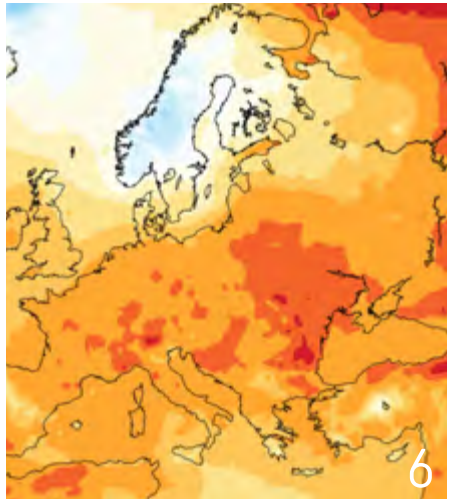
Urban Insight
By Sweco

Building heatwave resilience in European cities

SWECO

Europe is the fastest warming continent, with temperatures rising at around twice the global average rate.



There are signifcant gaps in urban heatwave adaptation policies, particularly with regards to vulnerable populations.

The analysis revealed that cities with a track record of developing adaptation plans to address heatwaves specifically tend to take a more data-driven approach.

Climate action plans provide little information on the monitoring, evaluation and reporting of adaptation actions and what success looks like.

A study of European cities' preparedness

Content

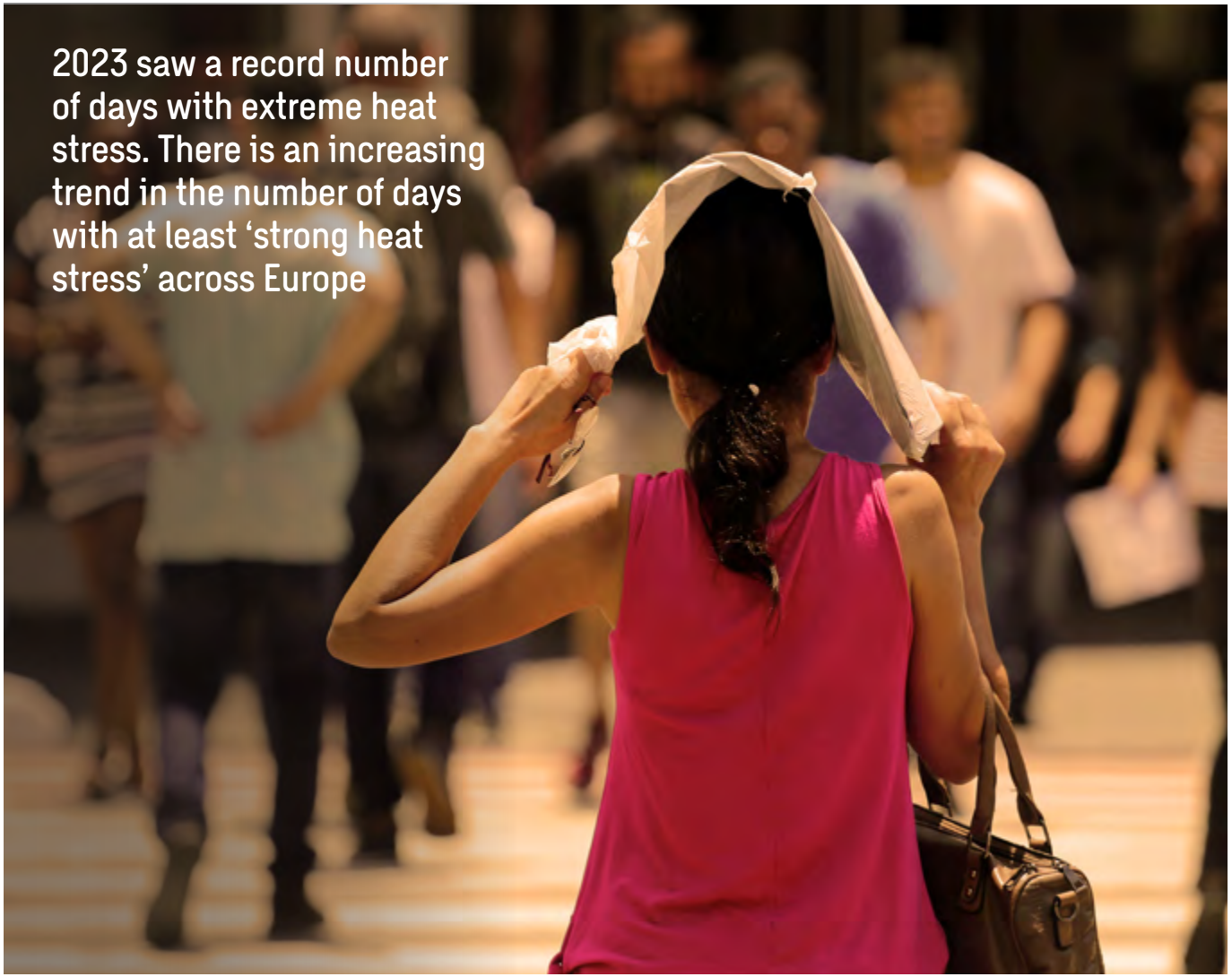
Executive summary

Europe is experiencing significant warming trends, with temperatures rising twice as fast as the global average. The urban heat island effect worsens this, causing cities to face even higher temperatures than rural areas. This poses risks to public health, infrastructure and the economy. Despite these challenges, heat-related concerns are often overlooked in cities' climate plans, especially for vulnerable populations.

Sweco conducted a study of 24 European cities to assess their preparedness for heatwaves. The study analysed climate resilience policies and heatwave data, focusing on six primary case study cities: Brussels, Copenhagen, Helsinki, Rotterdam, Oslo, and Stockholm. Despite projections showing a doubling of heatwave days by 2100, few cities have dedicated heatwave adaptation teams, especially in Northern Europe where heatwaves are relatively new.

While cities recognise the health risks of heatwaves, they often fail to incorporate equitable resource distribution and protection for marginalised communities into urban resilience planning. This is compounded by a lack of detailed data and vulnerability mapping across cities, hindering monitoring and evaluation of existing adaptation policies. To effectively tackle heatwaves, clear governance, innovation, and co-creation are crucial, along with long-term visions and adaptable strategies. Collaborative governance, public awareness and community empowerment are key for effective adaptation. Action on blue-green infrastructure is also vital, ensuring solutions meet community needs and have positive impacts.

Recommendations for European cities include investing in knowledge, integrating climate adaptation into urban planning laws, and optimising construction strategies. Urgent action is needed to mitigate heatwave impacts, build resilience, and create sustainable environments for all residents.



Introduction

The 2023 Global Carbon Budget projects that the carbon budget remaining before the 1.5° threshold will be breached consistently over consecutive years, rather than just for a single year. Based on current emission rates, the Global Carbon Budget team predicts a 50% likelihood of global warming consistently surpassing 1.5°C around 2030.[1] This rise in global temperatures is accelerating the frequency and intensity of extreme weather events, including heatwaves.[2]

The impacts of heatwaves are already being felt worldwide. Between 2013 and 2022, the number of heatwave days increased by 94% globally compared to the period from 1986 to 2005.[3]

How prepared are European cities?

So, how prepared are European cities for an increasingly warmer climate? In this Urban Insight study, Sweco identifies the approaches that European cities have adopted to enhance the resilience of their local communities in response to the increasing frequency and severity of extreme heatwaves.

A recent report, the European State of the Global Climate 2023, shows that Europe is the continent where warming is occurring most rapidly, with temperatures rising approximately twice as fast as the global average.

The Urban Heat Island (UHI) effect[4] exacerbates this situation, leading to significantly faster surface warming in cities compared to rural areas.[5] This temperature difference occurs when cities' unshaded roads and buildings absorb heat during the day and radiate that heat into the surrounding air.

This temperature difference is mainly caused by the extensive use of concrete and asphalt, which absorb and retain heat more efficiently than natural landscapes, as well as by heat generated from vehicles, industrial processes, energy systems and waste heat. The lack of vegetation in cities also contributes to this effect, as plants and trees can cool the air. The UHI effect can exacerbate the discomfort of hot weather, increase energy consumption for cooling, and can contribute to poorer air quality.

Increasing temperatures

European cities are projected to witness a rise in both the number of heatwave days per year and the maximum heatwave temperature. High-impact scenarios suggest that 72% of European cities will experience a temperature increase of at least 10° during heatwaves.[6]

These extreme heat events pose significant risks to public health, energy infrastructure and economic productivity in urban areas. During the summer of 2022, more than 61,000 people died because of Europe's record-shattering heat wave, according to scientists.[7]

A study published in the scientific journal Nature shows that heatwaves caused 0.3-0.5% of Europe's GDP in damages between 1981 and 2010.[8] Future projections suggest that by 2060, impacts could increase by a factor of almost five in Europe if no further mitigation or adaptation actions are taken.

Despite these risks, heat-related health concerns are often overlooked in climate mitigation and adaptation plans. Moreover, there is a significant heat disparity within urban centres that disproportionately impacts vulnerable and marginalised communities.[9]

The rapid urbanisation trend is undeniable, with over two-thirds of the world's population predicted to reside in urban areas by 2050. In Europe, this figure is even more staggering, reaching 84%.[10]

This demographic shift brings about a heightened focus on urban climate resilience, with heat management being a critical issue for cities to address.

Europe needs to improve its adaptation

Europe needs to improve its adaptation to the effects of climate change, according to the European Environment Agency (EEA), which recently warned that extreme heat, drought, wildfires and floods will worsen and negatively impact living conditions.

In its report, the EEA has examined how European cities are being equipped to withstand more frequent and intense extreme weather in the future. It turns out that almost all are increasingly using nature-based solutions to enhance resilience. Of the 19,000 local climate action plans analyzed, 91% included nature-based methods such as the construction and maintenance of parks, urban forests, and green roofs. Vegetation can help cool cities and manage water – but also brings other benefits, such as providing recreational spaces or reducing air pollution, as emphasised by the EEA.

However, the EEA warns that relying solely on nature-based tools is not enough. The climate effects are expected to grow to a magnitude that requires a combination of various measures, including changes in physical infrastructure.

Countries that fail to address climate change and its effects might face dire consequences. In the spring of 2024, Switzerland faced judgement from the European Court of Justice in Strasbourg for inadequately protecting vulnerable older women from the impacts of climate change, particularly heatwaves. This case, known as Klimaseniorinnen, marked the European Court's first climate-related conviction.

The methodology:

Examining heatwave impacts and strategies in European cities

During the study, Sweco's experts conducted a literature review on adaptation and resilience practices across 24 European cities, laying the groundwork for examining six primary case study cities: Brussels, Copenhagen, Helsinki, Rotterdam, Oslo and Stockholm. These cities were chosen for their status as cooler northern-European cities expected to face significant heatwave impacts due to potential unpreparedness.

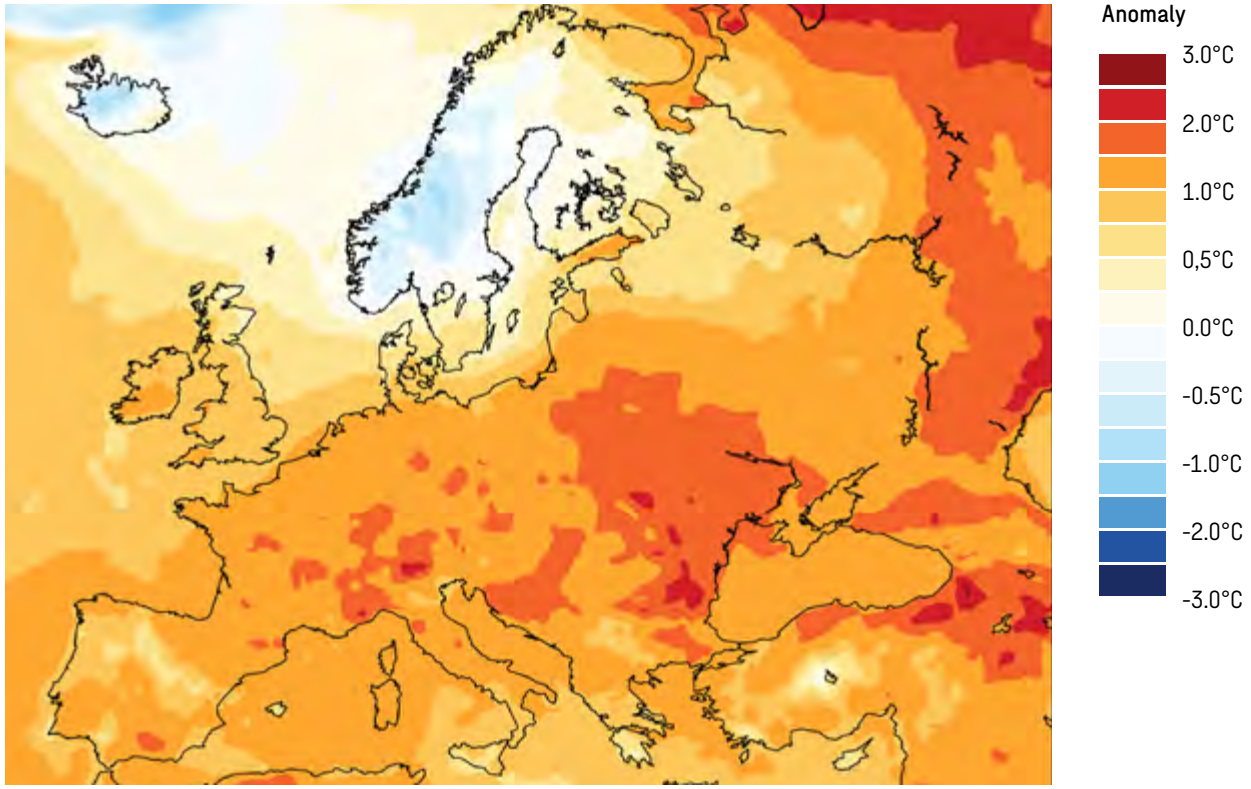
Commonalities among these cities include a history of climate change decision-making, recent experience with extreme heatwaves, and stakeholder engagement in policymaking.

As a complement to the literature review, interviews were conducted with a few selected northern European cities. Our team of Sweco experts interviewed representatives from multiple cities actively involved in climate resilience and adaptation policy. These interviews were further complemented by an in-depth analysis of heatwave data.

Insights from these analyses form the report's main body, offering key trends, lessons learned and high-level recommendations for policymakers and urban sustainability practitioners worldwide. Policy and strategy documents related to climate resilience, adaptation and heat were also analysed, along with data from academic sources.

The analysis from the in-depth case studies of northern European cities provided insights into heatwave experiences, current policies, implementation challenges, and opportunities for improvement.

Europe is the fastest warming continent, with temperatures rising at around twice the global average rate. According to the European State of the Climate (ESOTC) report 2023, the three warmest years on record for Europe have all occurred since 2020, and the ten warmest since 2007.



Average surface air temperature anomaly (°C) for 2023, relative to the 1991–2020 reference period. Data source: ERA5.
Credit: C3S/ECMWF.

Heat, health and vulnerable groups – a theoretical background

In this chapter, we highlight the findings from our literature review on the relationship between heat, health, and vulnerable populations, combined with a general view on how European cities address heatwaves today.

Human vulnerability to climate change is directly related to the adaptive capacity of the built environment, the possibility for change, social processes and institutional structures of a particular urban context.

Human health is particularly vulnerable to extreme heat. Studies highlight the following:

- 489,000 excess deaths (2000-2019) were due to heat globally[11], with over 20,000 excess deaths/year across 854 cities in Europe.[12]
- 37% of warm-season, heat-related deaths (1991-2018) are directly attributable to anthropogenic climate change.[13]
- There is a clear causal relationship between increased levels of air pollution and extreme heat, with air pollution consistently increasing respiratory and cardiovascular disease-induced mortality during the warmest months of the year.[14]

More frequent and intense heatwaves will affect citizens around the world, but their effects will not be felt equally. Cascade effects resulting from heatwaves, such as drought, access to food, employment, ecosystem collapse, biodiversity loss and mental health challenges, can trigger additional crises in various areas.

Each city will have its own adaptive capacities across each of these dimensions. However, what remains consistent across cities is the absence of adaptation measures that include communities, especially those particularly vulnerable to heatwaves.[15]

For example, a 2018 study found that people living in urban areas with less green space, which is highly correlated with negative socio-economic indicators,[16,17] have a 5% higher risk of dying from heat-related causes.[18] Additionally, research highlights how vulnerable groups across European countries are particularly susceptible to increased mortality from heart and lung diseases, accelerated by the interactive effects of air pollution and extreme heat.[19]

Effects from extreme heat globally and in Europe

489,000 excess deaths (2000-2019) were due to heat globally

>20,000 excess deaths/year across 854 cities in Europe

37% of heat-related deaths (1991-2018) are attributable to climate change.

In European regions, heat-related mortality has increased by around 30% in the past 20 years, according to the European State of the Climate report 2023.

The three most vulnerable groups:
- Elderly
- Infants
- People with pre-existing health conditions[20]

Other vulnerable groups:
- People with low income and education, including illiteracy or social isolation
- Underrepresented groups
- Tenants (particularly in old buildings)[21]

Engaging with inhabitants proactively is crucial to building resilience to extreme heat in these communities.[22] However, failing to properly account for vulnerable populations is one of the major weaknesses of urban climate adaptation plans across the EU-28. This is particularly acute in terms of monitoring and evaluation of adaptation measures, and participation in adaptation planning by vulnerable groups.[23]

If current trends continue, the existing heat inequity in cities, often reflecting social and racial disparities, will only deepen in the coming decades as our cities become warmer, posing a daunting challenge for cities to bridge.[24]

UN spokesperson

Urban resilience to heatwaves: transformational adaptation

Resilience can be defined as “the capacity to prepare for threats, to absorb them and quickly recover when they occur and to adapt and transform the way we cope in the future".[25]

Building urban resilience in the face of increasing risk from heatwaves is achieved through climate adaptation measures, broadly defined by the IPCC as "anticipatory or reactive adjustments to climate change and its impacts".[26]

Approaches taken by cities will vary as heatwaves impact cities differently depending on the local context and environmental conditions.

The results of our literature review indicate that resilience-enhancing heatwave adaptation measures in European cities typically encompass:

1. Enhancing green infrastructure using nature-based solutions[27] such as green roofs, urban trees and the replacement of impermeable surfaces with permeable vegetated areas.[28]

2. Cooling the built environment through measures like the integration of heatproofing in urban planning legislation and retrofitting existing infrastructure.

3. Targeted community engagement and locally led climate adaptation[29] to raise citizen awareness of heat risks and access to cooling infrastructure,[30] particularly among vulnerable populations.

Adaptation measures are wide-ranging and can be either incremental or transformational. While incremental adaptations occur when marginal changes are made over time within existing system parameters, transformational adaptation aims to “reduce the root causes of vulnerability to climate change by shifting systems away from unsustainable or undesirable trajectories”.[31]

Policies that fail to account for the vulnerability of certain communities or infrastructure to the effects of climate change can lead to maladaptation, which is “a process through which people become even more vulnerable to climate change”. [32]

Best practices in Europe

Building resilience through vulnerability mapping

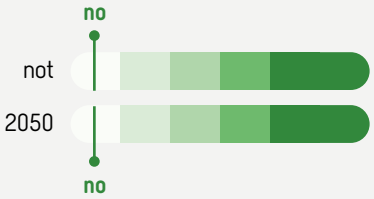
Properly identifying, engaging with and including fragile communities in policymaking is critical to increasing heatwave resilience in urban areas. Effective heatwave management starts with identifying and mapping vulnerabilities in urban areas.

Vulnerability mapping is typically done by overlaying thermal satellite imagery with relevant socio-demographic indicators.

> The greatest gains in well-being in urban areas can be achieved by prioritising investment to reduce climate risk for low-income and marginalised residents.[33]
>
> IPCC spokesperson

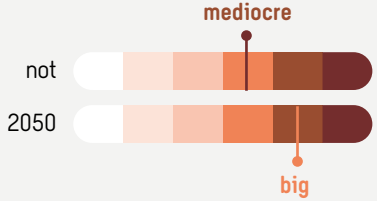
'Stress Test Your Address'
The Dutch national broadcasting organisation Nederlandse Omroep Stichting (NOS) developed an online tool for Dutch citizens to 'stress test' their address, with indicators including flood risk, heat vulnerability and subsidence. Sweco supported the process by picking the data sources, with data quality and fact checking the texts and information in the tool.

Risk of flooding



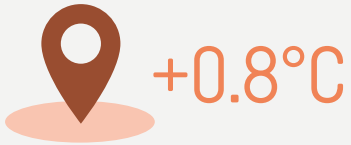
There is no chance of flooding at this location. There is also no chance of a flood in 2050. This concerns flooding due to a dike breach or from surface water, not flooding due to extreme weather or high groundwater.

Wildfires



There is now a moderate risk of wildfires in this region, but by 2050 the risk is high.

Heat island



The temperature in this postcode area is 0.8 degrees warmer due to the buildings.

Heat vulnerability mapping
The Mayor of London has created a city-wide map, overlaying key metrics to identify areas within London that are most exposed to climate impacts with high concentrations of vulnerable populations.

A climate risk map was used to analyse the exposure and vulnerability to climate change throughout Greater London. This tool proved valuable in enabling the mayor and other London-based organisations to allocate resources to support communities that face the greatest risks from climate change impacts.

Climate vulnerability encompasses both the exposure to climate change impacts, such as flooding or heatwaves and the personal and social factors that influence individuals' ability to cope with and respond to extreme events. Areas with high climate risk often coincide with regions characterised by income and health disparities.

Cities need to pinpoint vulnerabilities by comparing neighbourhoods and identifying specific hot and cool spots, providing much-needed relief for vulnerable groups during heatwaves. Steps are needed at various levels, including adaptation measures for buildings and neighbourhoods to reduce health risks and enable active governance for reducing health inequalities.

Public engagement and communication strategies

Engaging citizens in climate adaptation through sustained communication strategies and public participation in policymaking is vital to building urban resilience in the face of climate change.[34]

This is particularly true in the case of extreme heat,[35] where a lack of public engagement from local authorities regarding urban heatwave policies disproportionately effects vulnerable communities.[36]

Climate Vulnerability and Capacity Analysis handbook

The Climate Vulnerability and Capacity Analysis (CVCA) handbook is a tool developed by the CARE Climate Change and Resilience Information. It is used to collect and analyse information about community-level vulnerabilities to climate change and their capacity to respond. The CVCA helps identify actions that support communities in enhancing their resilience to climate change, whether at the community level or more broadly.

The CVCA process takes into account the potential adverse impacts of climate change on gender equality, ecosystems, and governance, and considers how these factors influence people's resilience. By addressing these issues as cross-cutting themes, the CVCA process enables an integrated approach that explores options for positive change in these areas while also enhancing climate resilience.

The CVCA handbook provides a robust tool for gathering and analysing information on community-level vulnerabilities to climate change and their adaptive capacities. Though primarily focussed on resilience-building in the Global South, the rigorous and holistic framework is highly adaptable to different contexts and centred on transformational adaptation through the empowerment of vulnerable communities.

European climate policy and action for health

The European State of the Climate 2023 (ESOTC 2023) report provides insights into the intersection of climate policy and health action within Europe.

Key points include:

- The number of adverse health impacts related to extreme weather and climate events is rising.
- Generally good awareness but a low-risk perception of heat by the public, vulnerable groups and some health care providers.
- Initiatives such as the WMO Regional Climate Centre's Climate Watch System, and other early warning systems, raise awareness of predicted extreme events to enhance societal preparedness.
- Health risk and adaptation differ between countries.
- Tailored climate services for the health sector are effective in increasing resilience, with significant potential for further development.
- Health adaptation can build on established health system infrastructures, but progress has been limited.

City networks

In the face of insufficient national progress on climate change mitigation and adaptation globally,[37] networks of cities across the world have formed to tackle these crises from the bottom up.

In terms of climate mitigation and actions for reducing carbon emissions, an analysis of 327 cities within the EU-28 demonstrates that European cities involved in networks like the Climate Alliance and the Covenant of Mayors are 90% and 75% more likely to have ambitions aligned with the Paris Agreement than cities that do not participate.[38]

Led by C40, the Cool Cities Network is a knowledge and policy-sharing alliance among major urban centres whose focus areas include heat and vulnerability mapping, heatwave emergency management, integrating heat into planning, highlighting the co-benefits of heat action and promoting heat mitigation solutions.

City networks are also associated with significant benefits for climate adaptation and resilience, promoting city-to-city learning through best practice knowledge-sharing, promoting adaptation and resilience work internally and increasing access to funding opportunities.[39]

Heat mapping and vulnerability analysis for urban areas

Sweco, on behalf of Ängelholm Municipality, has conducted an analysis of the national heat mapping available in Sweden. The purpose of the assignment was to select the most suitable heat mapping to understand heat issues within Ängelholm municipality and then carry out a vulnerability analysis. The vulnerability analysis maps the distribution of heat within these urban areas, as well as how vulnerable facilities (preschools, assisted living facilities, care homes, LSS housing, etc.) across Ängelholm Municipality are at risk of being affected during summer heatwaves.

The analysis results in a comparison of the relative vulnerability of the activities to heat impact during the summer. Sweco evaluated the vulnerability of 150 facilities in the municipality and mapped areas sensitive to heatwaves, as well as areas that are cooler and could be used as resource areas if further design and planning are carried out.

The Public Health Agency has compiled the following factors that influence heat development:

- Paved and dark surfaces, such as black roofs and asphalt, absorb heat.
- Green areas with high vegetation have a cooling effect.
- Trees have a cooling effect, primarily through shading, but also through evapotranspiration. As long as the tree roots have access to water, they transpire moisture through their pores in their leaves, which then evaporates and lowers the surrounding air temperature. However, during longer dry and hot periods, trees close these pores to conserve water.
- Low vegetation is considered neutral.
- Proximity to water can have either a cooling or warming effect, depending on the location and season.
- Buildings provide shade, but they can also emit heat.
- Wind has a cooling effect, with direction and strength being important factors.
- Humidity affects the perceived temperature.

By addressing these factors within the municipality, conditions can be created for a healthy outdoor and indoor climate. During the planning process and in the design of public spaces, consideration of these factors can create safe areas for residents and visitors within the municipality. Note, however, that if a neighbourhood has extensive green areas, the average temperature of the neighborhood may be relatively low, despite the presence of high surface temperatures near residential and commercial areas.

Trees can cool cities by up to 12°C on a hot day

Without trees

With trees

Urban heat map

Odense Municipality has wanted to map out how the higher temperatures of the future will affect the municipality. Sweco has therefore contributed by preparing an urban heat map of the entire municipality. Heat-related challenges have been mapped, and focus areas have been identified where vulnerable groups are particularly exposed.

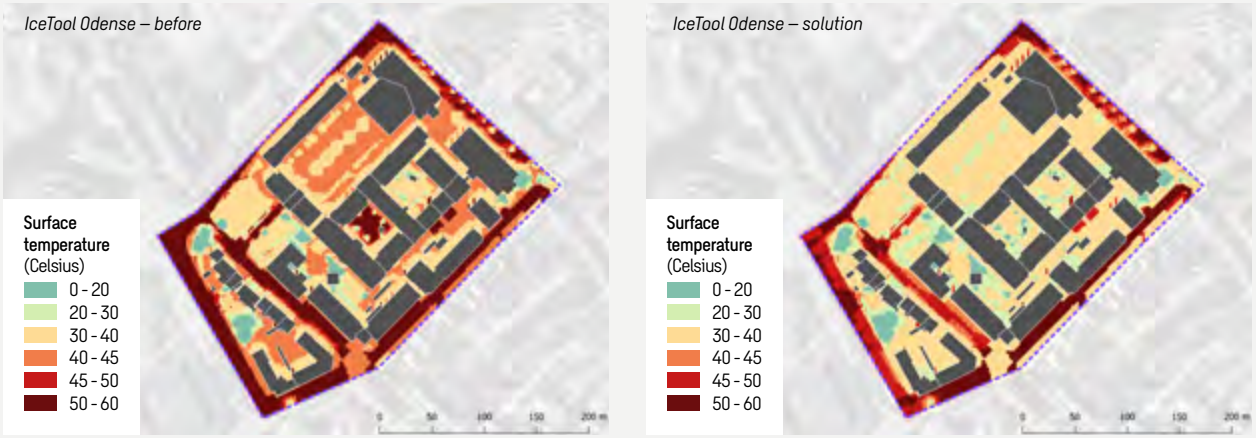
The designated focus areas concern the areas of the city that are at particular risk of overheating and where vulnerable citizens, such as children and the elderly, reside.

Solutions to Odense's heat-related challenges involve green optimisations such as water management and bright surfaces, and initiatives that increase biodiversity, including evaporation-promoting elements such as planting on surfaces and facades as well as more trees in selected areas. These measures will all contribute to reducing the temperature in the city and provide cooling properties.

An urban heat map will function as a resource-efficient and comprehensive mapping that forms the basis for identifying focus areas. The selection of focus areas is made on the basis of the calculated surface temperature and a demographic analysis, buildings, paving types and demographics, where one of our own tools, Spatial Suite, is used for the analysis

Camilla Hvid, Head of Sustainability at Sweco in Denmark

A digital twin to beat the heat



It is possible to calculate surface temperature with GIS tools at a relatively high resolution, here with a grid size of 1x1 m. This enables planners to assess the effectiveness of different blue and green solutions.

Photo Niels Nygaard

The approach to heatwave resilience in 24 European cities

How are European cities tackling heatwaves? This study covered 24 cities across Europe and explored how they are building up their resilience strategies to adapt to the heat.

Impact of increasing temperatures
Future climate projections anticipate a significant increase in the frequency and severity of heatwaves in urban areas. To address this, nearly all cities in the analysis developed a climate action plan that included urban adaptation actions for mitigating the impact of a warming climate. Many of these actions aim to cool urban areas to reduce the likelihood of health concerns and an increase in mortality rates across European cities.

Mapping heatwave impact
Most cities in the study acknowledged the impact of heatwaves on vulnerable communities, even though definitions varied in terms of what vulnerable communities are. Some cities focussed on the elderly or children, whereas others focussed on citizens residing in lower income areas and other socio-economic factors. As part of the development of urban adaptation plans, many cities engaged a wide range of stakeholders in the process. This tends to be the most common approach to reaching vulnerable groups. However, engaging hard-to-reach groups can be challenging. In the urban adaptation plans reviewed as part of the analysis, cities did not tend to provide too much detail on the stakeholder engagement process and the specific vulnerable groups that were included in the study.

The analysis revealed that cities with a track record of developing adaptation plans to address heatwaves specifically tend to take a more data-driven approach to understanding vulnerable communities. For example, cities used GIS spatial mapping to layer temperature data and socio-economic data on lower income areas to develop targeted adaptation actions. Overall, the analysis identified a gap between mentioning vulnerable communities in resilience plans and the engagement approach to work with them to co-create policies and projects.

Effective climate action plans
Most European cities in the study are currently implementing both green and blue infrastructure to create 'cooling corridors' for residents as an approach to mitigating the impact of heatwa-

ves. However, they are adopting many other actions that link to health, including:

- Investment in one-off projects (green roofs, wildlife corridors, etc.)
- Links to nature-based solutions, specifically in areas impacted by the UHI effect, and ties to vulnerable communities by spreading out green spaces across the city so that anyone can access them within a set amount of time.
- Awareness campaigns and early warning systems (helplines, etc.) targeted at vulnerable communities as a preventative measure.
- Development of resilience housing and infrastructure to protect residents.
- Reducing the number of vehicles on the road during heatwaves in order to lower temperatures from the UHI effect and to improve air quality.

However, do these strategies produce effective results?

The studied European cities climate action plans showed a lack of data on the impact of adaptation actions, specifically urban cooling actions, to address the impacts of heatwaves. General data and information are available on a select number of adaptation actions implemented in cities (such as green corridors), but most of this data around action benefits has not been confirmed and quantified in specific places or geographic regions. Therefore, it is too early to tell if these actions are effective in mitigating the impact of heatwaves in European cities. Furthermore, there is little information provided in the climate action plans on the monitoring, evaluation and reporting of adaptation actions and what success looks like.

The studied cities include:

1. Brussels
2. Copenhagen
3. Helsinki
4. Oslo
5. Rotterdam
6. Stockholm
7. Amsterdam
8. Edinburgh
9. Madrid
10. Glasgow
11. Seville
12. London
13. Rome
14. Lisbon
15. Paris
16. Vienna
17. Barcelona
18. Geneva
19. Prague
20. Istanbul
21. Toulouse
22. Gdansk
23. Warsaw
24. Athens

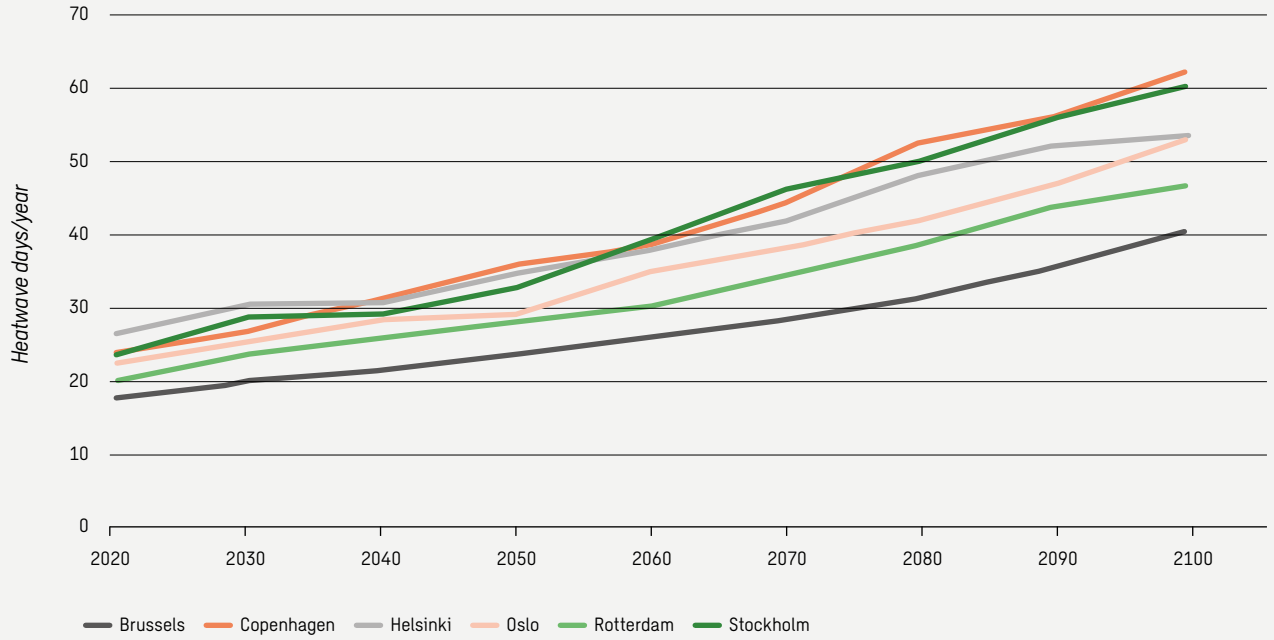
Image collage by Sweco. The collage includes an image from Getty, and the image on the computer represents the annual near surface temperature anomaly (°C, difference from the 1991-2020 average) for 2023. Data shown are the median of the following six data sets:
Berkeley Earth, ERA5, GISTEMP, HadCRUT5, JRA-55, NOAAGlobalTemp.

Heatwave trends in Europe[40]

European cities are increasingly experiencing a rise in temperatures as a consequence of global warming. This temperature rise has caused an increase in heatwaves, both in terms of frequency and likelihood of recurrence. Based on current carbon emission trajectories, Sweco experts have analysed case study data on heatwaves using the PROVIDE climate risk dashboard to understand the future likelihood of heat stress within these cities. PROVIDE enables users to explore the anticipated impacts of future climate change and the (un)avoidable risks ranging from cities to the global scale.

The number of heatwave days will double by 2100
All cities are set to experience at least double the number of heatwave days in 2100 compared with 2020. The biggest increase is in Copenhagen +38 days from 2020 to 2100. Helsinki is set to experience the smallest increase of +27 days, yet this still represents a 100% increase in heatwave days in the next 80 years, from 2020-2100.

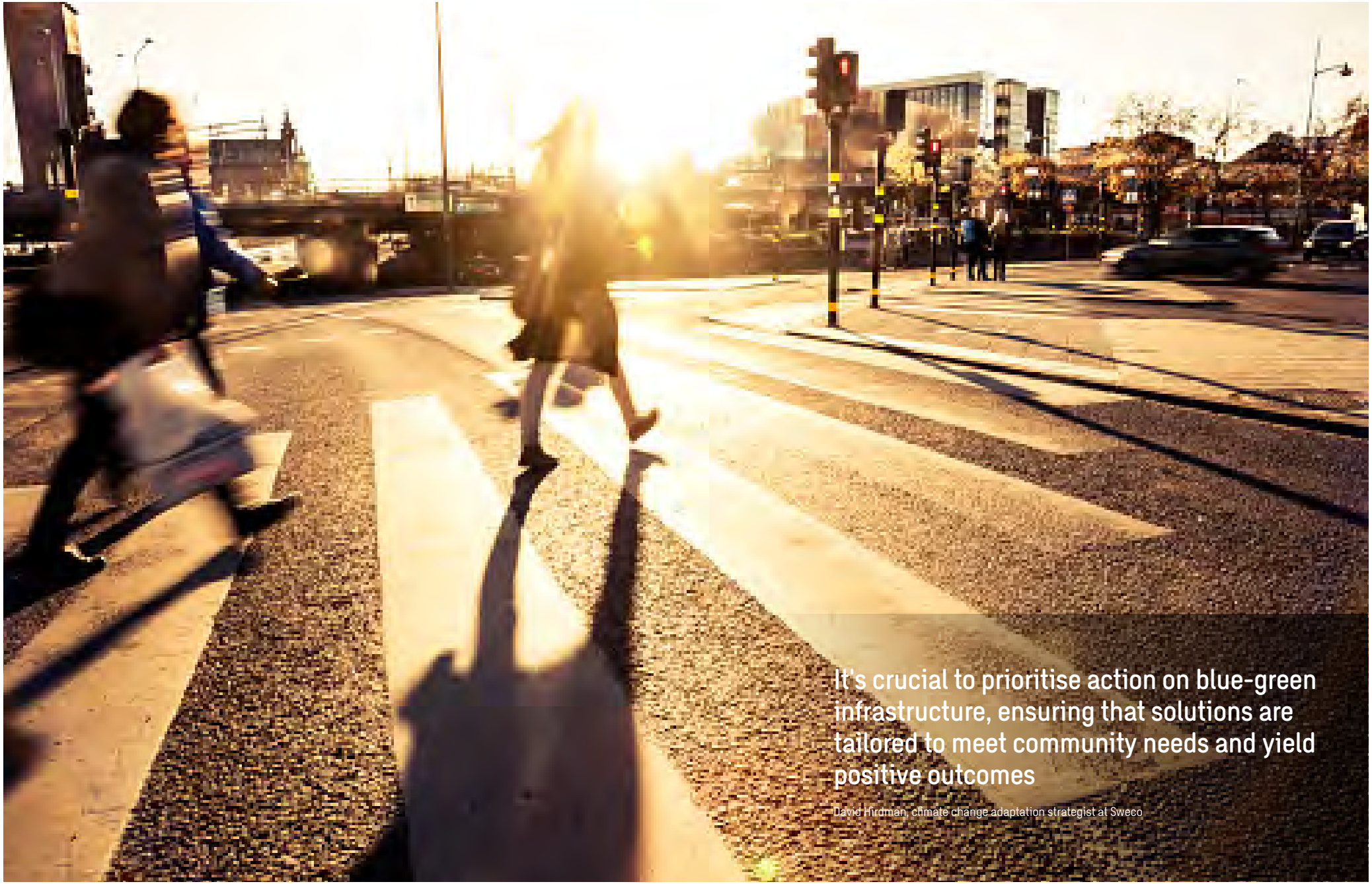
Heatwave days per year



Estimated increase in heatwave days from 2020 to 2100

Brussels +130%	Oslo +140%
Copenhagen +160%	Rotterdam +130%
Helsinki +100%	Stockholm +150%

Heatwave days per year: Periods of at least 3 days in which the maximum and minimum temperature exceeds the 90th percentile value of a reference present period (2011-2020). This graph shows how Heatwave days per year (expressed in d/yr) will play out over time on average over the urban area of Brussels, Copenhagen, Helsinki, Oslo, Rotterdam, Stockholm, according to the scenario 2020 climate policies. The line indicates the median estimate for this scenario. For more information go to Provide dashboard.



> It's crucial to prioritise action on blue-green infrastructure, ensuring that solutions are tailored to meet community needs and yield positive outcomes
>
> David Hirdman, climate change adaptation strategist at Sweco

Climate Risk Dashboard

The PROVIDE climate risk dashboard allows you to explore future climate change impacts and (un)avoidable risks, from cities to the global scale.

The climate risk dashboard is an online platform providing detailed information on overshoot scenarios and expected impacts and their reversibility. From urban heat stress to soil moisture and marine climate data, the dashboard allows climate scientists, urban planners, science communicators and policymakers to explore terrestrial and marine climate futures and the steps needed to avoid the worst climate impacts in urban centres worldwide. The platform provides data to address global temperature overshooting risks. It is led by Climate Analytics in partnership with 17 global institutions including Sweco.

This project has received funding from the European Union's Horizon 2020 research and innovation programme. More information: provide-h2020.eu

Estimated increase in moderate heat stress days from 2020-2100

Brussels +150%	Oslo +265%
Copenhagen +200%	Rotterdam +160%
Helsinki +185%	Stockholm +260%

Moderate heat stress: Number of days per year where wet bulb globe temperature goes over 25°C. Wet bulb globe temperature (WBGT) is a measure of heat stress in direct sunlight, which takes into account temperature, humidity, wind speed, sun angle and cloud cover (solar radiation).

From 2020-2100, both Brussels (+10 moderate heat stress days) and Rotterdam (+9 moderate heat stress in days per year) are expected to experience significant increases in moderate heat stress days, a 150% and 160% rise respectively by the end of the century. While the number of days per year is less for other cities, the percentage increases are more severe: Copenhagen +200%, Helsinki +185%, Oslo +265%, Stockholm +260%.[41]

Case studies:

Heatwave strategies in six large European cities

Current heatwave impact

Brussels is particularly vulnerable to heatwaves compared with other Belgian municipalities, with the UHI effect making air temperatures in the city up to 7-8°C greater than surrounding rural areas.[42]

The city is experiencing an increased frequency and intensity of heatwaves, with at least one heatwave occurring every year between 2015-2019.[43] Additionally, the duration of heatwaves doubled in the period 1988-2016 compared with 1901-1930.[44,45]

Predicted heatwave impact[46]

+23
heatwave days by 2100

+9.4
moderate heat stress days by 2100

Brussels

Climate Resilience Plans: Key Heat Policies
Brussels' key heat resilience policies span three key areas.

The city's climate plan[47] identifies nature-based solutions as the first step in combatting increased heat. Policy measures include creating and enhancing local greenspaces, a 'Reseau Nature' programme to increase urban biodiversity, and the continued development of the Neder-Over-Hembeek Urban Forest project. This is consolidated in the region's Air-Climate-Energy Plan, which asserts the need for diversified tree-planting to increase the climate resilience of local forests.[48]

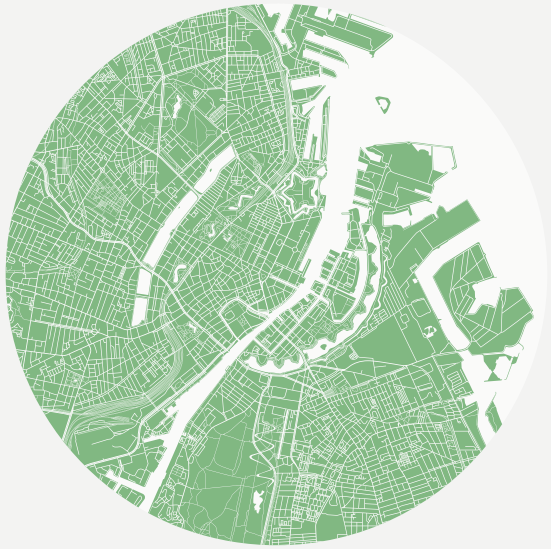
Infrastructure adaptation and retrofitting to improve comfort in the summer is another key part of the climate change plan. These are complemented by the promotion of the Sustainable Building Guide and Materials tool for architects and construction professionals.

Finally, the city recognises that "urban planning and urbanisation are essential levers"[49] for ambitious climate adaptation measures. Municipal authorities are looking to increase access to urban green space through a programme of 'verdurisation', in collaboration with the environmental division of the city authority Environnement.Bruxelles and Be.Sustainable, a network of Brussels transition actors who work towards developing a resilient city. The city is also "committed to carrying out three pilot projects to reduce the UHI", though no further detail is provided.

Vulnerable Communities: Engagement and Impact
Brussels' heatwave plan allows vulnerable individuals to register, so that when temperatures exceed 28 degrees, a phone number can be used to seek help. Dedicated teams help by providing regular contact, water and home visits to check citizens' living conditions.

In Belgium we have chosen to combine the management of high temperatures with the issue of ozone peaks, which are often associated with them. The implementation of the Heatwaves and Ozone Peaks plan adopted in 2015 was the subject of a coordination protocol between the three regions and CELINE (Interregional Environment Cell). The various authorities in Belgium have an ozone and heat plan.

Pascale Van Der Plancke, climate policy advisor at the City of Brussels



Current heatwave impact

The Copenhagen Climate Adaptation Plan (2011) identifies UHI and high surface temperatures as a key issue for the city. Copenhagen experienced its hottest average summer in 2018,[50] with heatwaves in consecutive years from 2020-2022,[51.52] and record July temperatures in 2022.[53]

Predicted heatwave impact[46]

+38
heatwave days by 2100

+3.2
moderate heat stress days by 2100

Copenhagen

Climate Resilience Plans: Key Heat Policies
To reduce probability, scale and vulnerability to heat, the plan promotes targeted multilevel actions at the municipal, district, street and property levels.[54] These include integration of nature-based solutions in local plans and legislation, establishment of continuous green structures and the Municipal District Cooling Act.

Case Study: District Cooling
Copenhagen's district cooling utilises seawater intake for heat absorption and produces an estimated 70 percent reduction in CO_2e emissions compared with conventional air-conditioning.[55]

Vulnerable Communities: Engagement and Impact
As part of its 2011 Adaptation Plan, the city produced a visual map of surface temperatures during a 2006 heatwave, identifying vulnerable areas to focus on and target measures. However, despite contemporary research highlighting the increase of heat-related morbidity for vulnerable populations during heatwaves,[56] while the municipality identifies vulnerable groups, the sick, the elderly and children, it does not include specific policy measures targeting these groups.

In Copenhagen's Municipality's climate adaptation plan, we have identified rising temperatures as a challenge that will grow in line with climate change. We have prepared a study of the extent of the problem and possible measures that can reduce the urban heat island effect (UHI). Handling of UHI is included in the municipal plan's general guidelines as a possible parameter that can be incorporated into local plans. Political decisions on prioritising the work with UHI and financing measures are needed to reduce UHI.

Jan Rasmussen, project director, Center for Climate Adaptation at the City of Copenhagen.

Current heatwave impact

The UHI effect and summer heatwaves are some of the key climatic and adaptation challenges faced by Helsinki.[57] A 2018 summer heatwave is estimated to have caused 380 premature deaths in the city.[58]

Predicted heatwave impact[46]

+27
heatwave days by 2100

+3.5
moderate heat stress days by 2100

Helsinki

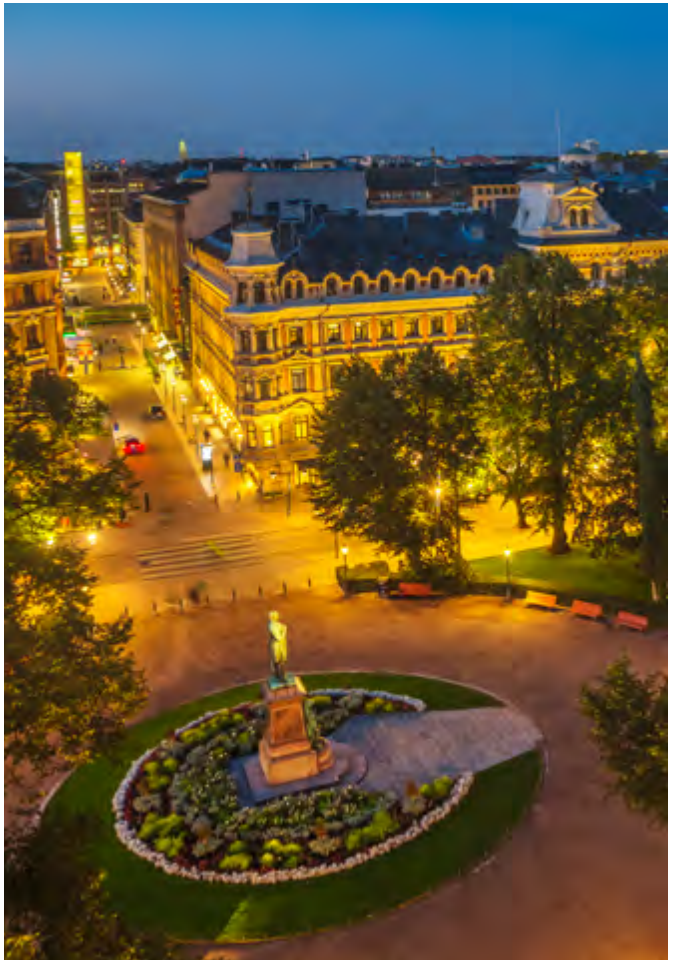
Climate Resilience Plans: Key Heat Policies
The 2017 Climate-Smart Helsinki city plan calls for the implementation of a green roof policy and expanded district cooling to help the city adapt to the UHI effect.

Climate adaptation strategies have been developed to combat increased heat, focusing on urban greening, and embedding climate adaptation measures into city administration.[59]

The City of Helsinki is a project partner in the Green Handbook, a model for the digital, participatory urban planning of multifunctional green infrastructure.

However, in its 2019-25 Climate Adaptation strategy, the city recognised that actions for mitigating the UHI effect remain insufficient due to resource constraints and that there is a need to integrate adaptation into city management through staff training and in-depth scenario planning.[60]

Vulnerable Communities: Engagement and Impact
In 2015, the Helsinki Region Environmental Services Authority leveraged GIS and city socio-economic data to assess vulnerability to extreme heat according to age, health, income, education and social networks.[61] Updated climate vulnerability mapping is underway as part of the CHAMPS programme, a research consortium between higher education and government institutions.[62]



The city has planned to launch policies regarding heatwaves this year (2024). However, since this is completely new, there is no city body that is ready and organised to take this as their responsibility. It requires cooperation and responsible parties throughout the city's different organisations. Regarding rain and flooding, these processes have existed for a long time, but for heatwaves everything needs to be built from scratch now.

Susanna Kankaanpää, project manager, adaptation to climate change at City of Helsinki

Current heatwave impact

The unique topography of Oslo, with its basin shape and compact city center, increases the risk of urban heat island effect.[63] Over the past century the climate in Oslo has become 1.5 degrees warmer and, with temperature rise projected to be highest in polar regions, this rise will be felt acutely in Norway's capital.[64] Despite its status as considered one of the cities with lower exposure to climate risks compared to other parts of the world, ranking 575th globally,[65] Oslo experienced consistently high temperatures and drought in 2016-2018. This acutely increased the risk of wildfires owing to drought-stressed fir trees in Oslomarka, the forest surrounding the city.[66]

Predicted heatwave impact[46]

+31
heatwave days by 2100

+1.0
moderate heat stress days by 2100

Oslo

Climate Resilience Plans: Key Heat Policies
In 2015, Oslo became the first Norwegian city to adopt a climate change adaptation strategy. This strategy was revised and integrated in the Climate Strategy of Oslo adopted in 2020, with goals for both adaptation and mitigation. The strategy has one focus area on managing and protecting the forest surrounding the city, and another focus area on building resilience in the built environment. Both focus areas include actions points that will increase resilience to heat such as further develop green spaces, planting trees, sustainable forestry, reopening streams. Other initiatives being implemented[67]:

- A clear focus on nature-based solutions through preservation and enhancement of blue-green infrastructure, including a flagship tree-planting project, green roofs and rain gardens.[68]
- Integration of climate change adaptation in urban planning.[69] For example, standards were developed by the Agency for Planning and Building Services for mandatory blue-green infrastructure and climate change criteria in new housing projects and other transport and construction works.[70]

Case Study: Oslotrær – Oslo Trees Project[71]
Initiated by Oslo City Council, the Oslotrær project promotes and organises urban afforestation in collaboration with NGOs, schools, homes for the elderly, and local civil society groups. Following a mapping of urban tree cover in 2021, the project has planted 3,200 trees to date and includes regular monitoring and evaluation with stakeholders in addition to a public portal showing new plantings.

The city might in the future implement various measures to help residents cope with the heat, especially for vulnerable populations like the elderly and those with pre-existing health conditions.

Guro Sørnes Kjerschow, special advisor for climate change adaptation, City of Oslo

Vulnerable Communities: Engagement and Impact
The climate change vulnerability analysis for Oslo (2020) assesses impacts of climate change on Oslo and the city's ability to adapt to these. One finding in the analysis was that there is limited research and mapping of the effects of higher temperatures in Oslo.

With a changing climate, the weather in Oslo is becoming wetter and warmer. "So far, the main challenge with climate change in Oslo is heavier rainfalls with subsequent storm water causing damages and operational abruptions to buildings and infrastructure. Hence, stormwater management has been prioritized the last decade with a cross-agency strategy and action plan", says Guro Sørnes Kjerschow, special advisor for climate change adaptation, City of Osloand and adds,

"Increasing mean temperatures, heatwaves and droughts is more unknown to Oslo, but has gradually become more prevalent and the climate projections inform that these challenges will become more serious also in Oslo. Increasing temperatures results in more subtle challenges to public health and nature. Therefore, the municipality are developing solutions to manage higher temperatures, especially for vulnerable population groups, in addition to strengthening biological diversity. We experience that many nature-based solutions to manage storm water is also beneficial for increasing temperature related challenges, such as securing green areas, planting threes, and reopening streams." Guro Sørnes Kjerschow explains.

Current heatwave impact

Rotterdam is experiencing longer periods of drought and more frequent and intense heatwaves,[72] with heatwaves labelled one of the "key shocks and stresses" impacting the city.

Additionally, these heatwaves are exacerbated by the UHI effect, which causes the city to be up to 8 degrees warmer than the surrounding countryside.[73]

Predicted heatwave impact[46]

+27
heatwave days by 2100

+8.8
moderate heat stress days by 2100

Rotterdam

Climate Resilience Plans: Key Heat Policies
Rotterdam has over a decade of experience implementing heat resilience measures. Today, the city identifies heat as a key risk factor influencing climate, biodiversity and health crises. It aims to adapt to extreme heat through policy implementation in four key areas: public spaces, existing properties, new properties, and 'residents in motion'.

Incorporating nature-based solutions in public spaces was a key focus area in its 2013 Climate Change Adaptation strategy. It included the expansion and creation of new blue-green networks, incorporating more flora and less paving into urban spaces, and increasing the number of green roofs and facades throughout the city.

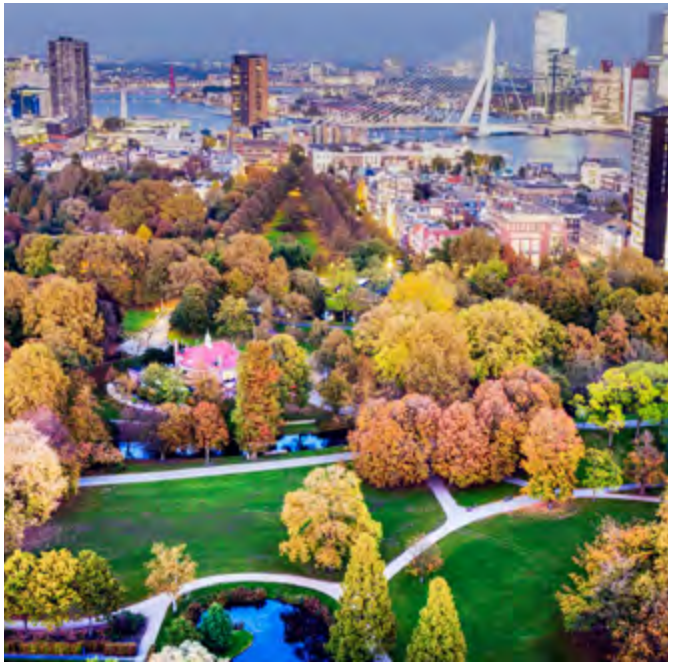
Infrastructure policies include encouraging heatproofing measures as standard at the design phase for all new construction projects and retrofitting existing buildings with heatproofing measures such as white and green roofs, sun blinds and easy-to-open windows.

The adaptation strategy also states an intention to "keep the people of Rotterdam well-informed about heat stress" to encourage behaviour change, though it is unclear exactly how this was operationalised. City planners state they will be working on a Rotterdam heat plan for 2028.

Vulnerable Communities: Engagement and Impact
Rotterdam developed an Interactive Climate Atlas used to create a city-wide heat risk map highlighting the UHI effects by 2050 and focusing on the concentrations of vulnerable communities like the elderly and nursing homes, as well as offices.

> Since 2019, we have been mapping and using all kinds of data in WeerWoord Rotterdam. There is also a national programme for measuring heatwaves to reduce heat stress. Inclusive Climate Action Rotterdam (ICAR), a part of WeerWoord, is putting a lot of effort into inclusive climate action, and making sure that the policies and projects we develop reach as many Rotterdammers as possible.

Johan Verlinde, programme manager, Rotterdams WeerWoord



Current heatwave impact

Climate change is faster in Sweden than the global average, with temperatures already nearly 2°C higher than the pre-industrial average and rising higher in Stockholm.[74,75]

Heatwaves are rare in Sweden compared with southern Europe,[76] yet the last decade has brought the three hottest years since 1945[77] with record-breaking 2018 heatwaves directly attributable to anthropogenic climate change.[78] These resulted in drought and wildfires across the country.[79]

Predicted heatwave impact[46]

+37
heatwave days by 2100

+2.2
moderate heat stress days by 2100

Stockholm

Climate Resilience Plans: Key Heat Policies
One-third of Swedish municipalities have developed routines, checklists and action plans to counter extreme heat,[80] although Stockholm has not.

The Stockholm Environment Programme for 2020-2023 does, however, identify the need to create an action plan for heatwaves.

Example mitigation measures identified by the city include:
- A risk and vulnerability analysis for city operations
- Nature-based solutions
- Temperature-lowering measures on buildings
- Cool rooms in homes
- Rainwater collection[81]

Case Study: Stockholm Heat, Senseable Stockholm Lab
In 2021-2022, the City of Stockholm, in partnership with global universities and other public institutions, combined data from low-cost sensors on vehicles with existing data on forest and other tree-cover habitats to measure ambient and ground temperatures and quantify greenery at street level, in order to assess the benefits of urban greenery at the hyperlocal level.

Source: Stockholm Heat | KTH (senseablestockholm.org)

Vulnerable Communities: Engagement and Impact
Our interview with city representatives highlighted several measures the City of Stockholm is developing and collaborating on to increase the resilience of vulnerable communities to extreme heat. These include:

- City-wide heat analysis and vulnerability mapping focussed on schools, preschools, retirement homes and areas of the city with a high proportion of elderly residents.[82]
- Targeted messages sent to businesses warning about high temperatures, giving them sufficient time to prepare for the heat and reducing economic vulnerability.
- MiCasa – the primary provider of residential care homes and serviced housing apartments owned by the city – have conducted mappings for their buildings, ensuring efficient, targeted maintenance of homes experiencing heat stress.
- Installation of thermometers in schools to inform city policy on school opening times during the summer months.

It is important to realise that climate adaptation is about managing risks in many ways. If you link up with others who also do this, you can benefit greatly.

Karin Dhakal, strategist at the City of Stockholm administration

Conclusions

European cities are facing a pivotal moment in their approach to managing the increasing severity and frequency of heatwaves.

Our case study cities have taken some key steps in the right direction. They have emphasised nature-based solutions across green and blue infrastructure, integrating heatwave adaptation measures into planning legislation and conducting limited GIS mapping.

However, cities across Europe are still learning how to mitigate and adapt to the risks posed by heatwaves to residents, services and assets.

Only a select number of cities have dedicated adaptation teams who have planned for heatwaves. This is particularly true for Northern European cities, where heatwaves are a relatively new and uncommon phenomenon.

Climate equality - data and vulnerability mapping needed
Beyond investment in green-blue infrastructure and technological innovation, there is an urgent need to pivot towards participatory policymaking informed by city-to-city learning and centred on those most affected by heat extremes.

This emerging challenge exposes significant gaps in urban heatwave adaptation policies, particularly with regards to vulnerable populations. While cities recognise the correlation between heatwaves and negative health outcomes, the concept of climate equality remains underrepresented in urban resilience planning. This absence is exacerbated by granular data and vulnerability mapping across cities, with little to no monitoring and evaluation available for current adaptation policies across the board.

For policymakers and urban practitioners, it is imperative to prioritise the development of comprehensive heatwave-response strategies informed by robust empirical evidence and grounded in principles of climate equality, ensuring safety measures for especially vulnerable populations.

Resilience and governance
Resilience is a broad and contested concept, with each case study city offering a slightly different definition. The cities all had a common focus on adapting urban infrastructure to the changing climate. However, resilience and adaptation were not immediately and explicitly linked to vulnerable communities by all of them. Developing a holistic and nuanced understanding of resilience, in line with transformational adaptation, is essential to ensuring just and equitable responses to heatwaves.

Due to links to net zero, health and urban planning, resilience is a cross-departmental and cross-partner issue for cities that requires collaboration and leadership from multidisciplinary expert networks. Cities simply do not have the power to do everything themselves – they require collaboration and an evolution in governance models.

Financing presents a challenge, emphasising the need for cost-effective measures and innovation in business models to address heat-related issues effectively.

In the face of accelerating polycrises, cities can design heatwave responses that are not only effective but equitable, ensuring that every resident can withstand the heat and thrive. Cities have the information and understanding needed for cooler, liveable cities. Now is the time to act and build the resilient cities of tomorrow, today.

Recommendations for heatproofing European cities

Invest in knowledge-building

Set long-term visions and short-term actions: Set long-term goals for heat resilience, aiming towards 2100, and then work backward to trace the steps needed to achieve those goals. This helps clarify the necessary goals and actions for the medium and the short term.

Make action plans and set priorities: For policymakers and urban practitioners, it is imperative to prioritise the development of comprehensive heatwave response strategies. These strategies should be informed by robust empirical evidence and grounded in principles of climate equality, like accessibility and fair distribution of resources.

Test, monitor, assess and adjust: Approach heat management in the same proactive manner as water management – through testing, adaptation and modulation. When implementing blue-green solutions to combat heat, it is crucial to conduct thorough testing and follow-up assessments to ensure that these solutions effectively meet the needs of the community and make the desired positive impact.

Innovate and optimise

AI, digital twins and IoT

- Develop advanced AI algorithms to predict and monitor heatwaves, allowing for early warnings and proactive planning.
- Implement smart infrastructure solutions, such as intelligent cooling systems and energy-efficient designs, to reduce the urban heat island effect and provide cooling in high-risk areas.
- Utilise digital twins of cities or specific regions to simulate and optimize urban planning strategies, including the placement of green spaces, shading structures, and cooling measures.
- Incorporate IoT sensors and data analytics to gather real-time information on temperature, humidity, and air quality, enabling targeted interventions and resource allocation during heatwaves.
- Enable and optimise the use of renewable energy sources and energy-efficient technologies to reduce heat-related energy consumption and greenhouse gas emissions.

Develop ecological networks and cooling corridors

- Develop urban cooling corridors: Create visions and plans to configure networks of open spaces at the city level, reinforcing existing landscape and green-blue structures, connecting the missing links and providing the framework to incrementally create cooling corridors at the city level that have high ecological value.
- Create multifunctional open spaces: Many blue-green solutions can effectively manage both stormwater and heat. These solutions optimise land use efficiency and prioritise biodiversity and social sustainability.
- Optimise building orientation: The orientation of buildings towards the outdoor environment is vital. Buildings can serve as a significant component of shading functionality.

Upgrade systems and networks with nature-based solutions

- Develop nature-based solutions: Improve existing mobility infrastructure through nature-based solutions. These are actions that protect, sustainably manage and restore natural or modified ecosystems in order to address societal challenges effectively and adaptively while providing human well-being and biodiversity benefits.
- Define the role and goal of greenery: Set specific objectives and desired outcomes that greenery should achieve in the project, like improving air quality or providing recreational spaces by selecting appropriate plant species and implementing green infrastructure techniques, for instance. Identify the critical factors and requirements necessary for a successful implementation, such as site conditions and collaboration with stakeholders.
- Optimise paved surfaces: Another multifunctional approach involves integrating heating adaptation with mobility strategies in cities. By reducing space for cars through measures like reducing lanes and implementing one-way streets, more space becomes available for greenery.

Increase building performance

- Design high-performance buildings with advanced technology to remain functional even in extreme heat. Incorporate effective ventilation and cooling systems during construction. Engage with users to understand their needs. Consider ceiling height, awnings, blinds and operable windows to mitigate solar radiation and heat buildup.
- Redesign building regulations: In the Nordic countries, today's building regulations are designed to keep heat inside and cold outside. However, in light of the increasingly warmer climate, we need to rethink these regulations.

The presence of extensive green areas in a neighborhood can help lower the overall average temperature, but higher surface temperatures in specific residential and commercial areas can still be problematic, especially in schools, elderly care, and health facilities.

Laura Roemer, Water and Climate department, Sweco Denmark

Co-create

Establish heatwave governance: Cities need to create crisis teams dedicated to managing heatwaves, mirroring the approach taken for heavy rainfall and floods.

Set cooperation frameworks: City networks offer significant benefits for climate adaptation and resilience. They facilitate city-to-city learning through the sharing of best practices and increase access to funding opportunities.

Raise awareness and involvement: Enhance public awareness, education and participation, cities can harness local knowledge, resources and creativity to develop more effective and inclusive climate adaptation measures.

Extend heatwave mapping: Mapping vulnerable groups in relation to heatwaves is crucial. In addition to geographic information systems (GIS), alternative data gathering methods such as citizen science can be leveraged. Citizen science provides precise data on fine-grained contexts and helps raise awareness and foster community engagement.

Co-create: Engage intended users in the design process. For instance, educators should be consulted when designing a preschool playground. It's crucial to designate responsibility for playground upkeep upfront. Besides greenery, immediate shade solutions like pergolas or sunshades are vital, especially since newly planted trees take years to mature.

Empower communities: Proactive measures are crucial in helping vulnerable populations cope with extreme heat. Cities and organisations can engage with these groups to implement strategies, such as setting up cooling centres, providing multilingual heat safety information and offering assistance with utility bills or access to air conditioning units during heatwaves.

About the authors

Feel free to contact us with your questions and thoughts. E-mail: urbaninsight@swecogroup.com

Séverine Hermand, PhD,
Climate resilience planning expert.
Sweco Belgium

Kristina Holmblad, Landscape Architect, Sweco Norway

Filemon Wolfram, Urban Designer, Land Use Planning, Sweco Finland

Enrico Moens, Programme Manager and Senior Expert, climate change adaptation in the urban planning and environmental division, Sweco Netherlands

Dr. Katherine Maxwell, Technical Director, Net Zero Cities, Asset Management, Sweco UK

David Hirdman, PhD, Climate Change Adaptation Strategist, Sweco Sweden

Laura Roemer, Water and climate expert, Sweco Denmark

Special thanks to contributing experts:

- John Rembowski, Net Zero Consultant, Asset Management, Sweco UK
- Lucas Nieuweboer, Urban Planner, Sweco Netherlands
- Anais-Marie De Keijser, PhD, Climate resilience planning expert, Sweco Belgium.
- Jens Aerts, Civil Engineer and Urban Planner, Sweco Belgium
- Diego Luna Quintanilla, Project Manager and Urban Designer, Sweco Belgium
- Hampus Nilsson, Consultant Environment & Planning, Sweco Sweden
- Helene Piellard, Carbon Management Consultant, Asset Management, Sweco UK
- Camilla Hvid, Head of Sustainability, Sweco Denmark
- Caitlin Hill, Team Manager, Decarbonisation Advisory Services, Sweco UK
- Elle Bartleet, Carbon Consultant, Asset Management, Sweco
- Joseph F. MacNamara, Carbon Management and Climate Resilience Consultant, Asset Management, Sweco UK
- Karin Dhakal, strategist at the City of Stockholm administration
- Johan Verlinde, Programme Manager, Rotterdams WeerWoord
- Guro Sørnes Kjerschow, Special Advisor for climate change adaptation, City of Oslo
- Susanna Kankaanpää, Project Manager, adaptation to climate change at City of Helsinki
- Pascale Van Der Plancke, Climate Policy Advisor at the City of Brussels

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