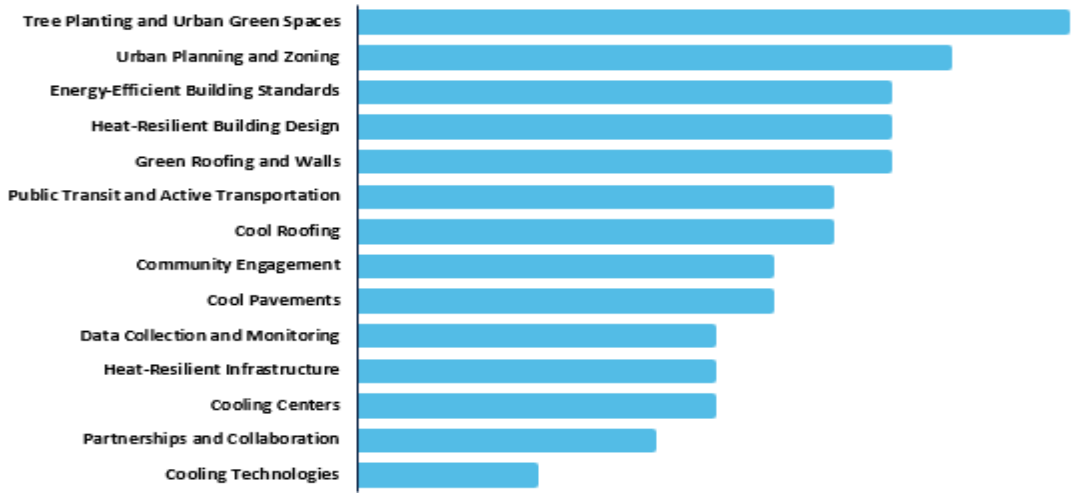
51% of respondents indicated that they have specific measures, initiatives, or programs in place to support vulnerable populations (such as the elderly, children, and people with health vulnerabilities) during times of extreme heat. Some of these measures include:

- Ghent (Belgium): Heat Action Plan (emergency department);
- Ioannina (Greece): Municipal programs for protection in periods of extreme heat;
- Thessaloniki (Greece): Urban Heat Island Forecasting System;
- West Athens (Greece): All Municipalities provide cool places;
- Genova (Italy): Civil Protection Department is in charge to induce and inform on preparatory measures, disseminating alerting messages to most vulnerable groups;
- Parma (Italy): Municipal plan called "Piano Caldo" focused on supporting vulnerable people;
- Krakow (Poland): Activities in the field of maintaining an appropriate living environment, systemic protection and shaping of urban ecosystems (blue and green infrastructure);
- Braga (Portugal): Establishing designated cooling centers in community facilities such as libraries, recreation centers, and senior centers to provide relief from high temperatures;
- Bistrița (Romania): During periods of heat wave, the municipality sets up hydration points in the city;
- Buzau (Romania): Water and medical consultations are provided during the heat wave;
- Cluj-Napoca (Romania): Temporary cooling centers for vulnerable groups during heatwaves;
- Tulcea (Romania): Action plan for days with extreme temperatures, setting up tents, emergency medical assistance, offering water;
- Stockholm (Sweden): The city has routines regarding heatwaves relating to children day-care and elderly care.

Strategically, 67% of cities that responded have considered coupling mitigation measures with urban heat adaptation measures, to ensure higher impact of investments and more cost-effective interventions. Some examples of joint adaptation-mitigation measures implemented by cities include:

- Vaasa, Kavala, West Athens: development of pedestrian and bike paths with heat and water absorbent materials (e.g. biochar use in biking roads to prevent frost heave).
- Mannheim, Parma, Rotterdam: Green roofs and photovoltaics.
- Genova: project waterfront di Levante - combination of grey, green and blue infrastructure to build resilience against the impacts of heat waves, heat stress and humidity on the coastal line.
- Genova: several bike lanes in the city combine mitigation and adaptation measures like green infrastructure, trees, plants and improved soil moisture.
- Groningen: guidelines for designing public spaces include space for trees, extra space for pedestrians and bikers, space for water retention, heat grids, storm drainage and sewage.
- Järfälla: In Barkarbystaden neighborhood, the new created city park, Kyrkparken, functions as stormwater treatment, promotes biological diversity, evens out heat, acts as a carbon sink and is also a nice place for recreation.
- Košice: Coupling of thermal insulation with installation of green walls.
- Buzau: Installation of solar panels with cool roofing intervention.

Figure 15. Joint adaptation-mitigation measures aimed to address the impact of urban heat islands of most interest to cities that responded to survey



Going forward, cities are considering the following joint adaptation-mitigation approaches:

At a more general level, significant disparities were found between larger and smaller cities in terms of the strategic and institutional framework in place to address climate change. Most large cities (90%) tend to have an overarching document which references climate change in place, while 80% have a climate-action strategy or specific plan. Approximately three fourths (74%) of medium sized cities surveyed indicated that they had an overarching strategic plan that includes climate change, while 88% indicated that they had a climate-action strategic or specific plan. This may suggest strategic disconnect (siloed climate strategy). Meanwhile, less than half of small cities surveyed address climate change in an overarching or specific strategic document.

There is a disparity of funding and human resources for climate change between large and small cities. Most large cities have a dedicated unit or department with staff members focused on climate change; medium sized cities tend to have staff focused on climate change (59%), though not formalized in a department or unit. Few small cities have dedicated units (20%) or staff (40% focused on climate change. Less than 50% of cities (40%) have made dedicated budget investments in the area of urban heat in recent years - this figure is even smaller (40%) among medium and small-sized cities.

Common constraints in designing and implementing joint mitigation-adaptation measures include funding, and particularly, lack of funds for comprehensive solutions, technical limitations, and limited knowledge of solutions.

CONCLUSIONS

46% of the cities that responded to survey in this study indicated that they have experienced a dramatic, climate-related event in the past 5 years (not just heat related), which resulted in damage and losses at the local level. Encouragingly, a significant share of the cities surveyed actively implement adaptation measures, and a majority see this as a priority.

The World Bank flagship report "Thriving" proposes a framework of five I's (Information, Incentives, Insurance, Integration, Investments) for addressing climate-related challenges, and shows how these challenges vary for different cities, as it draws on a pool of 10,000 cities from around the Globe. In what follows, we will outline several recommendations for strengthening adaptation approaches in European cities, with a focus on adaptation to urban overheating.

1. **Mainstream cooling measures in Spatial and Urban Planning.** It is important for national and local planning frameworks to set up a broader understanding of the ecosystems that cities are built in, such as ventilation corridors (e.g. vegetation corridors and water courses), the built form, or passive cooling options. This should be coupled with analytics to better understand urban overheating, the key urban hotspots, and how vulnerable populations are impacted by these hotspots. Rotterdam, for example, has undertaken an in-depth analysis of urban overheating, and how this affects its inhabitants, particularly the vulnerable populations[6].
2. **Strengthen heat early waning and public health readiness systems.** Evidence from such systems in France, Portugal, and other countries, show strong evidence for the cost-effectiveness of these systems. However, most EU Member Countries have no or under-developed heat readiness systems. There is an urgent, need to start filling those gaps, using the diverse set of available policy instruments (from long-term actions for cool physical spaces in the city through to short-term actions focused on preventing avoidable deaths in heatwaves).
3. **Find ways to measure adaptation success**. Mitigation has clear policies, strategies, and action plans, as well as significant dedicated financing, because mitigation success can be properly measured – both ex-ante and post-ante. The success of mitigation measures hinges on the reduction of GHG emissions. Having the option of setting clear targets, also enables initiatives such as the "100 Climate Neutral and Smart Cities by 2030" Mission, which focus on providing support to cities that commit to reduce GHG emissions by at least 80% over a 2018 baseline. For adaptation measures to have the same level of success, they would need to accurately determine the impact of adaptation interventions – both ex-ante and post-ante. This is unfortunately easier said than done, as the impact of climate-related events is quite varied – from flash floods, to heat waves, or landslides. Climate-related events are also difficult to anticipate. We know what causes climate change, and what we need to do to reduce it, but we don't know how exactly climate change will impact different communities. One way to mainstream adaptation measures is to ***link average temperature changes at the local level, to estimated impact on people, places, and institutions***. Big data allows to make broad estimates on how a 1°C change in average temperature will impact lives (e.g. estimate how many lives may be list

[6] van der Hoeven, Frank and Alexander Wandl. 2018. *Hotterdam: Mapping the social, morphological, and land-use dimensions of the Rotterdam urban heat island*. Urbani Izziv 29(1):58-72

because of heat waves) and local economies (e.g. reduction in economic output). Having clear estimates on the impact of temperature changes, makes it easier to prepare comprehensive intervention packages aimed at adapting to climate change.

4. **In the short-term and medium-term, couple adaptation measures to mitigation measures.** Mitigation policies, strategies, and plans have significant traction now, with substantial funds allocated to mitigation measures, through various EU-funded operational programmes. Strategies and plans, both at the national and at the subnational level, both of public and private entities, now include a myriad of mitigation measures. It thus makes sense to think of how to tack on adaptation measures to already planned mitigation measures. For example, the installation of solar panels on an apartment block building, could be coupled with the painting of the roof in sun-absorbent colors. The development of new bike paths and pedestrian areas could be made with water and sun absorbent materials. The planting of new trees could take into consideration not just the GHG abatement potential of the tree, but also its ability to provide shade in the summertime. Annex 5 includes a comprehensive list of adaptation and mitigation measures cities could consider, including several joint adaptation-mitigation approaches.

5. **Make adaptation a global, European, and national priority.** The Paris Agreement, the European Green Deal, the Fit-for-55 Initiative, the "100 Climate Neutral and Smart Cities by 2030" Mission, are high level priorities that fund, guide, and encourage mitigation interventions at the local level. Obviously, having a similar high-level focus on adaptation measures, would also translate into a higher take-up of adaptation measures at the local level. A precondition for increased high-level focus on adaptation measures hinges on being able to better measure, ex-ante and post-ante, the impact of adaptation measures. As mentioned earlier, this could be achieved by determining how a 1°C change in average temperature would impact lives and livelihoods. The next cohesion policy could have a stronger focus on Adaptation measures, assuming that by 2030 most EU Member Countries will be well on their way to achieving Mitigation targets (for example, Romania already achieved the Fit-for-55 goal in 2020).

6. **Embed adaptation measures in cross-sectoral and integrated strategies and plans.** The smart approach behind the "100 Climate Neutral and Smart Cities by 2030" Mission is that it does not seek to duplicate local strategic planning efforts, but rather build on them. Normally, a comprehensive Integrated Urban Development Strategy would cover all sectors relevant for an urban area, including adaptation to climate change. The IUDS would then propose a clear implementation timeline (usually 5-10 years), with a realistic budget attached (based on past budget expenditures, external funds that can be attracted, and capacity to efficiently cover operation and maintenance costs for planned investments), and a list of priority projects to be financed from the allocated budget (including a list of reserve projects). A purposeful focus on adaptation measures would first require a clear understanding of the potential impact of climate-related events in the proposed planning period. For example, if average temperature is expected, according to past and current trends, to increase by 1°C in 10 years, and if this increase is estimated to result into 1,000 preventable deaths, and $20 million in economic losses, the local administrations would have a better

gauge of the resources they would have to allocate to ensure that these losses are prevented. Otherwise, allocating resources for adaptation measures is more of a guessing game, and overall sums are likely to be on the lower side. This was also clear from the responses received for the survey.

7. **Develop methodologies for the development of local UHI resilience/adaptation plans.** There are clear methodologies for the elaboration of sectoral strategies/plans such as Sustainable Urban Mobility Plans, Sustainable Energy Climate Action Plans, or Action Plans for the Transition to Climate Neutrality. There are also different methodologies for the elaboration of local resilience/adaptation plans, but these have the shortcoming of being too broad in nature (often they end up being as comprehensive as an integrated urban development strategy, covering multiple sectors and issues) and are often focused on multiple outcomes. To make resilience/adaptation plans more actionable, it is important to focus them on specific issues (e.g. adaptation to urban heat islands) and to have clearly defined outcomes.

8. **Provide incentives for individuals and businesses to internalize some of the negative externalities of urban overheating.** As is the case with mitigation measures, the cost of dealing with the impact of urban overheating should not be borne by the public sector alone. Households play an important role in reducing the impact of heatwaves, both for themselves, and for their neighbors. And private companies play a critical role in addressing UO outcomes. For example, some of the hottest areas in a city include its industrial areas, its major retail areas, and privately owned brownfields or fallow plots of land. Average temperatures in and around those areas could be reduced significantly with simple and cost-effective measures (e.g. painting the roofs of large retail buildings and parking lots, with sun-absorbent materials.

9. **Improve data collection.** While the EU has one of the most advanced data-for-policy systems in the World, it still has some blind spots when it comes to Climate Adaptation data. For example, the EU does not systematically collect data on hospital admissions for heat-related illnesses. As such, it is also difficult to properly measure and monitor the impact of UO measures.

10. **Strengthen institutional coordination.** Multiple stakeholders need to come to the table to address heat risks effectively. Public health stakeholders, and urban planning stakeholders, tend to be siloed. Cities, national government taskforces, and the EC play a critical role in de-siloing efforts. City heat action plans have been particularly effective mechanisms in this regard. It is also important to prioritize policies based on cost-effectiveness. If early warning systems (like the Athens example we discussed in the report) save lives at low cost, why don't we do more of them? The EC and national government could be more pro-active in driving a faster adoption of measures that have the highest ratio of benefits to costs.

ANNEX 1. QUESTIONNAIRE FOR LOCAL AUTHORITIES

BACKGROUND

Since the 1980s, Europe has been warming twice as much as the global average (1.13°C - 1.17°C). By 2022 it was already approximately 2.3°C above pre-industrial (1850-1900) averages and is currently the fastest-warming continent in the world. Most of the continent has been experiencing intense heatwaves since 2000, having far-reaching consequences not only on the region's ecosystems and socio-economic fabric, but also on human health resulting in fatalities, affecting well-being and labor productivity. In addition to changing temperature patterns and increasing heat.

Between 1980-2017, heatwaves accounted for 5% of economic losses within the European Economic Area countries and ~85% of all natural hazard related fatalities. Between 1980-2021, economic losses and damages from climate-related extreme events amounted to ~EUR 560 billion (EEA, 2023). Annual economic losses for just 2021 and 2022 exceed EUR 50 billion, and this is expected to be similar for 2023. 2022 was one of the hottest summers on record for Europe, with heatwaves resulting in over 60,000 fatalities, despite many countries already having active prevention plans in place after the heatwave of 2003 resulted in over 70,000 excess deaths. By 2040, Europe could potentially face up to over 94,000 excess fatalities every year due to extreme heat without effective adaptation plans in place.

While governments are quickly coming to terms with the physical and economic costs of a changing climate, the articulation of adequate policies and investments has lagged the increasing pace and severity of impacts. The European Commission has spent substantially higher attention and political capital to promoting the decarbonization elements of the EU Green Deal than its adaptation pillar, essentially relegating adaptation to a secondary role vis-à-vis mitigation within Europe's climate policy circles. The EU Climate Adaptation Strategy (2021) identifies the importance of increasing adaptive capacity while recognizing the lack of preparedness, both in-country and across the region. The EU's long-term vision to be climate resilient and "fully adapted to the unavoidable impacts of climate change" by 2050, reaching climate neutrality with reinforced adaptive capacity and minimized vulnerability to climate impacts in line with the Paris Agreement and proposed European Climate Law.

SCOPE OF THE SURVEY

Your city has been selected for this survey based on its intention join the "100 Climate-Neutral and Smart Cities by 2030" Mission, which also includes a clear commitment to allocate substantial resources and form local partnerships to achieve the transition to climate neutrality by 2030. This survey draws on the structure of the Application for the "100 Climate-Neutral and Smart Cities by 2030" (including information from the actual application) and tries to understand to what extend adaptation measures could be coupled with planned mitigation measures, to enable synergies, cost savings, and joint mitigation-adaptation outcomes. A particular focus will be on options for addressing urban heat impacts.

Definitions:

Climate Action: a package of efforts and measures taken to mitigate and adapt to climate change. It involves reducing greenhouse gas emissions, promoting renewable energy sources, implementing sustainable practices, and enhancing resilience to the impacts of climate change. Climate action aims to limit global warming and minimize the negative effects of climate change on the environment, society, and the economy. It requires the involvement and collaboration of governments, businesses, communities, and individuals to transition to a low-carbon and climate-resilient future.

Climate Mitigation: actions and strategies taken to reduce or prevent the emission of greenhouse gases (GHGs) into the

atmosphere. It involves implementing measures to decrease the sources of GHG emissions and enhance the sinks that absorb these gases. Examples of climate mitigation measures include transitioning to renewable energy sources such as solar and wind power, improving energy efficiency in buildings and industries, promoting sustainable transportation systems, implementing sustainable agricultural practices, and preserving and restoring forests and other natural ecosystems that act as carbon sinks.

Climate Adaptation: process of adjusting and preparing for the actual or expected impacts of climate change. It involves taking proactive measures to reduce the vulnerability of human and natural systems to the risks and challenges posed by climate change. The goal of climate adaptation is to enhance the resilience and adaptive capacity of communities, ecosystems, and infrastructure to cope with the changing climate conditions. Adaptation can take various forms, including developing and implementing strategies, policies, and practices that minimize the negative impacts of climate change on sectors such as agriculture, water resources, infrastructure, and human health. It may involve measures such as building climate-resilient infrastructure, implementing early warning systems, promoting sustainable land and water management, diversifying livelihoods, and enhancing disaster preparedness.

Urban Heat impacts: effects and consequences of elevated temperatures in urban areas. As cities experience the urban heat island effect, where urban areas are significantly warmer than surrounding rural areas, the impacts of heat in urban environments become more pronounced. Examples of urban heat impacts include: Heat-related illnesses, Increased energy demand, Reduced air quality, Infrastructure damage, Impact on urban ecosystems, Economic impacts.

SURVEY

SURVEY: CURRENT STATE OF URBAN HEAT IMPACT PLANNING

Introduction

The World Bank is conducting a survey in a limited set of EU member states to gather valuable information about your planning and investments related to climate adaptation and specifically urban heat impacts. As urban areas face increasing challenges from rising temperatures and the urban heat island effect, it is crucial to understand the measures being taken by local governments and cities to address these issues.

The purpose of this survey is to assess the current state of your urban heat impact planning and identify the investments made towards mitigating the adverse effects of heat in your jurisdiction. By collecting this information, we aim to gain insights into the strategies, policies, and initiatives implemented by local governments and cities to create more resilient and livable urban environments.

The survey will cover various aspects, including:

- Urban heat impact planning: We will explore the key areas of focus in your planning efforts to address urban heat impacts. This includes understanding the policies, regulations, and guidelines in place to mitigate heat-related challenges.
- Investments and initiatives: We will inquire about the investments made by your local government or city towards mitigating urban heat impacts. This includes infrastructure projects, green initiatives, urban greening programs, and other measures aimed at reducing temperatures and enhancing urban resilience.
- Challenges and barriers: We are interested in understanding the challenges you have encountered in planning and investing for urban heat impacts. This will help identify common obstacles and potential areas for support and collaboration.

Your participation in this survey is crucial in providing valuable insights into the efforts being made to address urban heat impacts. All responses will be treated confidentially, and the data collected will be used for research purposes only. Your input will remain anonymous, and the findings will be presented in an aggregated and non-identifiable manner.

Thank you in advance for your time and contribution. Should you have any questions or require further information, please do not hesitate to contact us.

BIOGRAPHICAL INFORMATION

* Name of city / entity / municipal administration

* Country

* City population

* Website

* Position / role of person completing the survey

THEME: CLIMATE CHANGE PLANNING

* Does your city have an **overarching strategic plan or integrated development document** that references climate change?
  - ○ Yes
  - ○ No

* Has your city developed and adopted **climate-specific action plans or strategies** (mitigation, adaptation, climate neutrality, clean energy)?
  - ○ Yes
  - ○ No

* Does any of your **sectoral city plans** reference and include climate-specific actions or response strategies?

- [ ] Sustainable Urban Mobility Plan (SUMP)
- [ ] Energy Plan
- [ ] Transport Plan
- [ ] Waste/wastewater management
- [ ] Air quality plan
- [ ] Health sector plans
- [ ] Education sector plans
- [ ] Other

* Does your city have a **dedicated unit** or department focused on climate change?

- ( ) Yes
- ( ) No

* Does your city have **dedicated staff members** focused on climate change?

- ( ) Yes
- ( ) No

* Is your city participating in any **climate related networks** or pilot projects?

- ( ) Yes
- ( ) No

THEME: CLIMATE FINANCE

* Has dedicated budget allocations (in operational or capital investments) been made to **climate investments** as identified in climate plans, strategies or sectoral plans?

- ( ) Yes
- ( ) No

THEME: CLIMATE ADAPTATION

* Has your city **experienced any dramatic, specific climate-related events** in the past 5 years which resulted in damage and losses at local level?

- ( ) Yes
- ( ) No

* In which of the following dimensions is **climate adaptation** a high priority in your city?

- [ ] Planning
- [ ] Investment prioritization
- [ ] Capital fund allocation
- [ ] Operational funds allocation
- [ ] Communication and outreach

*

Please provide additional explanations to justify your responses above.

THEME: URBAN HEAT

* Does any of the climate plans, strategies or sectoral plans explicitly reference and consider **urban heat impacts**, or do you have a specific urban heat action plan?

- ( ) Yes
- ( ) No

* Have urban heat island studies been carried out in your city?

- ( ) Yes

* Please indicate which of the following intervention measures are considered **the most urgently needed** in your city. *Ranking from 1 being the most important to 15 being the least important.*

Use drag&drop or the up/down buttons to change the order or accept the initial order.

- **Cool Roofing:** investments in cool roofing materials, which reflect more sunlight and absorb less heat than traditional roofing materials.
- **Green Roofing and Walls:** installation of green roofs and walls, which use vegetation to provide insulation and reduce heat absorption.
- **Tree Planting and Urban Green Spaces:** tree planting programs and creation of urban green spaces, parks, and tree-lined streets.
- **Cool Pavements:** deployment of cool pavement materials that reflect more sunlight and reduce heat absorption.
- **Heat-Resilient Building Design:** incentives to heat-resilient building design practices, including the use of heat-absorbing materials, shading devices, and natural ventilation strategies.
- **Cooling Centers:** investments in cooling centers or public facilities that offer air-conditioned spaces for vulnerable populations during heatwaves.
- **Energy-Efficient Building Standards:** supporting and enforcing energy-efficient building standards that reduce the need for energy-intensive cooling systems.
- **Urban Planning and Zoning:** incorporating urban heat mitigation strategies into urban planning and zoning regulations. This includes requirements for green infrastructure, tree planting, and cool roofing in new developments.
- **Public Transit and Active Transportation:** investments in public transportation and active transportation infrastructure (e.g., bike lanes, pedestrian-friendly streets) to reduce the reliance on heat-producing vehicles.
- **Heat-Resilient Infrastructure:** upgrade and design of infrastructure to withstand extreme heat, including heat-resistant road materials and improved stormwater management systems.
- **Community Engagement:** incentives to community participation in heat management efforts through education, outreach, and participatory planning processes.
- **Data Collection and Monitoring:** investments in weather monitoring networks and heat mapping to better understand urban heat patterns and track progress in mitigating the urban heat island effect.
- **Cooling Technologies:** explore innovative cooling technologies, such as cool roofs with solar reflectance, energy-efficient air conditioning, and district cooling systems.
- **Heat Action Plans:** development and implementation of heat action plans that include early warning systems, public education campaigns, and emergency response protocols for extreme heat events.
- **Partnerships and Collaboration:** collaboration with local governments, non-profit organizations, private sector stakeholders, and researchers to pool resources and expertise in urban heat management efforts.

* Has any specific budget allocation been made for investments to combat urban heat in **historic** years?

- ○ Yes
- ○ No

* Has any specific budget allocation been made for investments to combat urban heat in this **current year or future years**?

- ○ Yes
- ○ No

* Are you aware of **national programs** available to fund heat adaptation measures?

- ○ Yes
- ○ No

* Are there any **partnerships or collaborations** with external stakeholders, such as employers, neighbourhood associations, or botanical gardens, to support the design and upkeep of green assets and cool buildings?

- ○ Yes
- ○ No

* Are there any **specific measures, initiatives or programs in place to support vulnerable populations** in your city (such as the elderly, children, and people with health vulnerabilities) during times of extreme heat?

- ○ Yes
- ○ No

THEME: LINKING ADAPTATION & MITIGATION

* Have you considered **coupling mitigation measures with urban heat adaptation measures**? Such measures could include, for example: coupling installation of solar panels with cool roofing interventions; coupling thermal insulation with installation of green walls; development of pedestrian and bike paths with heat and water absorbent materials; and community engagement campaigns that promoted both mitigation and adaptation approaches.

- ○ Yes
- ○ No

* For the following years, which of the following joint **adaptation-mitigation measures** aimed to address the impact of urban heat islands are of most interest for your urban area? *Ranking from 1 being the most important to 15 being the least important.*

Use drag&drop or the up/down buttons to change the order or accept the initial order.

- **Cool Roofing:** investments in cool roofing materials, which reflect more sunlight and absorb less heat than traditional roofing materials, which reflect more sunlight and absorb less heat than traditional roofing materials.
- **Green Roofing and Walls:** installation of green roofs and walls, which use vegetation to provide insulation and reduce heat absorption, and also act as carbon sinks.
- **Tree Planting and Urban Green Spaces:** tree planting programs and creation of urban green spaces, parks, and tree-lined streets, which help to cool urban spaces and act as carbon sinks.
- **Cool Pavements:** combine rehabilitation/modernization/development of pedestrian and/or bike infrastructure (which encourages green transportation) with the deployment of cool pavement materials that reflect more sunlight and reduce heat absorption.
- **Heat-Resilient Building Design:** provide incentives to heat-resilient building design practices, including the use of heat-absorbing materials, shading devices, and natural ventilation strategies, which also help reduce cooling needs.
- **Cooling Centers:** investments in cooling centers or public facilities that offer air-conditioned spaces for vulnerable populations during heatwaves, and also make walking and/or biking safer and more pleasant during hot days.
- **Energy-Efficient Building Standards:** supporting and enforcing energy-efficient building standards that reduce the need for energy-intensive cooling systems, and which reduce the impact of heat waves on people and livelihoods.
- **Urban Planning and Zoning:** incorporating urban heat mitigation strategies into urban planning and zoning regulations. This includes requirements for green infrastructure, tree planting, providing shading and cooling in public transport stops, or limiting dark surfaces (e.g. large parking lots or tar roofing).
- **Public Transit and Active Transportation:** investments in public transportation and active transportation infrastructure (e.g., bike lanes, pedestrian-friendly streets) to reduce the reliance on heat-producing vehicles.
- **Heat-Resilient Infrastructure:** upgrade and design of infrastructure to withstand extreme heat, including heat-resistant road materials and improved stormwater management systems.
- **Community Engagement:** investments in weather monitoring networks and heat mapping to better understand urban heat patterns and track progress in mitigating the urban heat island effect.
- **Data Collection and Monitoring:** Investments in weather monitoring networks and heat mapping to better understand urban heat patterns and track progress in mitigating the urban heat island effect.
- **Cooling Technologies:** explore innovative cooling technologies, such as cool roofs with solar reflectance, energy-efficient air conditioning, and district cooling systems, which also help reduce energy consumption.
- **Partnerships and Collaboration:** collaboration with local governments, non-profit organizations, private sector stakeholders, and researchers to pool resources and expertise in urban heat management and climate mitigation efforts.

ANNEX 2. EU MISSION OF CLIMATE-NEUTRAL AND SMART CITIES

The following map presents the 100 EU selected for the EU mission of climate-neutral and smart cities by 2030. 12 cities were selected from countries associated to Horizon Europe, and there are cities from every Member State, including capital cities, small, medium, and large cities, as well as frontrunners and less prepared cities.

Source: European Commission, https://op.europa.eu/en/publication-detail/-/publication/822ee360-c9bf-11ec-b6f4-01aa75ed71a1/language-en/format-PDF/source-256649647

The table below lists all the EU cities that have expressed their interest to participate in the Climate-Neutral and Smart Cities Mission and whose “Expressions of Interest” have been found eligible.

COUNTRY	CITY	COUNTRY	CITY
Austria	Graz	Italy	Genova
Austria	Klagenfurt am Wörthersee	Italy	Giugliano in Campania
Austria	Linz	Italy	L'Aquila
Belgium	Antwerp	Italy	Lecce
Belgium	Brussels Capital Region	Italy	Legnano
Belgium	Charleroi	Italy	Lucca
Belgium	Ghent	Italy	Messina
Belgium	Kortrijk	Italy	Milan
Belgium	La Louvière	Italy	Novara
Belgium	Leuven	Italy	Parma
Belgium	Liège	Italy	Pavia
Belgium	Mechelen	Italy	Pescara
Belgium	Verviers	Italy	Pordenone
Bulgaria	Asenovgrad	Italy	Prato
Bulgaria	Blagoevgrad	Italy	Ragusa
Bulgaria	Burgas	Italy	Reggio Emilia
Bulgaria	Gabrovo	Italy	Rimini
Bulgaria	Sofia	Italy	Rome
Bulgaria	Stara Zagora	Italy	Salerno
Bulgaria	Varna	Italy	Savona
Bulgaria	Vratsa	Italy	Siena
Croatia	Karlovac	Italy	Torino
Croatia	Križevci	Italy	Trento
Croatia	Poreč-Parenzo	Italy	Unione dei Comuni della Romagna forlivese
Croatia	Pula	Italy	Venice

COUNTRY	CITY	COUNTRY	CITY
Croatia	Rijeka	Latvia	Jūrmala
Croatia	Velika Gorica	Latvia	Liepāja
Cyprus	Limassol	Latvia	Ogre
Cyprus	Pafos	Latvia	Rīga
Cyprus	Strovolos	Latvia	Valmiera
Czech Republic	Liberec	Lithuania	Alytus
Denmark	Aalborg	Lithuania	Gargždai
Denmark	Aarhus	Lithuania	Kaunas
Denmark	Copenhagen	Lithuania	Kėdainiai
Denmark	Sonderborg	Lithuania	Klaipėda
Estonia	Pärnu	Lithuania	Panevėžys
Estonia	Tartu	Lithuania	Tauragė
Finland	Espoo	Lithuania	Vilnius
Finland	Helsinki	Lithuania	Visaginas
Finland	Joensuu	Luxembourg	Dudelange
Finland	Lahti	Luxembourg	Esch-sur-Alzette
Finland	Lappeenranta	Luxembourg	Schifflange
Finland	Tampere	Malta	Rabat - Gozo
Finland	Turku	Netherlands	Amstelveen
Finland	Vaasa	Netherlands	Eindhoven
Finland	Vantaa	Netherlands	Groningen
France	Angers Loire Métropole	Netherlands	Haarlem
France	Antony	Netherlands	Helmond
France	Bordeaux Métropole	Netherlands	Leeuwarden
France	Clermont Auvergne Métropole	Netherlands	Leiden
France	Dijon Métropole	Netherlands	Rotterdam
France	Dunkerque	Netherlands	The Hague
France	Grand Poitiers	Netherlands	Utrecht

COUNTRY	CITY	COUNTRY	CITY
France	Grenoble-Alpes Métropole	Netherlands	Zwolle
France	Issy-les-Moulineaux	Poland	Gdansk
France	Ivry-sur-Seine	Poland	Krakow
France	La Rochelle	Poland	Legnica
France	Le Havre Seine Métropole	Poland	Łódź
France	Le Mans Métropole	Poland	Radom
France	Limoges	Poland	Rumia
France	Lorient	Poland	Rzeszow
France	Lyon	Poland	Warsaw
France	Marseille	Poland	Włocławek
France	Nantes Métropole	Poland	Wrocław
France	Paris	Portugal	Braga
France	Pau	Portugal	Cascais
France	Rennes Métropole	Portugal	Coimbra
France	Rouen Normandie Métropole	Portugal	Comunidade Intermunicipal da Região de Coimbra
Germany	Aachen	Portugal	Figueira da Foz
Germany	Augsburg	Portugal	Guimarães
Germany	Bad Homburg vor der Höhe	Portugal	Intermunicipal Community of the West (OesteCIM)
Germany	Braunschweig	Portugal	Lisbon
Germany	Darmstadt	Portugal	Loures
Germany	Dortmund	Portugal	Maia
Germany	Dresden	Portugal	Matosinhos
Germany	Erlangen	Portugal	Municipality of Abrantes and Municipality of Tomar
Germany	Frankfurt am Main	Portugal	Porto
Germany	Fulda	Portugal	Sintra
Germany	Göttingen	Portugal	Torres Vedras
Germany	Heidelberg	Portugal	Valongo

COUNTRY	CITY	COUNTRY	CITY
Germany	Herne	Portugal	Viana do Castelo
Germany	Konstanz	Portugal	Vila Franca de Xira
Germany	Landshut	Portugal	Vila Nova de Famalicão
Germany	Leipzig	Portugal	Vila Nova de Gaia
Germany	Lüneburg	Romania	Alba Iulia
Germany	Mannheim	Romania	Bistrita
Germany	Marburg	Romania	Brașov
Germany	Munich	Romania	Bucharest 2nd district
Germany	Münster	Romania	Buzau
Germany	Rostock	Romania	Cluj-Napoca
Germany	Rüsselsheim am Main	Romania	Piatra Neamt
Germany	Schwäbisch Gmünd	Romania	Ramnicu Valcea
Germany	Schweinfurt	Romania	Roman
Germany	Solingen	Romania	Suceava
Germany	Tübingen	Romania	Sfântu Gheorghe
Germany	Wiesbaden	Romania	Timisoara
Germany	Wuppertal	Romania	Tulcea
Germany	Würzburg	Slovakia	Bratislava
Greece	Agrinio	Slovakia	Galanta
Greece	Athens	Slovakia	Košice
Greece	Halandri	Slovakia	Martin
Greece	Heraklion	Slovakia	Mesto Nové Zámky
Greece	Ioannina	Slovakia	Skalica
Greece	Kalamaria	Slovenia	Ajdovščina
Greece	Kalamata	Slovenia	Izola
Greece	Karditsa	Slovenia	Kranj
Greece	Komotini	Slovenia	Ljubljana
Greece	Kozani	Slovenia	Maribor

COUNTRY	CITY	COUNTRY	CITY
Greece	Larissa	Slovenia	Nova Gorica
Greece	Municipality of Central Corfu and Diapontia Islands	Slovenia	Občina Ormož
Greece	Mytilene	Slovenia	Velenje
Greece	Neapoli and Sykies	Spain	Avilés
Greece	Piraeus	Spain	Barcelona
Greece	Rethymno	Spain	Ceuti - Molina de Segura
Greece	Rhodes	Spain	Elda
Greece	Thermi	Spain	Fuenlabrada
Greece	Thessaloniki	Spain	Gijon
Greece	Trikala	Spain	Girona
Greece	West Athens (9 municipalities)	Spain	Las Rozas de Madrid
Hungary	Budapest 18. district	Spain	L'Hospitalet de Llobregat
Hungary	Budapest	Spain	Logroño
Hungary	Érd	Spain	Madrid
Hungary	Kaposvár	Spain	Marbella
Hungary	Kecskemet	Spain	Mollet des Vallès
Hungary	Miskolc	Spain	Murcia
Hungary	Nyíregyháza	Spain	Pamplona
Hungary	Pécs	Spain	Sant Boi de Llobregat
Hungary	Szeged	Spain	Sant Cugat del Vallès
Ireland	Cork	Spain	Santander
Ireland	Galway City	Spain	Sevilla
Ireland	Sligo	Spain	Tres Cantos
Ireland	Waterford	Spain	Valencia
Italy	Arezzo	Spain	Valladolid
Italy	Assisi including Bastia, Cannara, Bettona	Spain	Viladecans
Italy	and Valfabbrica	Spain	Vitoria-Gasteiz

COUNTRY	CITY	COUNTRY	CITY
Italy	Bagheria	Spain	Zaragoza
Italy	Battipaglia	Sweden	Borlänge
Italy	Bergamo	Sweden	Eskilstuna
Italy	Bologna	Sweden	Gävle
Italy	Busto Arsizio	Sweden	Gothenburg
Italy	Campobasso	Sweden	Helsingborg
Italy	Cinisello Balsamo	Sweden	Järfälla
Italy	Ferrara	Sweden	Kalmar
Italy	Florence	Sweden	Lund
		Sweden	Malmö
		Sweden	Stockholm
		Sweden	Umeå
		Sweden	Uppsala
		Sweden	Växjö
TOTAL EU CITIES			**295**

ANNEX 3. CITIES THAT HAVE SUBMITTED COMPLETED SURVEYS

NO.	COUNTRY	CITY
1	Bulgaria	Blagoevgrad
2	Croatia	Pula
3	Croatia	Rijeka
4	Croatia	Zagreb
5	Cyprus	Strovolos
6	Greece	Ioannina
7	Greece	Karditsa
8	Greece	Kavala
9	Greece	Kozani
10	Greece	Thessaloniki
11	Greece	West Athens (9 municipalities)
12	Poland	Krakow
13	Poland	Rzeszów
14	Poland	Warsaw
15	Poland	Wrocław
16	Romania	Alba Iulia
17	Romania	Bistrita
18	Romania	Brașov
19	Romania	Bucharest 2nd district
20	Romania	Buzau
21	Romania	Cluj-Napoca
22	Romania	Piatra Neamt
23	Romania	Ramnicu Valcea
24	Romania	Roman
25	Romania	Sfântu Gheorghe
26	Romania	Suceava
27	Romania	Timisoara
28	Romania	Tulcea

NO.	COUNTRY	CITY
29	Slovakia	Bratislava
30	Slovakia	Galanta
31	Slovakia	Košice
32	Slovakia	Nové Zámky
33	Slovakia	Skalica
34	Belgium	Ghent
35	Czech Republic	Liberec
36	Estonia	Tartu
37	Finland	Helsinki
38	Finland	Vaasa
39	France	Nantes Métropole
40	Germany	Mannheim
41	Hungary	Budapest
42	Hungary	Pécs
43	Ireland	Sligo
44	Ireland	Waterford
45	Italy	Genova
46	Italy	Parma
47	Italy	Torino
48	Latvia	Rīga
49	Lithuania	Kaunas
50	Netherlands	Groningen
51	Netherlands	Rotterdam
52	Portugal	Braga
53	Portugal	Coimbra
54	Portugal	Figueira da Foz
55	Portugal	Loures
56	Portugal	Matosinhos

NO.	COUNTRY	CITY
57	Portugal	Vila Franca de Xira
58	Slovenia	Ljubljana
59	Slovenia	Velenje
60	Spain	Madrid
61	Sweden	Järfälla
62	Sweden	Stockholm
63	Sweden	Uppsala
64	Sweden	Växjö

ANNEX 4. METHODOLOGY ON UHI ANALYSIS BASED ON LAND SURFACE TEMPERATURE

Urban Heat Islands (UHI) analysis based on Land Surface Temperature (LST)

Land surface temperature is a crucial parameter for various applications, such as urban heat island studies, climate change monitoring, and thermal mapping. By leveraging the multispectral thermal bands of Landsat satellites, accurate LST estimation can be achieved. Various methodologies have beendeveloped in recent years to retrieve LST from space-based thermal infrared (TIR) data. This report provides a brief description of two advanced methodologies for extracting and analyzing LST from Landsat 8 satellite imagery, including data pre-processing, atmospheric correction, and surface temperature retrieval techniques. The results of the analysis can contribute to a better understanding of land surface temperature patterns and their implications for various environmental studies.

1. Conceptual aspects

Land surface temperature is the radiative skin temperature of the land derived from solar radiation. LST measures the emission of thermal radiance from the land surface where the incoming solar energyinteracts with and heats the ground, or the surface of various objects. This quality makes LST a good indicator of energy partitioning at the land surface–atmosphere boundary and sensitive to changing surface conditions (Nemani et al., 1996). Its retrieval from remotely sensed thermal infrared (TIR) dataprovides spatially continuous LST measurements with global coverage to examine the thermal heterogeneity of the earth's surface and the impact on surface temperatures resulting from natural and human-induced changes (Li et al., 2015).

In other words, LST refers to the perceived temperature of the Earth's surface in a specific location. When observed from a satellite, the "surface" represents the objects and materials visible through theatmosphere, such as snow, ice, grass, buildings, or the canopy of a forest.

It is important to note that land surface temperature differs from the air temperature commonly reported in daily weather forecasts. Consequently, LST plays a significant role in the Earth's energy balance and is closely associated with the distribution of sensible and latent heat fluxes. With the advancements in satellite technology, high-resolution LST data obtained from satellites is being utilized in various applications toassess land surface conditions. These applications include mapping urban areas and the intensity of urban micro-climates, estimating evapotranspiration at a high resolution for effective water resource management, and evaluating vegetation stress.

The Landsat series of satellites are well suited for local and small-scale studies due to their ability to provide high-resolution LST estimates. Thus, in recent years, several LST retrieval algorithms have beendeveloped that aimed at the automatic or semi-automatic processing of satellite images. While some algorithms are based only on Landsat data, some of them also involve auxiliary data sets that are usually accessible online, but often involve handling large volumes of data.

2. Analytical framework

The analyses aimed at retrieving Land Surface Temperature data from the Landsat satellite images involve several major steps:

Data acquisition: To conduct a proper UHI/LST analysis, Landsat 8 satellite imagery needs to be acquired. The United States Geological Survey (USGS) provides free access to Landsat 8 data through its Earth Explorer web portal. The chosen imagery should have minimal cloud cover and be representative of the study area. It is important to note that in certain situations the positioning of thearea of interest at the contact between the satellite scenes can induce considerable difficulties in termsof data acquisition.

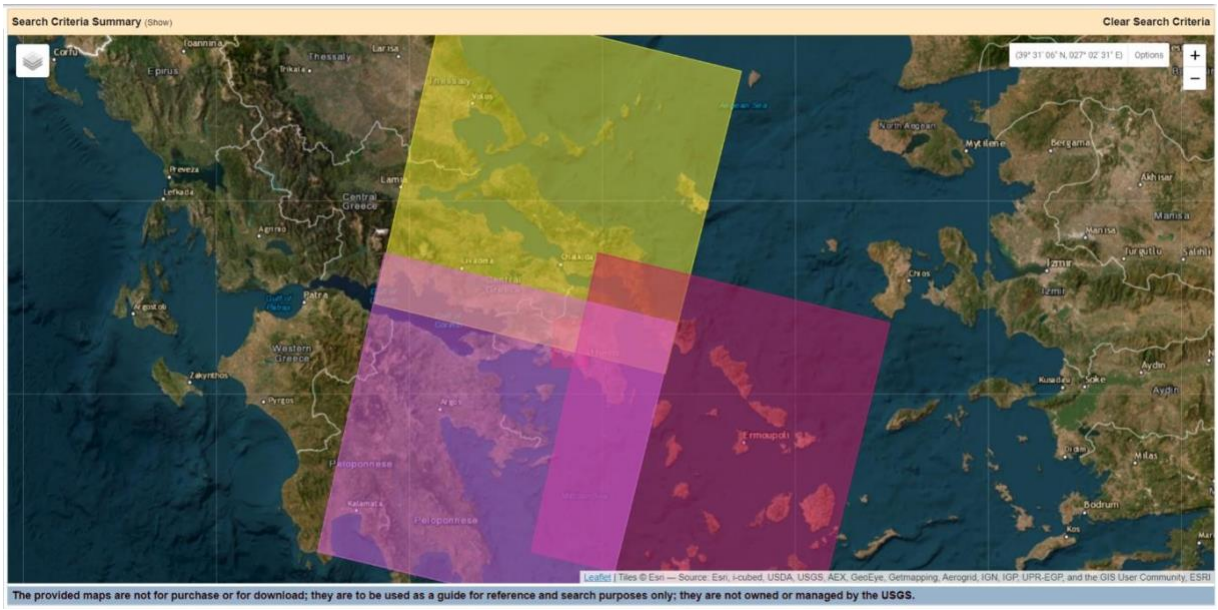


Figure. Earth Explorer web portal interface

Data pre-processing: The acquired Landsat 8 imagery needs to undergo several pre-processing steps to ensure accurate LST analysis:

a) Radiometric Calibration: The imagery should be radiometrically calibrated to convert digital numbers (DN) to at-sensor radiance values using calibration coefficients provided by USGS.

b) Atmospheric Correction: Atmospheric effects, such as scattering and absorption, can distort the thermal signal. Several atmospheric correction algorithms are available, such as the Single-Channel Algorithm or the Atmospheric and Topographic Correction (ATCOR) method. The selected algorithm should be applied to remove atmospheric influences.

c) Cloud Masking: Clouds can significantly affect LST analysis. Cloud masking techniques, such as the use of the Quality Assessment (QA) band provided in Landsat 8 imagery, can identify and mask out cloud-covered pixels.

LST retrieval: Once the pre-processed imagery is available, land surface temperature can be retrieved using the thermal bands (Band 10 and Band 11) of Landsat 8. The Radiative Transfer Equation (RTE) and Planck's Law can be used to calculate LST from at-sensor radiance values. The conversion involves considering atmospheric emissivity, sensor-specific calibration constants, and atmospheric transmissivity.

Accuracy assessment: To validate the accuracy of the retrieved LST, ground truth data can be collected using handheld infrared thermometers or ground-based weather stations. A statistically representative sample should be selected across the study area, and a comparison can be made between the ground truth measurements and the estimated LST values.

Analysis and Visualization: The retrieved LST data can be further analyzed to identify temperature patterns, hotspots, and spatial variations across the study area. Geographic Information Systems (GIS) software, such as ArcGIS or QGIS, can be employed to visualize the LST results through thematic maps, heat maps, or temperature profiles.

3. Land surface temperature (LST) estimations using Methodology no. 1

Source: *Ermida, S.L., Soares, P., Mantas, V., Göttsche, F.-M., Trigo, I.F., 2020. Google Earth Engine open- source code for Land Surface Temperature estimation from the Landsat series. Remote Sensing, 12 (9), 1471; https://doi.org/10.3390/rs12091471.*

Google Earth Engine (GEE) is an online platform that enables remote sensing users to conduct big data analyses without requiring significant computational resources. GEE provides direct access to LandsatLevel-1 and Level-2 data, including top-of-atmosphere (TOA) and surface reflectance (SR) data. However, high-resolution LST datasets from Landsat have not been available in GEE until recently.

The methodology offers a way to derive LST from the Landsat series of satellites (Landsat 4, 5, 7, and 8) using Google Earth Engine (GEE) and is fully implemented within GEE, providing users with the abilityto compute LST without the need to download large amounts of data. Users can perform various data analyses within GEE without the need to store the data locally. However, it's important to mention that the resulting thematic layers can be exported and used later in specialized GIS and Remote Sensing software. The code is written in JavaScript and utilizes the "GEE modules capability," simplifying its application.

The methodology for computing LST utilizes the Statistical Mono-Window (SMW) algorithm developed by the **Climate Monitoring Satellite Application Facility** (CM-SAF). This algorithm is originally designed for deriving LST climate data records from Meteosat first and second-generation satellites. The SMWalgorithm is known for its simplicity, making it easy to calibrate and implement.

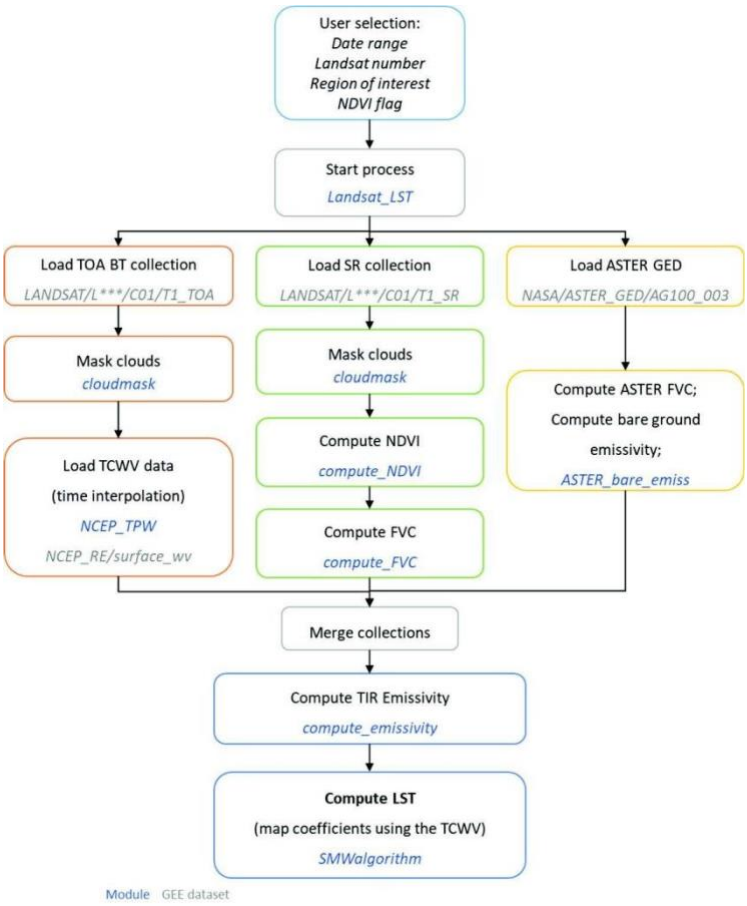


Figure. Google Earth Engine (GEE) processing chain for retrieving Landsat Land Surface Temperature (LST). The blue text indicates coded functions in modules. The grey text indicates GEE datasets used in the production.

In addition to Landsat data, the LST production code within the methodology incorporates two other datasets available in Google Earth Engine (GEE). These datasets include ***atmospheric data from the re-analyses of the National Centre for Environmental Prediction (NCEP) and National Centre for Atmospheric Research (NCAR)***, as well as ***surface emissivity data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Emissivity Database (ASTER GED) developed by NASA's Jet Propulsion Laboratory (JPL)***.

Figure. Landsat 8 satellite imagery (July, 2022)

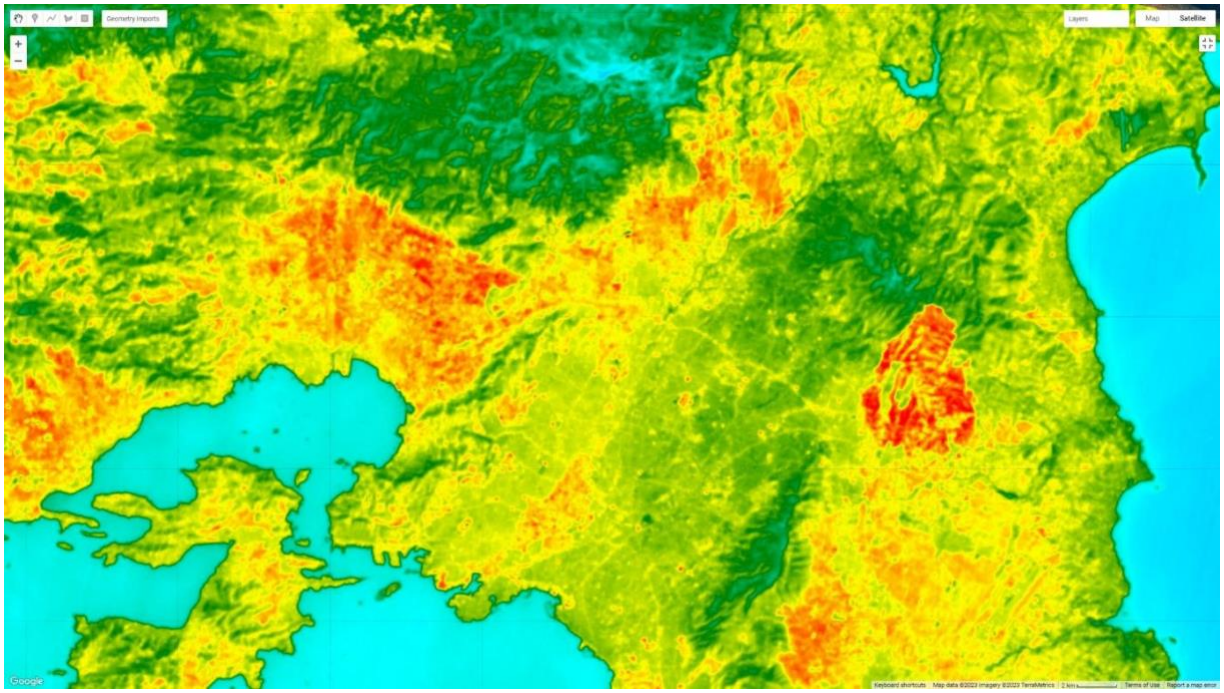


Figure. Landsat8 Land surface emissivity (TIR)

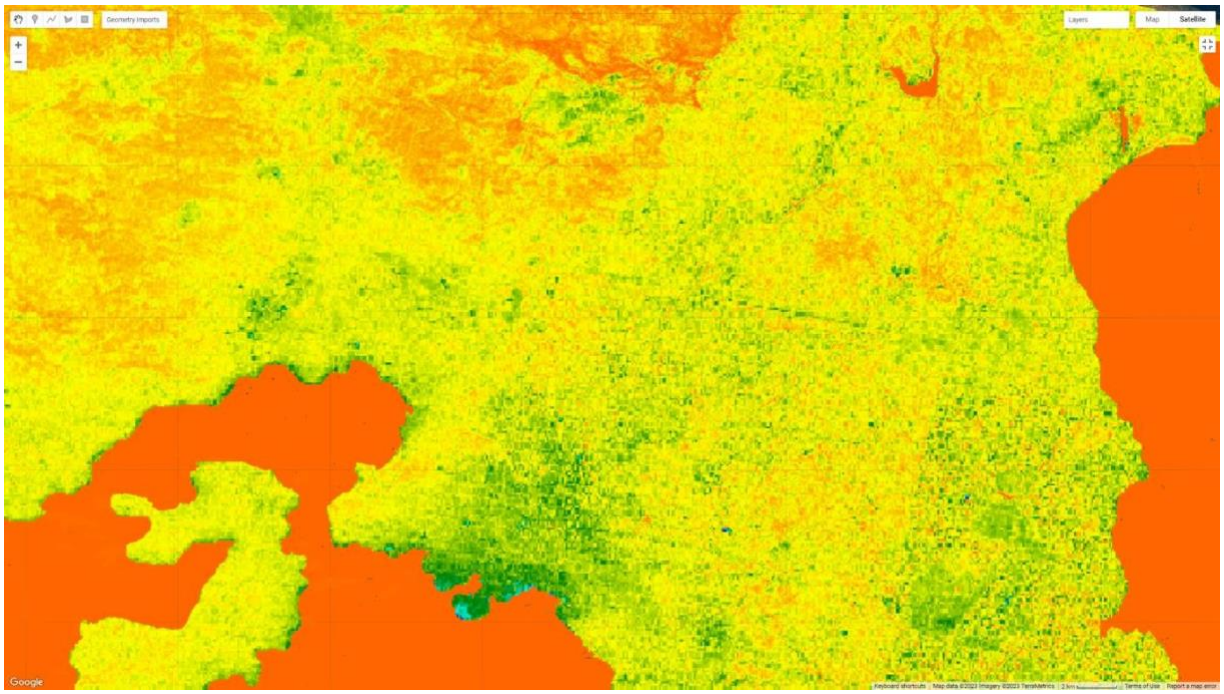


Figure. ASTER Global emissivity

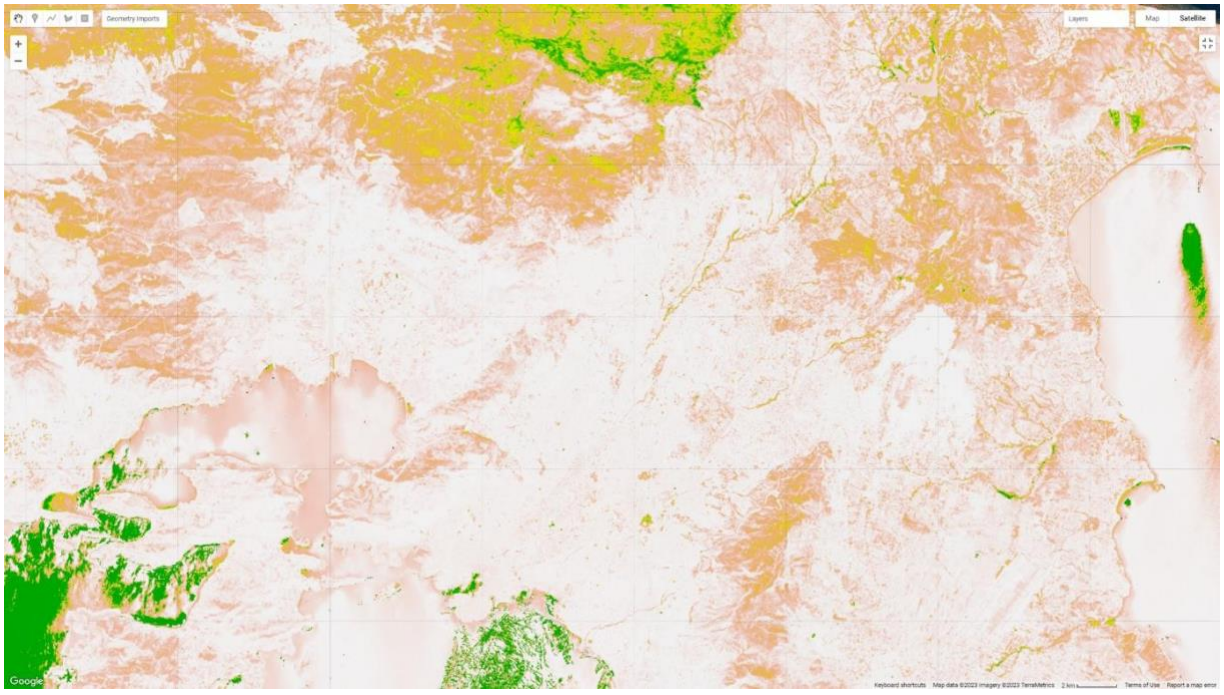


Figure. Fraction of vegetation cover (FVC) emissivity

The LST values are estimated using the SMW algorithm developed by CM-SAF. For each Landsat, the algorithm coefficients were derived using the same calibration database, thereby ensuring consistency between the satellites. All inputs to the algorithm are obtained from the GEE catalogue, i.e., the water vapor content from NCEP/NCAR reanalysis data and emissivity from the ASTER GEDv3 dataset with anNDVI-based correction for vegetation dynamics.

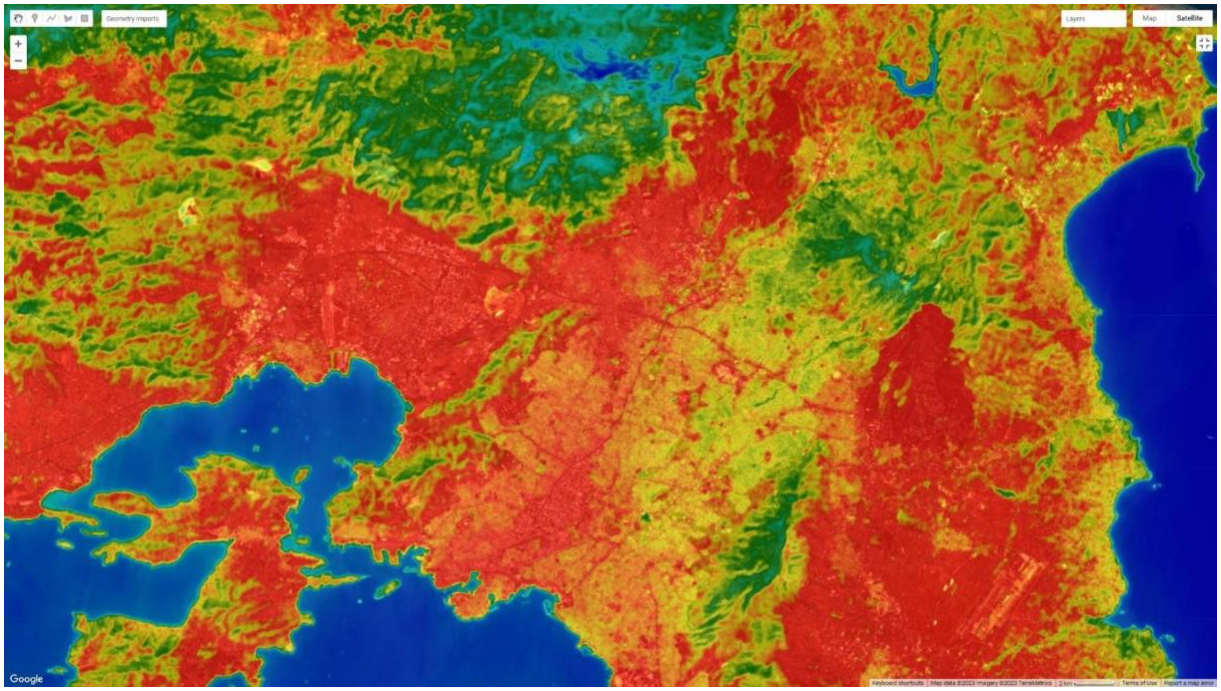


Figure. Land Surface Temperature (LST) based on Landsat 8 satellite imagery

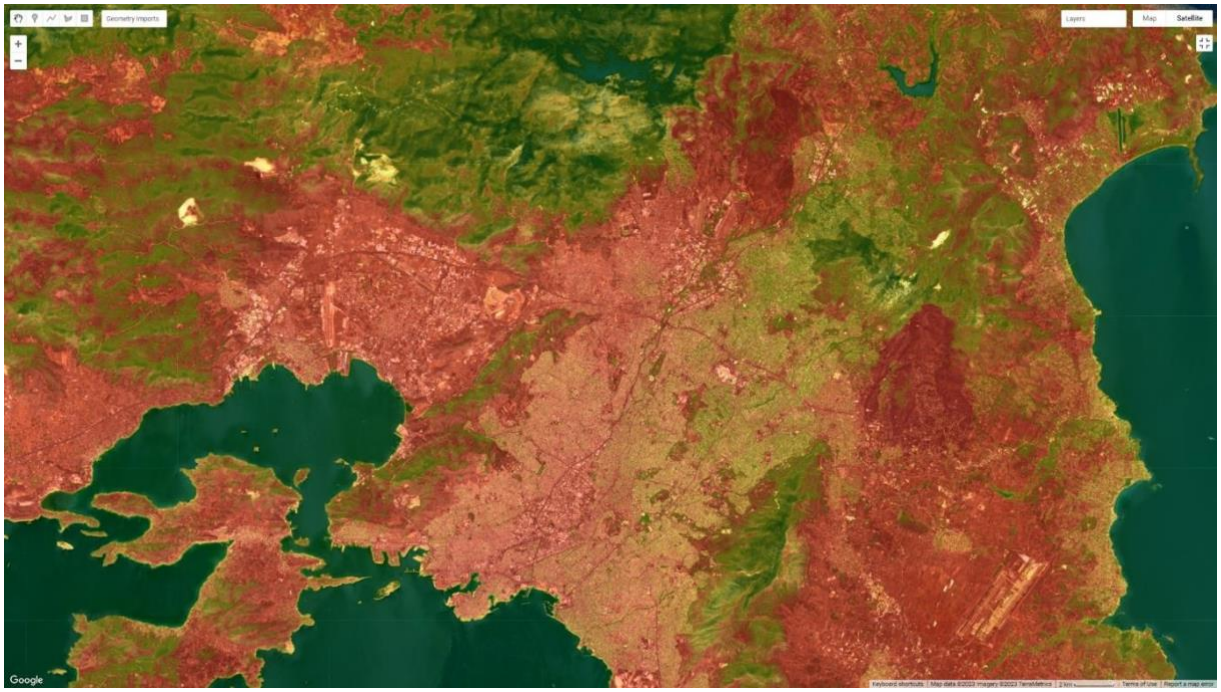


Figure. Land Surface Temperature (LST) and Landsat 8 satellite imagery

4. **Land surface temperature estimation using Methodology no. 2**

Source: *https://ericsamson.com/projects/Python-LandSurfaceTemperature.html*

A different methodology considered the creation of a tool to automate the process of estimating LST from Landsat 8 satellite data only. The tool helps automate three main steps: retrieving variables from a Landsat metadata file, creating an NDVI layer using bands 4 and 5, and performing raster calculations using the gathered variables, NDVI information, and bands 10 and 11 (Thermal Infrared Sensor bands).

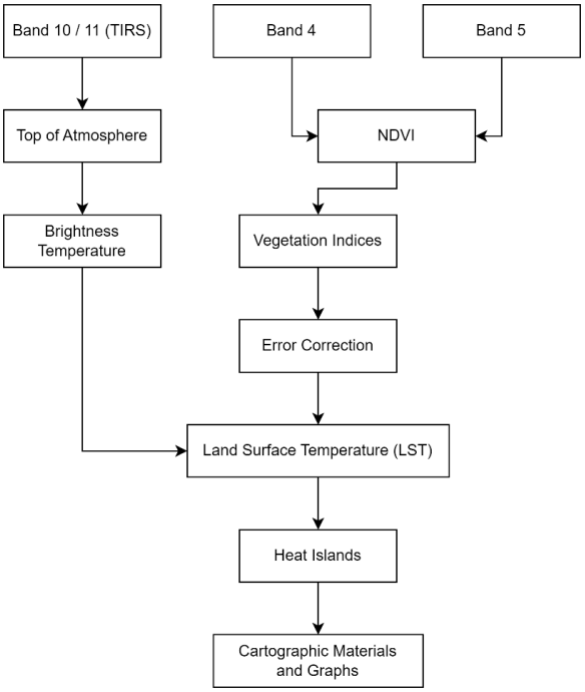


Figure. The simplified processing chain for retrieving Land Surface Temperature (LST) based on Landsat 8 imagery and Urban Heat Islands evaluation.

The tool, developed as a Python script within ArcGIS Pro, calculates several products including LST, NDVI, NDISI, and MNDWI. It requires a path to the folder containing Landsat 8 bands and metadata, which can be obtained from the USGS's Earth Explorer. It can also take a mask geometry to limit the analysis to specific areas of interest.

The output LST raster is in degrees Celsius and is labelled with a naming convention indicating the time and date of acquisition.

The script is designed to estimate the LST using user-inputted Landsat 8 bands. It also has the option to generate outputs for NDVI, MNDWI, and NDISI.

However, it is important to note that the script specifically works with Landsat 8 bands obtained from the Level-1 Product Bundle. The tool requires a folder path containing bands 3, 4, 5, 6, 10, and 11 of Landsat 8.

Additionally, the associated MTL metadata file (e.g., LC08_L1TP_147047_20181110_20181127_01_T1_MTL) is necessary. The script will extract the required variables from the metadata file to be used in the equations within the script.

5. Urban Heat Islands (UHI) analysis based on LST data

Land surface temperature (LST) analysis plays a crucial role in studying and understanding urban heatislands (UHIs). UHIs generally refer to the phenomenon where urban areas experience higher temperatures compared to their surrounding rural areas due to human activities and urbanization. However, frequently, UHI analyses are strictly urban oriented and aim to identify and evaluate urban areas with very high temperatures compared to the surrounding areas.

By leveraging LST data derived from Landsat 8 satellite imagery, urban heat island studies can providevaluable insights into the thermal behavior of urban environments and their implications for urban planning, climate adaptation, and public health.

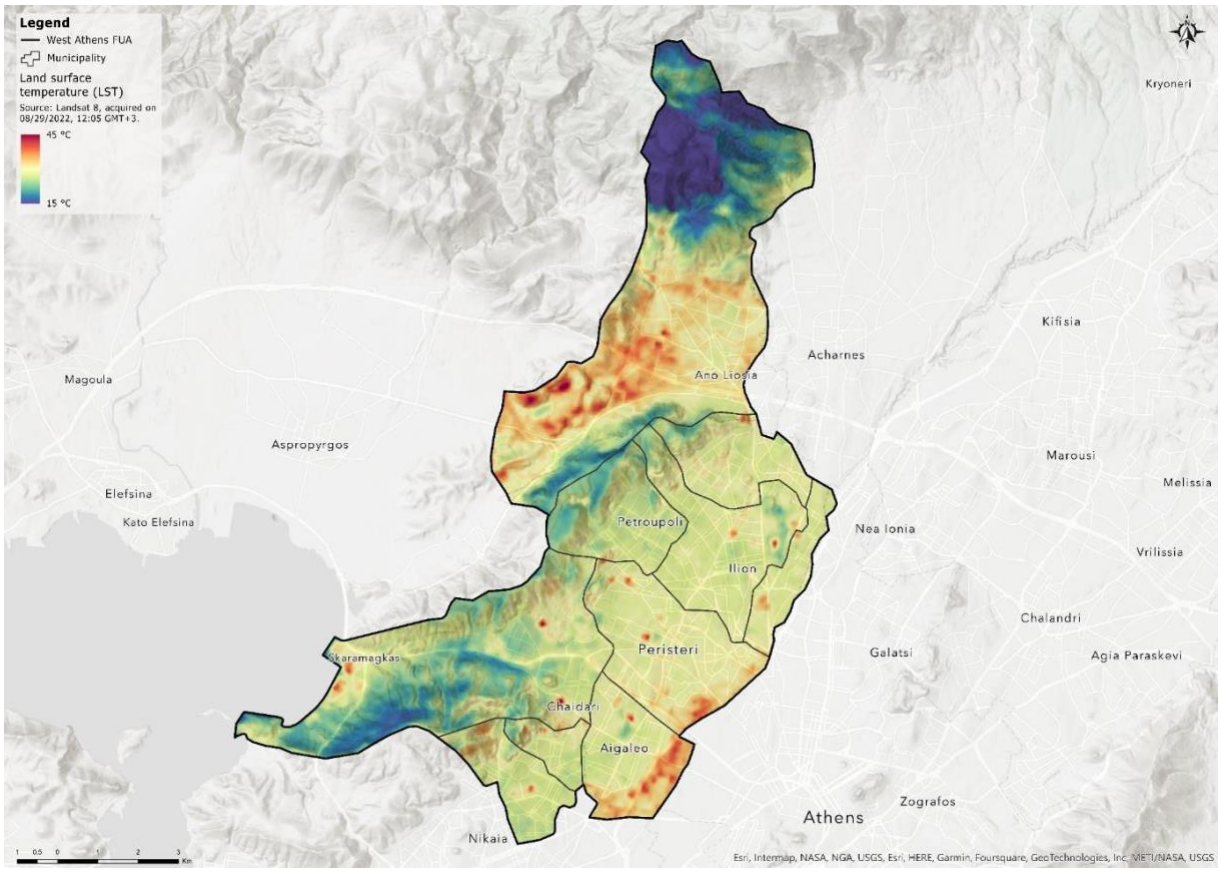


Figure. Land Surface Temperature (LST) in West Athens, August 2022

UHI analysis involves the identification and mapping of urban heat islands. By comparing LST values between different areas, heat island intensity and spatial extent can be quantified. This information helps in delineating areas that are most affected by urban heat and guides the implementation of heatmitigation strategies.

Spatial Analysis: LST data is analyzed using geographic information systems (GIS) software, such as ArcGIS or QGIS, to identify and map UHI patterns. Spatial analysis techniques, including zonal statistics and hotspot analysis, help characterize UHI intensity and spatial extent.

Statistical Analysis: Statistical techniques, such as correlation analysis and regression modelling, can be applied to explore the relationships between LST and various urban parameters (e.g., land use, vegetation cover, building density) to identify factors influencing UHI formation.

Temporal Analysis: Temporal analysis of LST data allows for the examination of UHI dynamics over time. By analyzing long-term trends, seasonal variations, and diurnal patterns, researchers gain insights into the temporal behavior of UHIs.

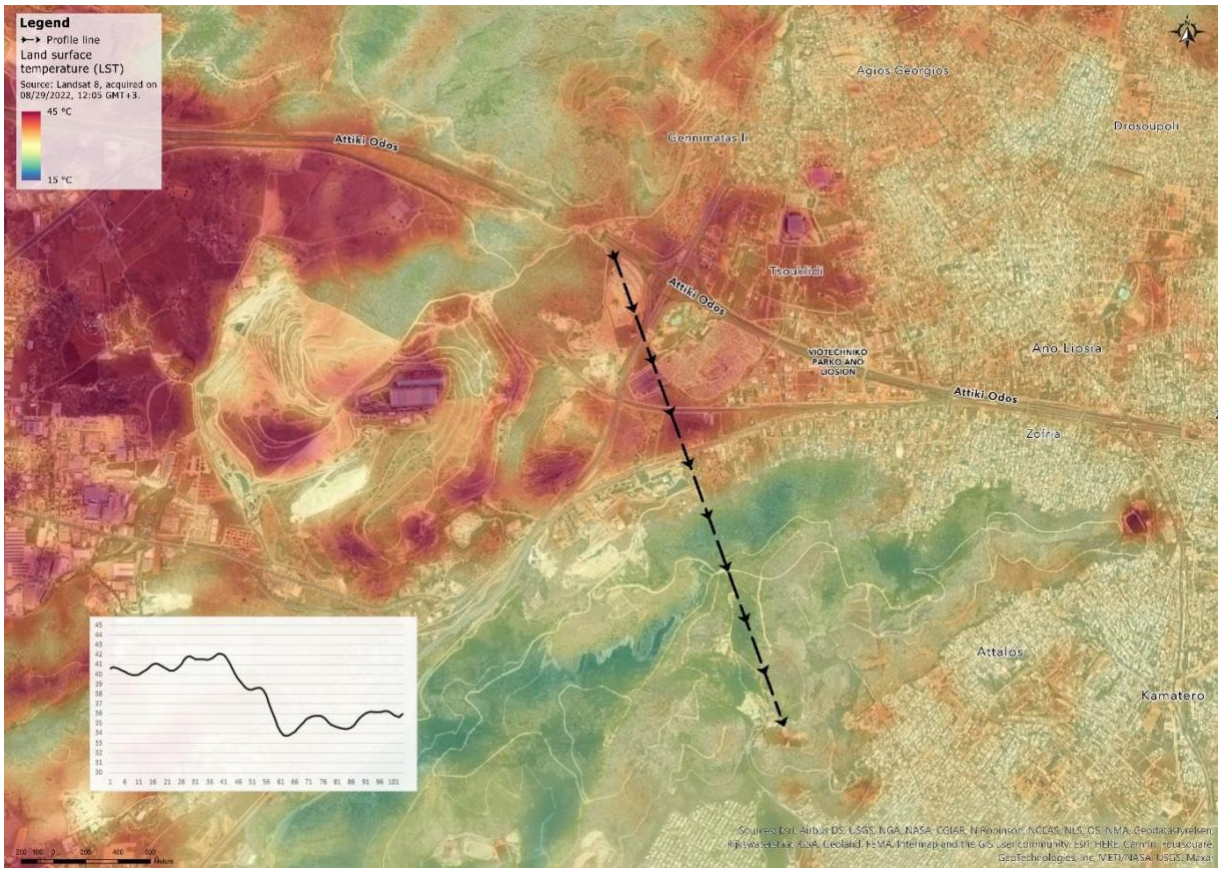


Figure. Urban Heat Island analysis in the norther part of West Athens, based on LSA data from August 2022

Note: The accuracy and reliability of the UHI analysis are subject to the quality of Landsat imagery, calibration techniques, atmospheric correction methods, and assumptions made during the LST retrieval process.

Recommendation: It is important to specify that a proper analysis (on solid foundations) of urban heat islands must be based on both Land Surface Temperature (LST) data and auxiliary data series (climate,land use / land cover etc.) as well as data taken from the field and local knowledge. Moreover, to reduce possible errors and deviations as much as possible, a more suitable approach could be to use the average LST values of all available data for a certain season and year (for the average LST situation in the summer season of 2022, to analyze all available satellite images for the months of June,July, August).

Additional information on LST models, methods, and techniques.

Radiative Transfer Equation (RTE) Models: RTE models simulate the radiative transfer process fromthe land surface to the satellite sensor. These models account for factors such as atmospheric conditions, sensor characteristics, and land surface emissivity. By solving the RTE equations, specialists can estimate LST from the measured at-sensor radiance values.

Split-Window Algorithms: Split-window algorithms utilize the thermal bands (Band 10 and Band 11) of Landsat imagery, which are sensitive to different atmospheric absorption and emission properties. By considering the brightness temperature differences between these bands and using predefined coefficients, specialists can estimate LST. Split-window algorithms are computationally efficient and widely used for LST retrieval.

Planck's Law: Planck's Law relates the spectral radiance emitted by an object at a specific temperatureto the wavelength and temperature of the object. By applying Planck's Law to the thermal infrared bands of Landsat imagery and considering atmospheric and sensor-specific parameters, specialists can calculate LST from the measured at-sensor radiance values.

Atmospheric Correction: Atmospheric correction techniques are essential to remove the influence ofatmospheric effects on the thermal signal. These techniques involve estimating and compensating for atmospheric scattering and absorption. Various methods, such as the Single-Channel Algorithm and the Atmospheric and Topographic Correction (ATCOR) method, are employed to correct for atmospheric influences and improve the accuracy of LST retrieval.

Calibration and Validation: Calibration of the Landsat thermal bands is crucial to convert digital numbers (DN) to at-sensor radiance values. Calibration coefficients provided by the satellite instrument's specifications are used for this purpose. Additionally, validation of LST data is essential toassess its accuracy. Ground truth measurements obtained from handheld infrared thermometers or ground-based weather stations are compared with the estimated LST values to validate the retrieval methodology.

ANNEX 5. COMPENDIUM OF CLIMATE CHANGE ADAPTATION AND MITIGATION MEASURES FOR CITIES

Compendium for Municipalities

Climate Change Adaption and Mitigation Measures

Introduction

Measures for climate adoption and mitigation

In an era marked by unprecedented climatic changes, the urgency to address and adapt to these shifts has never been more critical. The focus of this paper extends to listing and examining innovative adaptation measures designed to build resilience in diverse ecosystems and communities. Concurrently, the paper explores effective mitigation strategies aimed at reducing greenhouse gas emissions and curtailing the progression of climate change.

Adaptation Measures: These are strategies designed to help individuals, communities, and ecosystems cope with the effects of climate change that are either already occurring or are inevitable. Adaptation measures are about managing the risks and reducing the vulnerabilities associated with climate change. Adoption measures can be considered **reactive** in combating climate change.

Mitigation Measures: These are actions taken to reduce the magnitude of future climate change. Mitigation involves reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing sources of these gases (like the burning of fossil fuels for electricity, heat, or transport) or enhancing the "sinks" that accumulate and store these gases (such as the oceans, forests, and soil). Mitigation measures can be considered **proactive** in increasing resilience and fighting climate change and have a strong behaviour change component.

Urban Heat Management

Adaptation Measures

These measures are primarily focused on coping with the effects of climate change:

- Improving Early Warning Systems: Develop systems that help to better prepare for heat waves
- Impact Scenarios: Improve strategic planning by assessing how urban overheating could impact lives, livelihoods, and infrastructure.
- Training of Emergency Response Personnel/Volunteers: Prepare emergency response personnel/volunteers to better address the impact of urban overheating (e.g. first aid, stockpiling/review of equipment/etc related to UHI impact, readiness of emergency systems to deal with large UO events, ensuring functionality of critical (first responders') infrastructure/services, heat action planning).
- Cooling Centres: Provide relief during heatwaves, particularly for vulnerable populations.
- Heat-Resilient Building Design: Incentives for designs that cope with heat.
- Energy-Efficient Building Standards: Minimize energy use for cooling systems.
- Heat-Resilient Infrastructure: Upgrade infrastructure to withstand extreme heat.
- Community Engagement: Engage communities in managing heat effects.
- Data Collection and Monitoring: Monitor heat patterns and track mitigation progress.
- Heat Action Plans: Plans for response to extreme heat events.
- Heat-Resilient School Yards: Protect children from heat during school activities.
- Public Building Energy Audits: Assess and improve cooling efficiency in buildings.
- Heat Officer in Every Neighbourhood: Monitor and coordinate responses to heat risks.
- Festival and Event Cooling Strategies: Implement cooling measures for large public events.
- Heat Mitigation Impact Bonds: Finance projects aimed at coping with urban heat.

Mitigation Measures

These measures aim to reduce the future impact of climate change:

- Tree Planting and Urban Green Spaces: Absorb CO2 and reduce heat through transpiration.
- Public Transit and Active Transportation: Reduce reliance on heat-producing vehicles.
- Expansion of Urban Wetlands: Cool areas through evaporation and increase biodiversity.
- Urban Albedo Enhancement Projects: Reflect more sunlight to reduce heat absorption.
- Solar-Powered Street Vendors: Reduce heat generated by cooking with renewable energy.

Measures that Blend Both Adaptation and Mitigation

These strategies help manage the risks of climate change while also reducing its causes:

- Cool Roofing: Reflect sunlight to reduce heat and energy consumption for cooling.
- Green Roofing and Walls: Insulate buildings and absorb CO2, providing cooling and habitat.
- Cool Pavements: Reflect sunlight and reduce heat absorption, lowering local temperatures.
- Urban Planning and Zoning: Integrate green infrastructure to manage and reduce urban heat.
- Cooling Technologies: Such as cool roofs and district cooling systems, reduce energy use and manage heat.
- Partnerships and Collaboration: Pool resources to both manage and reduce urban heat.
- Incentives for Permeable Pavements: Enhance ground cooling and water absorption.
- Urban Canopy Goals: Increase tree coverage for both CO2 absorption and shade.
- Night Sky Radiation Encouragement: Enhance heat loss to reduce stored heat in structures.
- Vertical Gardens on Freeways: Add greenery to absorb pollution and provide cooling.
- Cooling Microclimate Creation: Use water and vegetation to cool dense urban areas.
- Enhanced Public Awareness Campaigns: Educate on risks of urban heat and mitigation methods.

- Urban Heat Research Partnerships: Develop localized solutions to manage and reduce heat.
- Evaporative Cooling Public Art: Utilize cooling principles and add to urban aesthetic.
- Regulations for Dark Surface Albedo: Limit dark surfaces to reduce heat absorption.
- Subsidized Shade Sail Programs: Provide shade to cool areas and encourage outdoor activity.
- Mandatory Green Space in Development: Ensure developments include cooling green spaces.
- Cooling Bus Shelter Designs: Provide shade and cooling in public transport areas.
- Thermal Comfort Codes for Public Spaces: Ensure public spaces are designed to manage heat.
- Climate Adaptive Urban Planning Courses: Educate on integrating climate adaptation and mitigation.
- Innovative Heat-Resilient Pavement Trials: Test pavements that stay cool and reflect heat.
- Heat-Resilient Retrofitting Grants: Retrofit buildings to reduce heat absorption.
- Climate-Adaptive Building Materials Subsidies: Encourage use of materials that reduce urban heat.

Built Environment and Energy

Adaptation Measures

These strategies are primarily about adapting to the current and expected future impacts of climate change, often through improving energy efficiency or adjusting to the new conditions:

- Mandate Energy Performance Labels: Informing about efficiency adapts to energy demands.
- Mandate Higher EPL, Impose a Fine on Lower EPL: Encouraging higher efficiency standards.
- Improve Building Code - All new buildings: Ensuring new constructions are adapted to be more energy-efficient.
- Implement EE Refurbishment Program For All Municipal Buildings: Upgrading existing buildings to adapt to energy efficiency needs.
- Enforce Energy Retrofitting in Historical Buildings: Preserving historical buildings while adapting them for energy efficiency.
- Urban Planning for Thermal Comfort: Considering thermal comfort adapts urban planning to climate impacts.
- Establish Energy Auditing Services: Helps buildings adapt by identifying energy efficiency opportunities.
- Promote Window Retrofit Programs: Retrofitting existing buildings for better thermal performance.
- Incentivize the Use of Sustainable Insulation: Improving building adaptability to temperature extremes.
- Promote the Adoption of Energy Management Systems: Adapting building operations for optimal energy use.
- Public Facilities as Sustainability Hubs: Adapt public spaces to promote and educate on sustainability.
- Implement Seasonal Energy Conservation Campaigns: Adaptation to seasonal changes to conserve energy.
- Energy-Efficient Public Lighting Initiatives: Adapting public lighting to be more responsive and efficient.

Mitigation Measures

These measures focus on reducing the long-term impacts of climate change by lowering greenhouse gas emissions:

- Mandate Roof-top Solar Hot Water: Reduces reliance on non-renewable energy sources.
- Implement City-wide Emissions Trading System (ETS): Incentivizes emissions reductions.
- Require All New Developments to be High-density And Mixed-use: Reduces transportation emissions.
- Finance for Private Energy Efficiency Refurbishment: Financial support for energy efficiency reduces emissions.
- Finance Green Construction Through Banks: Promotes building projects that mitigate environmental impact.
- Finance Green Mortgages Through Banks: Encourages environmentally friendly renovations and purchases.
- Finance Green Municipal Buildings: Investment in sustainable, lower-emission municipal buildings.
- Implement Rooftop Solar PV Program: Directly reduces emissions by generating renewable energy.

- Integrate District Energy Into Communities: Efficient community energy use reduces emissions.
- Install Rooftop Solar PV on Municipal Buildings: Decreases municipal reliance on non-renewable energy.
- Upgrade All Streetlights With Energy Efficient Bulbs: Reduces energy consumption and associated emissions.
- Upgrade All Traffic Lights With Energy Efficient Bulbs: Lower energy use and greenhouse gas emissions.
- Develop Incentives for Passive House Standards: Encourages ultra-low energy buildings that reduce emissions.
- Promote Energy Sharing Platforms: Sharing excess renewable energy reduces overall emissions.
- Establish Renewable Energy Cooperatives: Facilitates community-driven emission reductions.
- Green Public Transportation Fleet: Lowers public transit emissions.
- Create a Sustainable Development Checklist: Ensures new developments are low-emission.
- Expand Urban Canopy on Public Lands: Trees absorb CO2, directly mitigating climate change.
- Offer Green Bonds for Sustainable Projects: Funds projects that aim to reduce emissions.
- Support Eco-District Concepts: Eco-districts are designed to minimize environmental impact.
- Subsidize Solar Battery Storage Systems: Encourages use of renewable energy, reducing emissions.
- Fund Green Tech Startups: Supports development of technologies to mitigate climate impact.
- Municipal Carbon Footprint Reporting: Sets targets for emission reductions.

Measures that Blend Both Adaptation and Mitigation

These measures combine elements of adapting to climate change while also working to mitigate its causes:

- Promote Cool Roofs: Reduces cooling needs (adaptation) and energy use (mitigation).
- Increase Extent of Urban Forestry: Improves climate resilience (adaptation) and captures carbon (mitigation).
- Incentivize Green Building Certification (e.g., EDGE): Recognizes buildings that are both adapted to and mitigate climate change.
- Implement Green Certification/Labeling For All Municipal Buildings: Ensures that municipal buildings are both adapted to climate impacts and are environmentally friendly.
- Implement Urban Heat Island Mitigation Strategies: Combines adaptation to urban temperatures with mitigation strategies like shading and cooling.
- Smart Energy Display Meters: Encourages energy-saving behaviors (adaptation) and reduces overall energy use (mitigation).

Natural Environment

Adaptation Measures

These strategies primarily focus on adapting to the effects of climate change, enhancing resilience, and managing the impacts on natural environments:

- Urban Biodiversity Programs: Adapting urban areas to support biodiversity.
- Mental Health and Well-being Initiatives: Utilizing green spaces for public health, an adaptive use of natural environments.
- Rainwater Harvesting Initiatives: Adapting to water scarcity and managing stormwater.
- Wildlife Corridors: Adapting urban landscapes to support wildlife movement.
- Climate-Resilient Green Infrastructure: Infrastructure that adapts to climatic changes.
- Urban Wetlands Restoration: Adapting urban areas to support natural water management and biodiversity.
- Conservation Easements: Protecting natural areas, adapting land use to conservation needs.
- Sustainable Urban Drainage Systems: Managing water in an adaptive manner mimicking natural processes.
- Enhanced Protection of Coastal and Riverbank Areas: Adapting to prevent erosion and protect ecosystems.
- Heat-Resilient Public Spaces: Adapting public spaces to cope with higher temperatures.
- Low-Impact Development (LID) Standards: Adapting development practices to manage stormwater sustainably.
- Protection of Urban Natural Springs: Preserving natural water sources as an adaptive strategy for water resource management.
- Environmental Restoration Volunteer Programs: Community involvement in adapting and restoring natural environments.

Mitigation Measures

- These actions are taken to reduce the long-term impact of climate change by addressing its root causes, such as greenhouse gas emissions:
- Community Gardens and Urban Agriculture: Mitigating food transportation emissions by promoting local production.
- Urban Tree Canopy Expansion: Trees sequester carbon, mitigating greenhouse gas concentrations.
- Sustainable Transportation Greenways: Mitigating emissions by promoting sustainable transit options.
- Green Roofs on Public Buildings: Green roofs provide insulation and carbon sequestration.
- Pollinator-Friendly Landscaping: Supports biodiversity, which can contribute to ecological carbon cycles.
- Carbon Sequestration Projects: Directly aimed at reducing atmospheric CO2 levels.
- Native Plant Landscaping Rebates: Native plants can be more efficient carbon sequesters and require less maintenance.
- Zero-Net-Loss Biodiversity Policies: Maintaining biodiversity can ensure ecosystems continue to sequester carbon effectively.
- Urban Orchard Programs: Trees in orchards can contribute to carbon sequestration.
- Eco-Tourism Development: Can reduce the carbon footprint of tourism and support conservation.

Measures that Blend Both Adaptation and Mitigation

- These strategies combine elements of adapting to climate change and mitigating its causes:
- Eco-Friendly Urban Design: Incorporates both adaptation to environmental challenges and mitigation through sustainable practices.
- Public Green Spaces: Provide cooling and stormwater management (adaptation) and improve air quality and carbon sequestration (mitigation).
- Educational Programs on Environment: Increase knowledge for both adapting to and mitigating climate change.
- Invasive Species Management: Controls invasive species to preserve ecosystem function, which is adaptive and supports carbon sequestration (mitigation).
- Environmental Impact Assessments for New Projects: Ensure new projects are environmentally friendly, considering both adaptation and mitigation.
- Citizen Science Programs: Engage the public in environmental monitoring, which informs both adaptation strategies and mitigation efforts.
- Dark Sky Initiatives: Protects nocturnal wildlife (adaptation) and reduces energy use (mitigation).
- Green Space Accessibility Standards: Ensures equitable access to green spaces for health (adaptation) and supports urban ecosystems that sequester carbon (mitigation).
- Climate-Adaptive Tree Species Planting: Ensuring urban forestry is resilient to climate change (adaptation) and enhances carbon sequestration (mitigation).
- Urban Permaculture Projects: Create sustainable ecosystems that are resilient to climate change (adaptation) and can also reduce food-related emissions (mitigation).

Transport

Adaptation Measures

These strategies focus on adapting the transportation system to the impacts of climate change and improving resilience:

- Climate-Resilient Transportation Infrastructure: Strengthening transport infrastructure to withstand extreme weather events.
- Street Design for Temperature Reduction: Using materials and designs to reduce heat in urban areas.
- Public Transit On-Demand: Adapting public transport services to be more flexible and responsive to demand in less densely populated areas.
- Urban Freight Delivery Regulations: Adapting delivery systems to be more efficient and less disruptive in urban settings.
- Telecommuting and Flexible Work Policies: Adapting work habits to reduce commuting and consequent transport demands.
- Pedestrianization Projects: Adapting urban areas for pedestrian use, improving walkability and reducing reliance on vehicular transport.
- Climate Education in Driver Licensing: Integrating climate adaptation knowledge into driver education.

Mitigation Measures

These measures aim to reduce the greenhouse gas emissions from the transportation sector:

- Mandate Retirement of Inefficient Cars/Motorcycles: Removing high-emission vehicles from roads.
- Mandate Min. Efficiency For New Cars/Motorcycles: Ensuring new vehicles are more fuel-efficient.
- Introduce Congestion Charging Zone: Discouraging car use in busy areas, thereby reducing emissions.
- Remove/Reduce Street Parking Spaces: Discouraging car use, leading to reduced emissions.
- Cap Existing Off-street Parking and Limit New Private Vehicle Registrations: Limiting the growth of vehicle numbers and use.
- Mandate Sharing in Ride-hailing Vehicles and Create Car-free Zones: Reducing the number of cars on the road.
- Provide EV Charging Infrastructure and Finance Electric Vehicles Through Banks: Supporting the transition to low-emission vehicles.
- Electrify Conventional and BRT Bus Fleets: Shifting public transport to cleaner energy sources.
- Add / Extend / Intensify Subway, BRT, and LRT Systems: Increasing the capacity and attractiveness of low-emission public transit.
- Green Vehicle Incentives and Sustainable Fuel Infrastructure: Promoting the use of lower-emission vehicles and fuels.
- Public Transport Green Energy Supply: Moving public transport to renewable energy.
- Green Airport Initiatives: Reducing the carbon footprint of airport operations.
- Low-Emission Zones and Shared Mobility Hubs: Encouraging the use of low-emission transport options.
- Transport Sector Emissions Tracking and Climate Impact Assessments for Transport Projects: Focusing on reducing emissions from transport projects.
- Urban Transport Decarbonization Goals: Setting specific targets for reducing emissions in the transport sector.

Measures that Blend Both Adaptation and Mitigation

These strategies have elements that both adapt to the effects of climate change and help to mitigate those effects:

- Densify City Areas and Adhere to TOD For New Developments: Creating more compact urban environments that reduce the need for transport (mitigation) and make infrastructure more efficient (adaptation).
- Build High-occupancy Vehicle Lanes, Designate Street Lanes as Bus Lanes, and Build Bicycle Lanes: Improving the efficiency of the transport system (adaptation) and encouraging modes that contribute less to emissions (mitigation).
- Expand / Redesign Conventional Bus System, Add / Extend Subway System, and Expand Subway Train Fleet: Increasing the capacity and efficiency of public transit (adaptation) while also promoting lower-emission transport options (mitigation).
- Introduce Fare Integration Across Transit System, Introduce Smart Transit Fare Cards, and Introduce Mobile Transit Ticketing: Making public transport more user-friendly (adaptation) and encouraging its use over private, higher-emission vehicles (mitigation).
- Traffic Flow Optimization: Utilizing smart systems to improve traffic (adaptation) and reduce idle times and emissions (mitigation).
- Cycle-to-Work Schemes and Urban Cargo Bike Programs: Encouraging cycling (adaptation to urban space and health) while also reducing vehicle emissions (mitigation).
- Vehicle Idling Restrictions and Navigation Apps Integration: Reducing unnecessary fuel consumption (mitigation) and improving air quality (adaptation).
- Subsidized Public Transit for Low-Income Residents: Making it easier for all segments of the population to use public transport (adaptation) and reducing the number of private vehicles on the road (mitigation).
- Encourage Remote Working Spaces and Multi-Modal Transport Apps: Facilitating alternatives to traditional commuting (adaptation) that also lower overall transport emissions (mitigation).

Waste

Adaptation Measures

These strategies focus on adapting to waste management challenges, improving resilience, and reducing environmental impact:

- Introduce 'pay-as-you-throw' at Consumer Level: Adapting waste management to financial incentives.
- Introduce Landfill Tax at Point of Disposal: Encouraging waste reduction through economic adaptation.
- Improve Waste Collection: Enhancing the adaptability of waste collection services.
- Install Landfill Gas Capture: Adapting to capture and use landfill emissions.
- Community Repair and Reuse Centers: Adapting consumption habits to promote reuse.
- Public Reusable Dish Programs: Encouraging the adaptation of events to reduce waste.
- Public Access to Hazardous Waste Disposal: Providing adaptation strategies for hazardous waste disposal.
- Support for Home Composting: Adapting household waste management practices.
- Phasing Out Disposable Items in Food Service: Adapting food service practices to reduce waste.

Mitigation Measures

- These measures aim to reduce environmental impacts and greenhouse gas emissions associated with waste:
- Mandate Decentralised Composting/Anaerobic Digestion: Mitigating methane emissions from organic waste.
- Ban Single Use Plastics: Mitigating plastic pollution.
- Mandate Extended Producer Responsibility For Packaging: Mitigating waste through producer action.
- Facilitate Safe Food Donation or Feed Production: Mitigating food waste.
- Zero Waste Policy Implementation: Aiming to mitigate the total waste footprint.
- Urban Mining Programs: Reducing the need for new materials extraction through recycling, thus mitigating environmental impact.
- Plastic Bag Levies: Mitigating plastic bag use and associated pollution.
- Eco-Labeling for Waste Reduction: Promoting products that mitigate waste generation.
- Green Procurement Policies: Mitigating waste through responsible purchasing.
- Waste-to-Energy Research and Development: Focusing on waste mitigation through energy recovery.
- Regulations for Sustainable Packaging: Mitigating waste by promoting sustainable packaging.
- Mandatory Commercial Waste Audits: Mitigating commercial waste through better practices.
- Subsidized Recycling Bins for Businesses: Mitigating waste by improving recycling rates.
- E-Waste Collection Drives: Mitigating environmental impacts of electronic waste.
- Food Waste Digestion for Energy Production: Reducing waste and greenhouse gas emissions through energy recovery.

Measures that Blend Both Adaptation and Mitigation

- These strategies combine elements of adapting to waste challenges and mitigating environmental impacts:
- Deposit Return Schemes For Containers: Encourages recycling (mitigation) and adapts consumer behaviour.
- Single-stream Collection For Recyclables: Simplifies recycling (mitigation) and adapts the collection process.

- Add / Expand Materials Recovery Facilities: Improves recycling rates (mitigation) and adapts to increased waste volumes.
- Add / Expand Incineration Facilities: Manages waste (adaptation) while potentially recovering energy (mitigation).
- Green Event Standards: Adapting event management to reduce waste (mitigation).
- Local Recycling Education Campaigns: Educating on proper waste handling (adaptation) to reduce environmental impact (mitigation).
- Textile Recycling Programs: Adaptation to textile waste with the mitigation of environmental impacts.
- Encourage Upcycling Markets: Adapting consumer behaviour and markets to reduce waste (mitigation).
- Incentives for Waste Sorting Technologies: Adopting new technologies (adaptation) to improve waste management and recycling (mitigation).
- Support for Local Reuse Organizations: Adapting local systems to promote reuse (mitigation of waste).
- Implement a City-wide Reusable Container Program: Adapting to reusable systems to reduce waste (mitigation).

Water and Waste Water

Adaptation Measures

These strategies are designed to adapt to changes in water availability and improve resilience to water-related challenges:

- Mandate Rooftop Harvesting: Require the installation of systems on rooftops to collect and use rainwater.
- Mandate Rooftop Greenery: Implement regulations for the establishment of green roofs, which can aid in water retention and provide insulation.
- Harvest Rainwater at Municipal Scale: Implement large-scale rainwater harvesting systems to collect and use rainwater for various municipal purposes.
- Develop Ponds / Lakes For Rainwater Storage: Create or enhance ponds and lakes to store rainwater, which can be used for various purposes, including irrigation and groundwater recharge.
- Install New Desalination Plants: Establish facilities to convert seawater into fresh water, increasing the supply of potable water.
- Reuse Wastewater at Municipal Scale: Implement systems to treat and reuse wastewater for non-potable purposes at a city-wide level.
- Incentivize Local Water Retention in Lakes / Ponds / Reservoirs: Offer incentives for the retention and management of water in local bodies of water.
- Mandate Reuse of Wastewater From New Buildings: Require new buildings to have systems for treating and reusing wastewater.
- Mandate Reuse of Greywater From New Buildings: Enforce regulations for new constructions to include systems for the collection and reuse of greywater (from sinks, showers, etc.).

Mitigation Measures

These measures aim to reduce the environmental impact associated with water and wastewater:

- Implement Sustainable Urban Drainage Systems (SUDS): Develop drainage systems that mimic natural processes to manage surface water run-off and improve water quality.
- Water-Sensitive Urban Design: Integrate water-sensitive design principles into urban planning to enhance water conservation and quality.
- Public Space Water Features: Incorporate water features in public spaces that utilize recycled water for aesthetic and cooling purposes.
- Water Conservation Awareness Programs: Launch comprehensive water conservation awareness programs for residents and businesses.
- Water Leak Detection Technology: Deploy advanced technologies for the rapid detection and repair of leaks in the water distribution system.
- Ultraviolet Disinfection for Wastewater: Implement UV disinfection systems for treating wastewater as a chemical-free alternative to chlorine.
- Wastewater Heat Recovery: Implement systems to recover and utilize heat from wastewater, which can be used for heating buildings or industrial processes.

Blended Measures

These strategies incorporate aspects of both adaptation to current water resource challenges and mitigation of environmental impacts:

- Mandate Reuse of Wastewater From Existing Buildings: Require existing buildings to retrofit systems for wastewater treatment and reuse.
- Mandate Reuse of Greywater From Existing Buildings: Implement regulations for existing buildings to install systems for greywater collection and reuse.

- Reuse Wastewater Locally For Flushing / Outdoor Uses: Promote the local reuse of treated wastewater for purposes like toilet flushing and outdoor watering.
- Reduce Unaccounted-for Water Losses: Implement measures to decrease water losses in the supply system due to leaks, unauthorized use, or metering inaccuracies.
- Improve Efficiency For Water Conveyance Pumps: Upgrade and enhance the efficiency of pumps used in water conveyance systems to reduce energy consumption and operational costs.
- Divert Untreated Fresh Water to Secondary Use: Implement systems to redirect untreated freshwater, such as rainwater or excess river water, for non-potable uses.
- Promote Voluntary Green Building Certification (EDGE): Encourage buildings to obtain green certification, like EDGE, which includes efficient water use as a key criterion.
- Mandate Efficient Fittings in New Buildings: Require new buildings to install water-efficient fixtures like low-flow taps and toilets to reduce water consumption.
- Mandate Efficient Fittings in Existing Buildings: Implement regulations for existing buildings to upgrade to water-efficient fixtures.
- Install Smart Meters to Reduce Consumption And Leakage: Deploy smart water meters to monitor and manage water use more effectively, helping to identify leaks and reduce consumption.
- Add New Centralised Wastewater Treatment Facilities: Develop new facilities for the centralized treatment of wastewater, improving the capacity and efficiency of wastewater management.
- Improve The Efficiency of Existing WWTP (Wastewater Treatment Plants): Upgrade existing wastewater treatment plants to enhance their efficiency and capacity.
- Add Pre-treatment Technology For Direct Discharge: Implement pre-treatment technologies in wastewater systems to treat water before it is discharged directly into the environment.
- Add Local Scale Wastewater Treatment Plant: Establish smaller, localized wastewater treatment facilities to manage waste in specific areas or communities.
- Add Biogas Recovery to Existing WWTP: Introduce biogas recovery systems in existing wastewater treatment plants to capture and utilize methane produced during the treatment process.

Economy and Industries

Adaptation Measures

Adaptation measures are actions taken to help businesses and the economy become more resilient to the impacts of climate change:

- Biodiversity Conservation Incentives: Incentives for businesses to support local biodiversity efforts.
- Climate-Adaptive Infrastructure Incentives: Incentives for investing in infrastructure resilient to climate impacts.
- Urban Heat Island Mitigation Requirements: Requirements for businesses to mitigate urban heat effects.
- Municipal Green Venture Capital Fund: Funding for local green startups adapting to sustainability needs.
- Climate Adaptation Tax Credits: Tax credits for businesses investing in climate adaptation.
- Climate Risk Assessment and Adaptation for Industries: Encouraging industries to assess and adapt to climate risks.
- Water-Sensitive Urban Design: Integrating design principles to adapt urban planning to water conservation and quality.
- Public Space Water Features: Using recycled water in public space features for aesthetic and cooling purposes.
- Waterway Restoration Initiatives: Restoring waterways to improve ecological health and water purification.

Mitigation Measures

Mitigation measures are efforts to reduce the long-term impact of climate change by reducing greenhouse gas emissions and enhancing sustainability:

- Green Building Incentives: Incentives for buildings that meet high environmental performance standards.
- Corporate Renewable Energy Pledges: Businesses pledging to shift towards renewable energy.
- Sustainable Agriculture Zone Designations: Designating zones for sustainable agriculture to promote local food production.
- Local Carbon Offset Programs: Programs for businesses to invest in local environmental projects to offset emissions.
- Green Patents Fast Track: Fast-tracking service for patents related to environmental technologies.
- Net-Zero Business Districts: Creating business districts with net-zero emissions.
- Carbon Tax and Emissions Trading: Implementing a tax or trading system to incentivize emission reductions.
- Green Job Creation Incentives: Incentives for creating jobs in green industries.
- Energy Efficiency Grants for Businesses: Grants for investing in energy-efficient technologies.
- Circular Economy Initiatives: Encouraging principles that focus on reducing waste and recycling materials.
- Sustainable Supply Chain Management: Promoting environmentally responsible supply chain practices.
- Waste-to-Energy Initiatives: Converting industrial waste into energy.
- Enhanced Reporting on Corporate Sustainability: Requiring reports on sustainability practices.
- Support for Transition to Clean Energy Sources: Support for industries to switch to clean energy.

Blended Measures

Blended measures encompass strategies that contribute to both adaptation and mitigation:

- Eco-Industrial Parks: Collaboration on sustainability goals like shared waste management and energy systems.
- Green Workforce Development Grants: Training programs focused on green jobs.
- Environmental Impact Bonds: Funding projects with environmental benefits.
- Sustainable Event Certifications: Certification system for sustainable events.
- Employee Commuter Incentive Programs: Encouraging the use of sustainable transportation among employees.
- Local Supply Chain Development: Developing local supply chains to reduce emissions and promote economic growth.
- Green Office Certification: Certifying office spaces for sustainability.
- Commercial Food Waste Reduction Programs: Reducing food waste in businesses.
- Business Energy Savings Challenges: Rewarding businesses for energy savings.
- Green Tech Research and Development Funding: Funding for green technology research.
- Tax Breaks for Sustainable Investments: Tax incentives for sustainable practices.
- Eco-Labeling and Consumer Awareness Campaigns: Promoting consumer choice towards eco-friendly products.
- Green Public Procurement Policies: Prioritizing sustainable products in government procurement.
- Industry-Specific Environmental Regulations: Tailored regulations to reduce pollution.
- Energy Audits and Management for Industries: Energy audits to identify savings measures.
- Training Programs for Green Skills: Equipping the workforce for green industry employment.
- Incentives for Eco-friendly Product Design: Encouraging sustainable product design.
- Low-Interest Loans for Green Business Ventures: Financial assistance for green businesses.
- Public-Private Partnerships for Sustainability Projects: Collaborations for sustainability projects.
- Support for Small and Medium-Sized Enterprises (SMEs) in Green Transition: Assisting SMEs in adopting sustainable practices.
- Innovation Hubs for Sustainable Development: Centers focusing on innovative environmental solutions.

- Promotion of Sustainable Tourism: Promoting environmentally sustainable tourism practices.
- Investment in Sustainable Urban Development: Funding sustainable urban development projects.
- Grants for Environmental Compliance: Grants to help comply with environmental standards.

Land Use and Agriculture

Adaptation Measures

These are focused on adjusting agricultural practices to climate change and enhancing resilience:

- Climate-Resilient Crop Varieties: Developing crops that can withstand climate impacts.
- Reforestation and Afforestation Programs: Restoring forests to adapt to and mitigate climate impacts.
- Wetland Preservation and Restoration: Preserving wetlands to maintain water quality and support biodiversity.
- Climate Change Adaptation Strategies for Agriculture: Developing strategies for the agricultural sector to adapt to climate change.
- Enhanced Agricultural Risk Insurance: Improving risk insurance products to protect against climate-related losses.
- Development of Drought-Resistant Farming Systems: Researching farming systems resilient to drought.
- Regenerative Agriculture Programs: Promoting practices that restore soil health and adapt to ecological conditions.
- Farm-to-School Programs: Providing local produce to schools, adapting to local food systems.
- Climate Adaptation Plans for Agriculture: Implementing plans to help the agricultural sector adapt to climate change.
- Agricultural Zoning for Climate Resilience: Zoning regulations that promote climate-resilient farming practices.

Mitigation Measures

These are designed to reduce greenhouse gas emissions and other environmental impacts:

- Sustainable Farming Practices: Enhancing soil health and reducing chemical inputs.
- Agroforestry: Integrating trees into farmland to sequester carbon.
- Precision Agriculture: Optimizing field management to reduce environmental impact.
- Sustainable Livestock Management: Reducing methane emissions from livestock.
- Incentives for Organic Farming: Transitioning to practices that reduce chemical use.
- Sustainable Fisheries and Aquaculture Practices: Protecting aquatic ecosystems and ensuring long-term viability of fish stocks.
- Promotion of Local and Seasonal Food Consumption: Reducing the carbon footprint associated with food transportation.
- Forest Management and Certification: Ensuring forestry practices are environmentally responsible.
- Renewable Energy on Farms: Incentivizing the installation of renewable energy sources on farms.
- Greenhouse Gas Inventories for Agriculture: Targeting emission reduction in agriculture.
- Nutrient Management Plans: Managing fertilizer application to reduce runoff.

Blended Measures

- These strategies contribute to both adapting to and mitigating climate change:
- Urban Agriculture Initiatives: Increasing local food production and green spaces.
- Land Conservation Programs: Conserving land to protect biodiversity and ecosystems.
- Water-Efficient Irrigation: Promoting irrigation systems that minimize water wastage.
- Protected Agricultural Zones: Protecting areas for agriculture from urban sprawl.
- Habitat Restoration Projects: Restoring ecosystems for biodiversity and land resilience.
- Sustainable Industry Practices: Promoting sustainable manufacturing and production processes.

- Local Seed Bank Initiatives: Preserving biodiversity with climate-resilient seeds.
- Urban Food Policy Councils: Working on policies for sustainable local food systems.
- Incentives for Carbon Sequestration in Agriculture: Encouraging practices that sequester carbon in soils.
- Conservation Agriculture: Improving soil health, conserving water, and increasing biodiversity.
- Technology Adoption in Agriculture: Adopting agricultural technologies for better resource management.
- Integration of Indigenous Knowledge: Incorporating traditional agricultural practices for sustainable land use.
- Urban Planning for Food Security: Ensuring access to fresh produce in urban areas.
- Protection of Urban Farmland: Protecting farmland within urban areas from development.
- Community Composting Programs: Turning organic waste into fertilizer for agricultural use.
- Incentives for Cover Cropping: Improving soil quality and preventing erosion.
- Urban Agriculture Education Centers: Educating urban residents about sustainable farming.
- Agricultural Water Pricing Reform: Encouraging water conservation in agriculture.
- Enhance Urban Beekeeping: Supporting pollination and biodiversity in urban settings.
- Peri-Urban Agriculture Development: Developing agriculture in transitional areas between urban and rural.

Culture and Tourism

Adaptation Measures

These strategies focus on adjusting cultural and tourism practices to cope with the impacts of climate change:

- Climate Change Education at Tourist Sites: Integrating educational content on climate change into tours and exhibits.
- Preservation of Natural and Cultural Sites: Protecting sites threatened by climate change.
- Resilience Building for Cultural Assets: Investing in cultural assets to make them more resilient to climate impacts.
- Climate-Resilient Tourism Infrastructure Grants: Providing grants for infrastructure resilient to climate impacts.
- Cultural Heritage Climate Resilience Assessments: Assessing cultural heritage sites for vulnerabilities to climate change.
- Climate Adaptation Planning for Tourism: Developing plans for the tourism sector to adapt to climate impacts.
- Climate Adaptation Workshops for Tour Operators: Conducting workshops to help tour operators integrate adaptation strategies.
- Beach Erosion Control Measures: Implementing control measures for beach erosion exacerbated by climate change.

Mitigation Measures

These measures aim to reduce the environmental impact of tourism and cultural activities:

- Promote Eco-Friendly Travel Options: Encouraging sustainable transportation methods for tourists.
- Carbon Offset Programs for Travelers: Implementing programs for tourists to offset their carbon emissions.
- Renewable Energy in Tourism Infrastructure: Encouraging the use of renewable energy in tourism facilities.
- Green Building Standards for Tourism Facilities: Adopting green building standards to minimize environmental impact.
- Sustainable Cruise and Aviation Practices: Working with industries to adopt sustainable practices.
- Certification for Carbon-Neutral Tourism Businesses: Certifying tourism businesses that achieve carbon neutrality.
- Sustainable Marina Development: Promoting sustainable marinas with environmental best practices.
- Greenhouse Gas Inventories for Agriculture: Conducting inventories to target emission reduction.

Blended Measures

These strategies contribute to both adapting to and mitigating climate change:

- Sustainable Accommodation Certifications: Promoting certifications for accommodations with high environmental standards.
- Green Event Planning: Promoting environmentally friendly practices in event organization.
- Local and Sustainable Food Offerings: Supporting locally sourced and sustainable food options.
- Water Conservation Measures: Implementing water-saving practices in tourism facilities.
- Reduce, Reuse, Recycle Initiatives: Facilitating waste reduction initiatives in tourism.

- Low-Impact Tourism Activities: Encouraging tourism activities with minimal environmental impact.
- Sustainable Souvenir Production: Encouraging the production of environmentally friendly souvenirs.
- Energy-Efficient Museums and Cultural Centers: Upgrading energy systems in cultural facilities.
- Promotion of Off-peak Tourism: Reducing the impact of tourism by promoting off-peak travel.
- Digital Access to Cultural Experiences: Enhancing digital access to reduce travel emissions.
- Community Involvement in Sustainable Tourism: Engaging communities in sustainable tourism practices.
- Biodiversity Conservation Efforts: Supporting biodiversity conservation in tourist destinations.
- Collaborations with Environmental Organizations: Partnering with organizations for sustainable tourism.
- Incentives for Sustainable Practices in Tourism: Offering incentives for sustainable practices in tourism businesses.
- Monitoring and Reporting on Tourism's Environmental Impact: Monitoring the environmental impact of tourism activities.
- Heritage Site Sustainability Assessments: Conducting sustainability assessments for heritage sites.
- Eco-Friendly Tourist Transport Services: Developing sustainable tourist transport options.
- Sustainable Tourist Pathways: Creating eco-trails that showcase sustainable practices.
- Tourism Carrying Capacity Limits: Enforcing limits to prevent overuse of natural and cultural resources.
- Tourism Impact Fee: Implementing a fee that contributes to environmental conservation.
- Tourism Sustainability Fund: Creating a fund for sustainability projects in tourism.
- Cultural Exchange for Sustainability Education: Fostering cultural exchange on sustainability.
- Tourism Worker Sustainability Training: Training workers in sustainability practices.
- Regenerative Tourism Projects: Supporting projects that restore ecosystems.
- Climate-Themed Cultural Festivals: Organizing festivals with a focus on climate change.
- Sustainable Film and Photography Guidelines: Issuing guidelines for sustainable practices.
- Eco-Tourism Volunteer Programs: Creating volunteer opportunities linked to eco-tourism.
- Sustainable Artisan and Craft Programs: Supporting local artisans using sustainable methods.
- Tourism Footprint Calculator: Developing a calculator for tourists to estimate their environmental impact.

ANNEX 6. DIMENSIONS AND CODES FOR THE TYPES OF INTERVENTION FOR THE ERDF, THE ESF+ AND THE COHESION FUND

INTERVENTION FIELD		Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
POLICY OBJECTIVE 1: A SMARTER EUROPE BY PROMOTING INNOVATIVE AND SMART ECONOMIC TRANSFORMATION					
001	Investment in fixed assets in micro enterprises directly linked to research and innovation activities	0 %	0 %	No	No
002	Investment in fixed assets in small and medium-sized enterprises (including private research centers) directly linked to research and innovation activities	0 %	0 %	No	No
003	Investment in fixed assets in public research centers and higher education directly linked to research and innovation activities	0 %	0 %	No	No
004	Investment in intangible assets in micro enterprises directly linked to research and innovation activities	0 %	0 %	No	No
005	Investment in intangible assets in small and medium-sized enterprises (including private research centers) directly linked to research and innovation activities	0 %	0 %	No	No
006	Investment in intangible assets in public research centers and higher education directly linked to research and innovation activities	0 %	0 %	No	No
007	Research and innovation activities in micro enterprises including networking (industrial research, experimental development, feasibility studies)	0 %	0 %	No	No
008	Research and innovation activities in small and medium-sized enterprises, including networking	0 %	0 %	No	No
009	Research and innovation activities in public research centers, higher education and centers of competence including networking (industrial research, experimental development, feasibility studies)	0 %	0 %	No	No
010	Digitizing SMEs (including e-Commerce, e-Business and networked business processes, digital innovation hubs, living labs, web entrepreneurs and ICT start-ups, B2B)	0 %	0 %	No	No
011	Government ICT solutions, e-services, applications	0 %	0 %	No	No
012	IT services and applications for digital skills	0 %	0 %	No	No

	INTERVENTION FIELD	Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
	and digital inclusion				
013	e-Health services and applications (including e-Care, Internet of Things for physical activity and ambient assisted living)	0 %	0 %	No	No
014	Business infrastructure for SMEs (including industrial parks and sites)	0 %	0 %	No	No
015	SME business development and internationalization	0 %	0 %	No	No
016	Skills development for smart specialization, industrial transition and entrepreneurship	0%	0%	No	No
017	Advanced support services for SMEs and groups of SMEs (including management, marketing and design services)	0 %	0 %	No	No
018	Incubation, support to spin offs and spin outs and start ups	0 %	0 %	No	No
019	Innovation cluster support and business networks primarily benefiting SMEs	0 %	0 %	No	No
020	Innovation processes in SMEs (process, organizational, marketing, co-creation, user and demand driven innovation)	0 %	0 %	No	No
021	Technology transfer and cooperation between enterprises, research centers and higher education sector	0 %	0 %	No	No
022	Research and innovation processes, technology transfer and cooperation between enterprises focusing on the low carbon economy, resilience and adaptation to climate change	100 %	40 %	No	No
023	Research and innovation processes, technology transfer and cooperation between enterprises focusing on circular economy	40 %	100 %	No	No
POLICY OBJECTIVE 2: A GREENER, LOW CARBON EUROPE BY PROMOTING CLEAN AND FAIR ENERGY TRANSITION, GREEN AND BLUE INVESTMENT, THE CIRCULAR ECONOMY, CLIMATE ADAPTATION AND RISK PREVENTION AND MANAGEMENT					
024	Energy efficiency and demonstration projects in SMEs and supporting measures	100 %	40 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
025	Energy efficiency renovation of existing housing stock, demonstration projects and	100 %	40 %	Potential for joint	Potential for joint

	INTERVENTION FIELD	Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
	supporting measures			adaptation-mitigation intervention	adaptation-mitigation intervention
026	Energy efficiency renovation of public infrastructure, demonstration projects and supporting measures	100 %	40 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
027	Support to enterprises that provide services contributing to the low carbon economy and to resilience to climate change	100 %	40 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
028	Renewable energy: wind	100 %	40 %	No	No
029	Renewable energy: solar	100 %	40 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
030	Renewable energy: biomass	100 %	40 %	No	No
031	Renewable energy: marine	100 %	40 %	No	No
032	Other renewable energy (including geothermal energy)	100 %	40 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
033	Smart Energy Distribution Systems at medium and low voltage levels (including smart grids and ICT systems) and related storage	100 %	40 %	No	No
034	High efficiency co-generation, district heating and cooling	100 %	40 %	No	No
035	Adaptation to climate change measures and prevention and management of climate related risks: floods (including awareness raising, civil protection and disaster management systems and infrastructures)	100 %	100 %	Yes	No
036	Adaptation to climate change measures and prevention and management of climate related risks: fires (including awareness raising, civil protection and disaster management systems and infrastructures)	100 %	100 %	Yes	No

INTERVENTION FIELD		Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
037	Adaptation to climate change measures and prevention and management of climate related risks: others, e.g. storms and drought (including awareness raising, civil protection and disaster management systems and infrastructures)	100 %	100 %	Yes	No
038	Risk prevention and management of non-climate related natural risks (i.e. earthquakes) and risks linked to human activities (e.g. technological accidents), including awareness raising, civil protection and disaster management systems and infrastructures	0 %	100 %	No	No
039	Provision of water for human consumption (extraction, treatment, storage and distribution infrastructure, efficiency measures, drinking water supply)	0 %	100 %	No	No
040	Water management and water resource conservation (including river basin management, specific climate change adaptation measures, reuse, leakage reduction)	40 %	100 %	Yes	Yes
041	Waste water collection and treatment	0 %	100 %	No	No
042	Household waste management: prevention, minimization, sorting, recycling measures	0 %	100 %	No	No
043	Household waste management: mechanical biological treatment, thermal treatment	0 %	100 %	No	No
044	Commercial, industrial or hazardous waste management	0 %	100 %	No	No
045	Promoting the use of recycled materials as raw materials	0 %	100 %	No	No
046	Rehabilitation of industrial sites and contaminated land	0 %	100 %	No	No
047	Support to environmentally friendly production processes and resource efficiency in SMEs	40 %	40 %	No	No
048	Air quality and noise reduction measures	40 %	100 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention

INTERVENTION FIELD		Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
049	Protection, restoration and sustainable use of Natura 2000 sites	40 %	100 %	Yes	Yes
050	Nature and biodiversity protection, green infrastructure	40 %	100 %	Yes	Yes
POLICY OBJECTIVE 3: A MORE CONNECTED EUROPE BY ENHANCING MOBILITY AND REGIONAL ICT CONNECTIVITY					
051	ICT: Very High-Capacity broadband network (backbone/backhaul network)	0 %	0 %	No	No
052	ICT: Very High-Capacity broadband network (access/local loop with a performance equivalent to an optical fibre installation up to the distribution point at the serving location for multi-dwelling premises)	0 %	0 %	No	No
053	ICT: Very High-Capacity broadband network (access/local loop with a performance equivalent to an optical fibre installation up to the distribution point at the serving location for homes and business premises)	0 %	0 %	No	No
054	ICT: Very High-Capacity broadband network (access/local loop with a performance equivalent to an optical fibre installation up to the base station for advanced wireless communication)	0 %	0 %	No 10	No
055	ICT: Other types of ICT infrastructure (including large-scale computer resources/equipment, data centers, sensors and other wireless equipment)	0 %	0 %	No	No
056	Newly built motorways and roads - TEN-T core network	0 %	0 %	No	No
057	Newly built motorways and roads - TEN-T comprehensive network	0 %	0 %	No	No
058	Newly built secondary road links to TEN-T road network and nodes	0 %	0 %	No	No
059	Newly built other national, regional and local access roads	0 %	0 %	No	No
060	Reconstructed or improved motorways and roads - TEN-T core network	0 %	0 %	No	No
061	Reconstructed or improved motorways and roads - TEN-T comprehensive network	0 %	0 %	No	No
062	Other reconstructed or improved roads (motorway, national, regional or local)	0 %	0 %	No	No
063	Digitalization of transport: road	40 %	0 %	No	No

INTERVENTION FIELD		Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
064	Newly built railways - TEN-T core network	100 %	40 %	No	No
065	Newly built railways - TEN-T comprehensive network	100 %	40 %	No	No
066	Other newly built railways	100 %	40 %	No	No
067	Reconstructed or improved railways - TEN-T core network	0 %	40 %	No	No
068	Reconstructed or improved railways - TEN-T comprehensive network	0 %	40 %	No	No
069	Other reconstructed or improved railways	0 %	40 %	No	No
070	Digitalization of transport: rail	40 %	0 %	No	No
071	European Rail Traffic Management System (ERTMS)	0 %	40 %	No	No
072	Mobile rail assets	40 %	40 %	No	No
073	Clean urban transport infrastructure	100 %	40 %	No	No
074	Clean urban transport rolling stock	100 %	40 %	No	No
075	Cycling infrastructure	100 %	100 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
076	Digitalization of urban transport	40 %	0 %	No	No
077	Alternative fuels infrastructure	100 %	40 %	No	No
078	Multimodal transport (TEN-T)	40 %	40 %	No	No
079	Multimodal transport (not urban)	40 %	40 %	No	No
080	Seaports (TEN-T)	40 %	0 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
081	Other seaports	40 %	0 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
082	Inland waterways and ports (TEN-T)	40 %	0 %	Potential for joint adaptation-mitigation intervention	Potential for joint adaptation-mitigation intervention
083	Inland waterways and ports (regional and local)	40 %	0 %	Potential for joint	Potential for joint

INTERVENTION FIELD		Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
				adaptation-mitigation intervention	adaptation-mitigation intervention
084	Digitizing transport: other transport modes	40 %	0 %	No	No
POLICY OBJECTIVE 4: A MORE SOCIAL EUROPE BY IMPLEMENTING THE EUROPEAN PILLAR OF SOCIAL RIGHTS					
085	Infrastructure for early childhood education and care	0 %	0 %	No	No
086	Infrastructure for primary and secondary education	0 %	0 %	No	No
087	Infrastructure for tertiary education	0 %	0 %	No	No
088	Infrastructure for vocational education and training and adult learning	0 %	0 %	No	No
089	Housing infrastructure for migrants, refugees and persons under or applying for international protection	0 %	0 %	No	No
090	Housing infrastructure (other than for migrants, refugees and persons under or applying for international protection)	0 %	0 %	No	No
091	Other social infrastructure contributing to social inclusion in the community	0 %	0 %	No	No
092	Health infrastructure	0 %	0 %	No	No
093	Health equipment	0 %	0 %	No	No
094	Health mobile assets	0 %	0 %	No	No
095	Digitalization in health care	0%	0%	No	No
096	Temporary reception infrastructure for migrants, refugees and persons under or applying for international protection	0 %	0 %	No	No
097	Measures to improve access to employment	0 %	0 %	No	No
098	Measures to promote access to employment of long-term unemployed	0 %	0 %	No	No
099	Specific support for youth employment and socio-economic integration of young people	0 %	0 %	No	No
100	Support for self-employment and business start-up	0 %	0 %	No	No
101	Support for social economy and social enterprises	0 %	0 %	No	No
102	Measures to modernize and strengthen labor market institutions and services to assess and anticipate skills needs and to	0 %	0 %	No	No

	INTERVENTION FIELD	Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
	ensure timely and tailor-made assistance				
103	Support for labor market matching and transitions	0 %	0 %	No	No
104	Support for labor mobility	0 %	0 %	No	No
105	Measures to promote women's labor market participation and reducing gender-based segregation in the labor market	0 %	0 %	No	No
106	Measures promoting work-life balance, including access to childcare and care for dependent persons	0 %	0 %	No	No
107	Measures for a healthy and well–adapted working environment addressing health risks, including promotion of physical activity	0 %	0 %	No	No
108	Support for the development of digital skills	0 %	0 %	No	No
109	Support for adaptation of workers, enterprises and entrepreneurs to change	0 %	0 %	No	No
110	Measures encouraging active and healthy ageing	0 %	0 %	No	No
111	Support for early childhood education and care (excluding infrastructure)	0 %	0 %	No	No
112	Support for primary to secondary education (excluding infrastructure)	0 %	0 %	No	No
113	Support for tertiary education (excluding infrastructure)	0 %	0 %	No	No
114	Support for adult education (excluding infrastructure)	0 %	0 %	No	No
115	Measures to promote equal opportunities and active participation in society	0 %	0 %	No	No
116	Pathways to integration and re-entry into employment for disadvantaged people	0 %	0 %	No	No
117	Measures to improve access of marginalized groups such as the Roma to education, employment and to promote their social inclusion	0 %	0 %	No	No
118	Support to the civil society working with marginalized communities such as the Roma	0 %	0 %	No	No
119	Specific actions to increase participation of third-country nationals in employment	0 %	0 %	No	No
120	Measures for the social integration of	0 %	0 %	No	No

INTERVENTION FIELD		Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
	third-country nationals				
121	Measures to enhancing the equal and timely access to quality, sustainable and affordable services	0 %	0 %	No	No
122	Measures to enhancing the delivery of family and community-based care services	0 %	0 %	No	No
123	Measures to improve the accessibility, effectiveness and resilience of healthcare systems (excluding infrastructure)	0 %	0 %	No	No
124	Measures to improve access to long-term care (excluding infrastructure)	0 %	0 %	No	No
125	Measures to modernise social protection systems, including promoting access to social protection	0 %	0 %	No	No
126	Promoting social integration of people at risk of poverty or social exclusion, including the most deprived and children	0 %	0 %	No	No
127	Addressing material deprivation through food and/or material assistance to the most deprived, including accompanying measures	0 %	0 %	No	No
POLICY OBJECTIVE 5: A EUROPE CLOSER TO CITIZENS BY FOSTERING THE SUSTAINABLE AND INTEGRATED DEVELOPMENT OF URBAN, RURAL AND COASTAL AREAS AND LOCAL INITIATIVES[1]					
128	Protection, development and promotion of public tourism assets and related tourism services	0 %	0 %	No	No
129	Protection, development and promotion of cultural heritage and cultural services	0 %	0 %	No	No
130	Protection, development and promotion of natural heritage and eco-tourism	0 %	100 %	No	No
131	Physical regeneration and security of public spaces	0 %	0 %	No	No
OTHER CODES RELATED TO POLICY OBJECTIVES 1-5					
132	Improve the capacity of programme authorities and bodies linked to the implementation of the Funds	0 %	0 %	No	No
133	Enhancing cooperation with partners both within and outside the Member State	0 %	0 %	No	No
134	Cross-financing under the ERDF (support to ESF-type actions necessary for the implementation of the ERDF part of the operation and directly linked to it)	0 %	0 %	No	No

	INTERVENTION FIELD	Coefficient for the calculation of support to climate change objectives	Coefficient for the calculation of support to environmental objectives	Extent to which intervention addresses also adaptation to climate change	Extent to which intervention also helps reduce impact of Urban Overheating
135	Enhancing institutional capacity of public authorities and stakeholders to implement territorial cooperation projects and initiatives in a cross-border, transnational, maritime and inter-regional context	0 %	0 %	No	No
136	Outermost regions: compensation of any additional costs due to accessibility deficit and territorial fragmentation	0 %	0 %	No	No
137	Outermost regions: specific action to compensate additional costs due to size market factors	0 %	0 %	No	No
138	Outermost regions: support to compensate additional costs due to climate conditions and relief difficulties	40 %	40 %	Yes	Yes
139	Outermost regions: airports	0 %	0 %	No	No
TECHNICAL ASSISTANCE					
140	Information and communication	0 %	0 %	No	No
141	Preparation, implementation, monitoring and control	0 %	0 %	No	No
142	Evaluation and studies, data collection	0 %	0 %	No	No
143	Reinforcement of the capacity of Member State authorities, beneficiaries and relevant partners	0 %	0 %	No	No

ANNEX 7. CLIMATE ADAPTATION APPROACHES IN EU COUNTRIES

Country: Bulgaria

Legal and policy framework: Bulgaria's approach to climate change adaptation is guided by its commitments under international conventions and EU legislation. At the national level, several key strategies and programs provide a foundation for legislation on climate change in general.

Transportation Sector: The Directorate "International and National Shipping Regulations" in the Maritime Administration Executive Agency is responsible for harmonizing national legislation with European requirements and policies concerning maritime transport and climate change. This includes ratifying the international requirements (effective from 2022) for ships to minimize the negative impact and limit harmful emissions from maritime transport on the environment.

Urban Sector: Energy Efficiency Legislation Updates: To align with EU directives, Bulgaria has updated its Energy Efficiency Act (EEE) of 2021 and promulgated two ordinances: Ordinance No. RD-02-20-3 of 9.11.2022 on the technical requirements for the energy characteristics of buildings: This ordinance outlines new requirements for energy efficiency in buildings; Ordinance No. E-RD-04-2 of December 16, 2022, on energy efficiency survey, certification and assessment of energy savings of buildings: This ordinance establishes procedures for assessing and certifying energy efficiency levels in buildings.

Energy Sector: Integrated Plan in the field of energy and climate (INPEC): Following EU regulations, Bulgaria has developed an Integrated Plan for the field of energy and climate (INPEC) for the period 2021-2030. This plan outlines strategies for promoting energy efficiency, renewable energy sources, and sustainable energy use. The Energy Efficiency Ordinance No. E-RD-04-1 of 2022 establishes requirements for conducting energy efficiency checks of heating, ventilation, and air conditioning systems. It also mandates the creation of a database to track energy efficiency data.

These legal and policy frameworks aim to guide Bulgaria's efforts to adapt to the impacts of climate change and transition towards a low-carbon economy.

Adaptation portals and platforms: N/A

Monitoring, reporting and evaluation indicators and methodologies: N/A

Adaptation priorities: institutional capacity building, mainstreaming of climate change adaptation, and raising awareness, laying the groundwork for more extensive climate change resilience measures in the medium- to long-term. This includes managing infrastructure and assets effectively, safeguarding natural capital, and implementing practical strategies for adapting to climate change impacts.

Adaptation challenges: The challenges in the adaptation efforts of the country include: the need for enhanced awareness-raising and communication, improved institutional capacity, addressing knowledge and data gaps, strengthening the policy and legal framework, and securing adequate financial and human resources.

Country: Czech Republic

Legal and policy framework: The most recent updates to the Czech Republic's National Adaptation Strategy and National Adaptation Plan were finalized in September 2021. These updates were developed based on a range of analytical documents, including an evaluation of the Adaptation Plan implementation to 2019, a comprehensive study on climate change impacts, vulnerabilities, and risk factors, and a vulnerability assessment of the Czech Republic based on 2017 data. The updated National Adaptation Strategy and National Adaptation Plan incorporated measures from previous documents that had not been fully implemented, measures that were reformulated to address current challenges, and new measures that were

introduced in response to emerging findings and challenges.

Adaptation portals and platforms: established - https://www.klimatickazmena.cz/en/; https://suchovkrajine.cz/; https://www.intersucho.cz/en

Monitoring, reporting and evaluation indicators and methodologies: The most recent comprehensive assessments of climate vulnerability and risk in the Czech Republic are the Updated Complex Study on Impacts, Vulnerability, and Sources of Risk Related to Climate Change in the Czech Republic (2019) and the Vulnerability Assessment of the Czech Republic Related to Climate Change (2019), available here.

The Updated Complex Study synthesizes relevant data and research findings on climate change impacts across various sectors, including economic consequences. The Vulnerability Assessment utilizes 98 indicators to evaluate vulnerability based on its relationship to specific climate change impacts and sectors or areas. Vulnerability is conceptualized as a composite of exposure, sensitivity, and adaptive capacity.

Adaptation priorities: Both the National Adaptation Strategy and the National Adaptation Plan comprehensively address the Czech Republic's exposure to long-term droughts, floods and flash floods, heavy rainfall, rising temperatures, extremely high temperatures, extreme wind, and wildfires. The Strategy identifies the sectors most vulnerable to climate change impacts, such as forest management, agriculture, water management, biodiversity, health, urban planning, tourism, industry, energy, transportation, cultural heritage, and environmental safety.

Adaptation challenges: The Czech Republic faces two primary challenges in its adaptation efforts. First, the recent assessment of climate vulnerabilities and risks has highlighted specific sectors, particularly forestry and agriculture, that require immediate and prioritized adaptation measures. Second, effectively organizing adaptation efforts on a national scale is essential to ensure coordination and consensus among ministries. This includes strengthening human resources dedicated to climate change adaptation at all levels of governance, including the Ministry of the Environment for national coordination, ministries responsible for key sectors, and regional and local authorities.

For more detailed information on specific country profiles and adaptation actions, the European Climate Adaptation Platform Climate-ADAPT offers comprehensive reports and data (Climate-ADAPT). Additionally, the IWRM Action Hub provides insights into the comparison of national adaptation strategies in Europe (IWRM Action Hub).

Country: Denmark

Legal and policy framework: Climate change adaptation in Denmark is primarily based on initiatives at the local level. Planning and implementing measures for adaptation is largely a municipal responsibility, which is outlined in several laws and executive orders. The main elements of the national regulatory framework are the Planning Act, the Floods Act, the Act on Watercourses, the Water Supply Act, and the Wastewater executive order under the Environment Act. The main role of the central government is to establish an appropriate framework for local climate change adaptation by, for example, adapting laws, regulations, and strategies, but also by ensuring coordination and providing information.

Adaptation portals and platforms: established - Klimatilpasning.dk (National web portal for climate change adaptation) and Kystplanlægger (Coastal planner).

Monitoring, reporting and evaluation indicators and methodologies: established - Miljøtilstand (State of the environment) and Ongoing in research programmes - Environmental indicators for assessment of the effects of climate change.

Adaptation priorities: The Danish work with climate change adaptation focuses strongly on water resource management including urban

water management and and flood prevention. Another priority is to maintain and enhance the Danish web portal (Klimatilpasning.dk) which collects and presents data, technologies, and technological development in the field of climate adaptation and combines it with prospects of financing and government subsidies.

Adaptation challenges: In June 2018, the European Commission evaluated Denmark's work through the 'Adaptation preparedness scoreboard' and highlighted that although all municipalities have developed local action plans, they are uneven in terms of detail and coverage. Currently, no systematic monitoring or evaluation mechanism is using relevant indicators for the NAS, NAP, or local adaptation plans. No systematic monitoring of the results of sectoral policies is conducted or disseminated. Local and regional effects of climate change may differ, making the decision-making on climate change adaptation initiatives subject to some uncertainties and this constitutes a challenge for municipalities, enterprises and individuals when prioritizing efforts, including the scope of these. Stakeholders often emphasize the challenge of the lack of adequate funding and financial support towards climate change adaptation. They request a better overview of funding opportunities both on a national level and on the EU level.

Country: Finland

Legal and policy framework: National adaptation planning is stipulated in Finland's *Climate Act* (2022). Under the *Climate Act* (423/2022), the Government adopts a *National Climate Change Adaptation Plan* at least every second parliamentary term.

Adaptation portals and platforms: established - climateguide.fi

Monitoring, reporting and evaluation indicators and methodologies: established - *Adaptation to climate change in Finland: Current state and future prospects* 2022

Adaptation priorities: to contribute to ensuring that national measures are taken to adapt to climate change by promoting climate change resilience and the management of climate risks. The three current priorities of the Finnish national adaptation activities are: 1) society's actors have a strong will to adapt to climate change; 2) society's actors have access to efficient means to assess, prevent and manage the climate change-related risks to nature as well as society; 3) society's actors have the capacity and capability to prevent, prepare for and manage the climate change-related risks to nature as well as society.

Adaptation challenges: There is an ongoing effort to establish coordinated decision-making in adaptation, but many sectors lack concrete targets and legal mandates, limiting authority to encourage rather than enforce adaptation. Labor shortages in critical sectors like healthcare and infrastructure maintenance, combined with limited financial and human resources, hinder the effective development and implementation of new measures. Adaptation actions, often project-based and resource-constrained, lead to a short-term approach. A lack of recognition of adaptation measures in many sectors complicates monitoring and performance evaluation, causing inefficiencies due to fragmented actions. Complex responsibilities, especially at local and regional levels, and a scarcity of localized, sector-specific knowledge further complicate effective adaptation. Lastly, insufficient systematic monitoring data impedes the assessment of the impacts and effectiveness of these measures.

Country: Ireland

Legal and policy framework: Ireland's climate adaptation policy was adopted in the Climate Action and Low Carbon Development Act 2015, which was amended by the Climate Action and Low Carbon Development (Amendment) Act 2021. This legislation mandates the development of a National Adaptation Framework and sectoral adaptation plans for priority sectors.

The 2021 Act introduced new provisions to enhance cross-sectoral cooperation on

adaptation. It also mandated local authorities to prepare Climate Action Plans that integrate mitigation and adaptation measures. These LA Plans are currently under development. The statutory NAF was reviewed in 2022, and a new National Adaptation Framework is being developed based on this review.

Adaptation portals and platforms: established - https://www.climateireland.ie/

Monitoring, reporting and evaluation indicators and methodologies: Ireland's approach to climate adaptation is guided by a comprehensive legal framework that mandates the development of a National Adaptation Framework and sectoral adaptation plans. These plans are subject to regular review and revision to ensure they align with evolving scientific knowledge and adaptation needs. To support decision-making for adaptation, Ireland is investing in research and developing a range of tools and reports, including a Climate Change Risk Assessment, a 5-Year Assessment Report on Climate Research, and a report on the status of Ireland's climate data and observing infrastructure.

Adaptation priorities: According to the National Adaptation Framework and the Climate Act of 2019, Government Departments overseeing priority sectors were tasked with developing Sectoral Adaptation Plans. These plans were allocated to specific departments, such as the Department of Agriculture, Food, and the Marine for Seafood, Agriculture, and Forestry; the Department of Housing, Local Government, and Heritage for Biodiversity, Built, and Archaeological Heritage; the Department of Transport for Transport Infrastructure; the Department of Environment, Climate, and Communications (DECC) for Electricity and Gas Networks, as well as Communications Networks; the Office of Public Works for Flood Risk Management; and the Department of Health for Health. The National Adaptation Framework Review in 2022 highlighted additional sectors where Sectoral Adaptation Plans may be suitable. Furthermore, all 31 Local Authorities had crafted local adaptation strategies by 2019.

Adaptation challenges: The Climate Change Advisory Council functions as an independent advisory body responsible for evaluating national climate policy. A crucial aspect of its role involves conducting an annual assessment of the progress achieved in advancing the shift towards a low-carbon, climate-resilient, and sustainable economy, and society by 2050. This review also presents the results of the CCAC adaptation scorecard, evaluating progress in implementing adaptation policy across all National Adaptation Framework sectors, the National Adaptation Framework itself, and locally. While recognizing advancements in key areas such as flood risk and local government, the scorecard identifies challenges and implementation gaps in other sectors, along with recommendations for enhancing adaptation responses.

In the 2022 National Adaptation Framework review, three potential additional sectors—Finance, Tourism, and Planning & Built Environment—were identified for potential development of Sectoral Adaptation Strategies. The process of formulating the new National Adaptation Framework In 2023 will weigh the pros and cons of creating Sectoral Adaptation Plans for these areas, considering existing policy frameworks and plans. Based on the outcomes of this assessment, a government decision on the necessity of additional SAPs for these sectors will be made when the new National Adaptation Framework is under consideration.

Country: Romania

Legal and policy framework: Romania has adopted the National Climate Change and Low Carbon Green Growth Strategy and its Action Plan for the period 2016-2020.

Adaptation portals and platforms: N/A

Monitoring, reporting and evaluation indicators and methodologies: To track the progress of actions aimed at reducing climate impacts, vulnerabilities, and risks, and enhancing adaptive capacity, responsible entities were required to submit annual reports to the Ministry of Environment Water

and Forests. The National Adaptation Plan (NAP) outlines specific metrics and benchmarks, primarily process-oriented, to guide implementation. These include the type of action, objective, timeline, responsible institutions, result indicators/unit measures, and estimated resources and their source of financing.

Adaptation priorities: The National Climate Change and Low Carbon Green Growth Strategy priorities adaptation measures and actions across 13 key sectors, namely industry, agriculture and fisheries, tourism, public health, buildings and infrastructure, transport, water resources, forests, energy, biodiversity, insurance, recreation activities, and education. These measures are designed to address various climate-related risks and events, including landslides, soil erosion, storm damage, droughts, floods, disease outbreaks, and water scarcity.

Adaptation challenges: The main obstacles to adaptation in Romania are inadequate financing and institutional barriers. The inefficient collaboration among various stakeholders affects accessing available funding sources. Moreover, the lack of specialized personnel poses a significant challenge to implementing effective adaptation measures.

To address these challenges and enhance adaptation efforts, Romanian government institutions are actively promoting interagency coordination and collaboration to foster a more cohesive approach to climate change adaptation.

Country: Spain

Legal and policy framework: The Climate Change and Energy Transition Law 7/2021, enacted on 20th May, designates the National Climate Change Adaptation Plan (PNACC) as the fundamental planning tool for coordinating and harmonizing efforts to address the impacts of climate change in Spain. The PNACC outlines objectives, criteria, work areas, and action plans to advance adaptation and enhance resilience to climate change.

The PNACC for the period 2021-2030, ratified in 2020, is an integral component of the strategic energy and climate framework, which encompasses various instruments, including the Climate Change and Energy Transition Law 7/2021, the long-term strategy for achieving a modern, competitive, and climate-neutral economy by 2050, the National Integrated Energy and Climate Plan for 2021-2030, and the Just Transition strategy. These documents incorporate climate change adaptation considerations and exhibit clear linkages to the PNACC.

The legislation stipulates that the PNACC will be implemented through successive Work Programmes (WPs), each spanning a five-year period. The Work Programme 2021-2025 outlines specific measures slated for the initial five years of PNACC implementation, detailing the responsible entities and elucidating associated reporting, monitoring, and evaluation mechanisms. The collaborative development of the Work Programme involved contributions from 18 ministries, alongside various state agencies and autonomous bodies, and underwent a period of public consultation and engagement.

Adaptation portals and platforms:
https://adaptecca.es/en.
https://escenarios.adaptecca.es/#&model=EURO-CORDEX-EQM.average&variable=tasmax&scenario=rcp85&temporalFilter=year&layers=AREAS&period=MEDIUM_FUTURE&anomaly=RAW_VALUE

Monitoring, reporting and evaluation indicators and methodologies:

The National Adaptation Plan (PNACC) 2021-2030 emphasizes adaptability and robust processes to prevent maladaptation. This ensures ongoing integration of the latest scientific knowledge. Within this framework, monitoring and evaluation processes assume strategic significance, guiding adaptation efforts by:

a) Identifying trends, impacts, and associated risks of climate change.

b) Assessing progress in PNACC and its work programs, recognizing achievements, and identifying ongoing challenges.

c) Systematizing and applying knowledge acquired through the assessment of initiative outcomes.

The PNACC 2021-2030 outlines a comprehensive system for monitoring, reporting, and evaluating (MRE) impacts, vulnerabilities, risks, and enhanced adaptive capacity. This system builds on the progress of the previous PNACC and incorporates various tools, including:

Reports on Climate Risks and Adaptation: The Law 7/2021 mandates the Ministry for the Ecological Transition to produce reports on climate change impacts, risks, and policies every five years. The ongoing assessment process, initiated in 2023, involves stakeholder workshops to define scope and methodology, with results expected in 2025.

Sectoral Assessments of Impacts, Vulnerabilities, and Adaptation (IVA): Sector-specific assessments have been conducted since the first PNACC in 2006, enabling monitoring of impacts, vulnerabilities, and adaptive capacity in various sectors. Recent examples include reports on cross-border climate effects, impacts on the hunting sector, and employment.

Climate Change and Adaptation Indicators: Annex 3 of the PNACC 2021-2030 includes a set of interim indicators for assessing climate change impacts and adaptation progress. This set will be reviewed in 2023 and regularly updated biennially, providing a dynamic overview and facilitating policy improvement based on progress analysis and identification of challenges. Sectoral indicators have also been developed, such as those related to health and climate change.

Platform on Adaptation to Climate Change in Spain (AdapteCCa): AdapteCCa serves as a valuable resource for accessing information on impacts, vulnerabilities, and adaptation in Spain.

Throughout PNACC development, specific actions will evaluate the implementation of measures, including ex post case studies to analyze and assess response quality to specific risks, particularly extreme weather, or climate events.

Adaptation priorities: The PNACC 2021-2030 outlines the following specific objectives:

- Enhance systematic observation, localized climate change projections, and climate services.
- Generate knowledge on impacts, risks, and adaptation, along with methodologies and tools for analyzing climate change impacts.
- Bolster adaptation capacities.
- Identify primary climate change risks and support the implementation of adaptation measures.
- Integrate adaptation considerations into public policies.
- Encourage the active involvement of all stakeholders, including governments, the private sector, social organizations, and the general public, in addressing climate change risks.
- Strengthen governance in adaptation efforts.
- Fulfil and advance commitments made by Spain in the EU and international contexts.
- Advocate for the monitoring and evaluation of adaptation policies and measures.

Adaptation challenges:

A comprehensive examination of gaps and obstacles to adaptation has not been conducted within the framework of the National Adaptation Plan. However, this issue was addressed in the thorough assessment conducted in 2019 and various participatory workshops organized to gather assessments and inputs for the new Adaptation Plan 2021-2030. Some of the most pertinent challenges, gaps, and barriers identified are highlighted below.

Challenges

- Education: There is a need for the full integration of capacity-building for adaptation into technical and vocational training.
- Monitoring: The implementation of an indicator-based monitoring system on climate change-related impacts

(already envisioned in PNACC 2021-2030).

Gaps

- Knowledge Gaps: Persistent gaps in knowledge, such as limited understanding of transboundary effects or methodologies for cost-benefit analysis.
- Knowledge Transfer Gaps: Difficulties persist in applying scientific knowledge to the development of practical adaptation initiatives.

Barriers

- Risk Perception: Certain economic sectors exhibit low risk perception regarding climate change, leading to a lack of interest in adaptation (e.g., tourism sector).
- Sectoral Integration: Public management is organized on a sectoral basis, posing challenges to the integration of adaptation into individual public policies.
- Lack of Economic Feedback: The existing tax and insurance systems do not provide sufficient incentives for adaptation.
- Short-Term Policies and Measures: The pursuit of short-term results at times conflicts with long-term and proactive visions of adaptation.

Country: Sweden

Legal and policy framework: The most direct law that concerns adaptation is the Swedish Planning and Building Act. One key piece of legislation with indirect control is the Swedish Environmental Code. The Adaptation Ordinance regulates the work of 32 agencies and all 21 county administrative boards. Central government agencies may also be entitled to make rules that specify the requirements. County Administrative Boards and municipalities also have the right to issue local regulations.

Adaptation portals and platforms: established - klimatanpassning.se

Monitoring, reporting and evaluation indicators and methodologies: The National Expert Council on Climate Adaptation is tasked to submit a report to the Government every five years, as support for the revision of the National Adaptation Strategy.

Adaptation priorities: Seven priority areas are identified based on the predicted consequences for society: Landslides and erosion that threaten communities, infrastructure and businesses; Flooding that threatens communities, infrastructure and businesses; High temperatures that involve risks for the health and well-being of people and animals; Water supply shortages for individuals, agriculture and industry; Biological and ecological effects that affect sustainable development; The impact on domestic and international food production and commerce; Increased incidence of pests, diseases and invasive non-native species that affect people, animals and plants.

Adaptation challenges: Providing national goals, principles and plans to improve steering, mainstreaming and connection of climate adaptation with other policy areas (financial frameworks, civil security, and transformation), ensuring knowledge needed for adaptation, ensuring cross-sectoral adaptation over administrative boundaries, and creating stronger incitements (responsibilities, financial and legal) to promote the implementation of necessary adaptation measures.

These case studies reveal the diverse nature of adaptation strategies across the EU, reflecting the unique geographical, economic, and social contexts of each Member State. They highlight the necessity for tailored approaches to effectively address the specific challenges posed by climate change in different regions.

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