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Climate-Resilient Development Pathways in Metropolitan Regions of Europe

Deliverable 1.2 - Report on climate change challenges

April 2025

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1.6	27 February 2026	Updated after the M18 review, incorporating Project Officer recommendations.

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Abbreviations

CARMINE	Climate-Resilient Development Pathways in Metropolitan Regions of Europe
CC	Climate Change
CSA	Case Study Area
D	Deliverable
EU	European Union
LL	Living Lab
M	Month
NbS	Nature-based Solutions
NGO	Non-governmental organization
NPO	Non-profit organization
PESTLE	Political, Economic, Social, Technological, Legal, and Environmental
R&I	Research and Innovation
T	Task
UHI	Urban Heat Island
WP	Work Package

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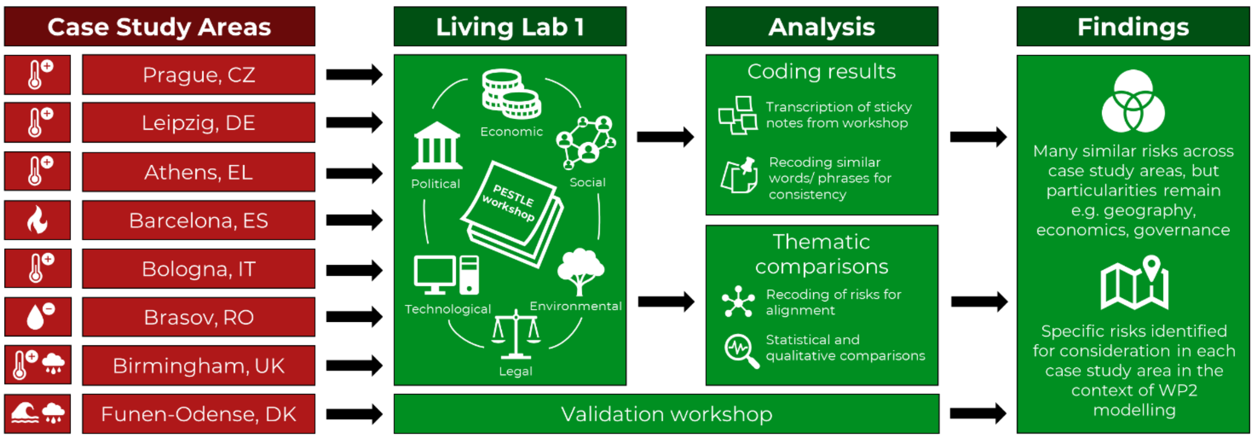
Executive Summary



Graphical abstract summarising Deliverable 1.2 of the CARMINE project

The project "*Climate Resilient Development Pathways in Metropolitan Regions of Europe"* (CARMINE) aims to help metropolitan communities become more climate resilient, by co-producing knowledge-based tools, strategies, and plans for enhanced adaptation and mitigation actions addressing the Charter of the European Union Mission on Adaptation to Climate Change by 2030.

Task 1.2 in the CARMINE project runs from Month 1-48 of the project and undertakes participatory documentation of Climate Change challenges and identification of adaptation measures via the three Living Lab workshops. Workshop one took place in Months 11-12; Workshop Two takes place in Months 15-18; and Workshop Three takes place in Months 21-24. Via these workshops, Task 1.2 will assess the climate change challenges, their interdependencies, and their synergies within the eight Case Study Areas.

This report, Deliverable 1.2 (D1.2, due Month 15 of the 48-month task), presents a preliminary and rapid analysis of the risks documented in LL Workshop One. The preliminary findings provide a foundation for LL Workshops Two and Three, and provide input into future CARMINE tasks, particularly Work Package 1, Work Package 2, and Work Package 6.

Either extreme heat or heatwaves was the challenge in five Case Study Areas; coastal and flooding is a challenge in Funen-Odense and pluvial flooding a challenge in Birmingham. Barcelona considered the challenge of wildfires, and Brasov, water scarcity. There were between 14 and 99 risks documented for each climate challenge.

Many of the risks associated with these climate challenges were the same across the Case Study Areas, such as negative impacts on health, higher energy demand, unequal access to air conditioning or cooler spaces, loss of biodiversity, and water scarcity. The impact on the economy, tourism, and the attractiveness of the city for investment were other shared risks. However, there

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are particularities such as geographies, economics, governance structures, or other vulnerabilities that make some risks in each Case Study Area unique. Several broad themes emerged from thematic coding, including: regulatory gaps, infrastructure damage, the need for institutional adaptation, transport and mobility, and negative economic impacts.

Consideration of the risks documented in the different Case Study Areas within the context of the Work Package 2 modelling framework showed that planned modelling activities will provide information on how the risks in the Case Study Areas will alter for different climate scenarios. It also highlighted some possible discrepancies between the stakeholder documentation of risks and planned modelling activities, which should be explored with the Case Study Areas to agree the shared way forwards.

The future Living Lab workshops will allow for a deeper exploration of the climate challenges within each Case Study Area and consider how the metropolitan areas can work together to enhance adaptation and mitigation efforts in accordance with the European Union Mission on Adaptation to Climate Change by 2030.

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1. Introduction

1.1 CARMINE Project

The project "*Climate Resilient Development Pathways in Metropolitan Regions of Europe*" (CARMINE) aims to help metropolitan communities become more climate resilient, by co-producing knowledge-based tools, strategies and plans for enhanced adaptation and mitigation actions addressing the Charter of the European Union (EU) Mission on Adaptation to Climate Change by 2030. To achieve this goal, focusing on a 2030-2035 timeframe and with longer perspectives up to 2050, CARMINE aims to:

- Co-create and co-develop decision-support services and guidelines for enhanced resilience and adaptive capacity, including early warning and disaster risk management systems;
- Cooperate closely with local to regional communities (stakeholders and users), decision and policymakers (local authorities) to co-develop cross-sectoral frameworks for adaptation and mitigation actions;
- Deliver science-based Research and Innovation (R&I) roadmaps for multi-level climate governance supporting local adaptation assessments and plans.

More information can be found on the CARMINE project website.

In the first 12 months of the CARMINE project, Work Package (WP)1 established Living Labs (LL) in eight CSAs (Section 1.2). Finalised deliverables (D) associated with this WP include:

- D1.1 Target groups (stakeholders) engagement strategy (Month 6);
- D1.4 Geo-designed adaptation and mitigation pathways - Version 1 (Month 12);
- D1.7 Living Labs creation in case studies (Month 12); and,
- D1.9 Report on the engagement of 5 target groups for each case study area (Month 12).

1.2 Purpose of CARMINE Task 1.2

Task 1.2 runs from Month 1-48 and undertakes participatory documentation of Climate Change (CC) challenges and identification of adaptation measures via the three LL workshops to be held during the implementation period, as follows: Workshop One took place in Months (M)11-12; Workshop Two takes place in M15-18; and Workshop Three takes place in M21-24. Via these workshops, Task 1.2 assesses the climate change challenges, their interdependencies, and their synergies within the eight Case Study Areas (CSAs). Accordingly, it combines information from the scientific data sources with local perspectives from the eight LLs, obtained via questionnaires, workshops, and follow-on interviews where appropriate. At the end of the participatory exercises undertaken in the three LL workshops, each LL will have a multi-criterion mapping system for the main climate change risks represented by a network of factors (i.e. main issues, challenges, and drivers related to climate change risks) and their causal relations. This mapping system will identify the ongoing and prospective adaptation measures in the CSAs, with a focus on Nature-based Solutions (NbS).

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Task 1.2 also captures essential ecosystem services to be considered within Task 1.4, that produces geo-design adaptation and mitigation pathways in selected CSAs and supports the co-design process of impact related indicators in Task 2.1. It also feeds into WP6, that undertakes a policy review (D6.5) and develops: a multi-level climate change governance framework (D6.1), R&I roadmaps for climate change adaptation and mitigation in the 8 CSAs (D6.2, D6.3), and climate policy recommendations (D6.4).

Deliverable 1.2 (due M15) is a *report on climate change challenges*. It should provide an *Assessment of CC challenges in the 8 CSAs. The deliverable includes the specific challenges derived from climate change in each CSA in different climate scenarios*. As such, D1.2 presents a preliminary and rapid analysis of the climate risks that were captured using the participatory approach of LL Workshop One and considers these within the different climate change contexts (i.e. scenarios) of each CSA.

2. Method

2.1 Case Study Areas

The CARMINE project has established eight LLs in eight CSAs across eight countries in Europe (Figure 1). The CSAs are diverse in terms of geography, climate, population, demographics, and socioeconomic profiles. However, all face climate challenges, which are driven by climatic hazards and socioeconomic factors. Many CSAs have climate adaptation plans e.g. Prague City Hall (2020); Municipality of Athens (2022); Barcelona Metropolitan Area (2018), Brasov Municipality (2016), and through CARMINE, the CSAs can work together to share good practices and develop solutions to maximise adaptation to climate change in the CSAs and other Metropolitan Areas, globally. A brief overview of the CSAs follows below.

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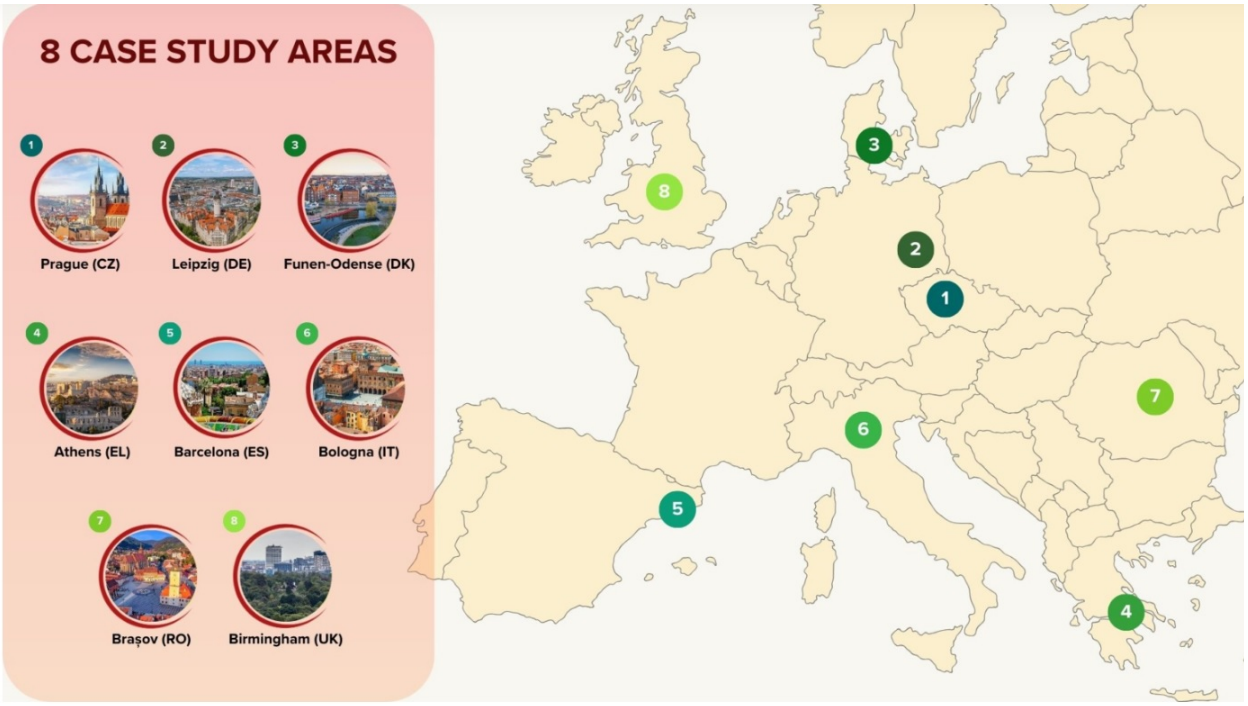

Figure 1: The 8 Case Study Areas in the CARMINE project. Source: [CARMINE website]

2.1.1 Prague, CZ

Prague is the largest city in the Czech Republic, with a population of approximately 1.3 million. It lies within the Prague Metropolitan area, home to almost 3 million people, a third of the country's population. This predominantly urban area has a high population density and faces the dual challenges of heat stress and air quality. Indeed, this region is warming at twice the global average (WMO, 2021), and in recent years there has been an increase in the frequency and intensity of heatwaves (Kašpar et al., 2023), which is associated with increasing heat-related mortality, particularly for the elderly population (Urban et al., 2020). The increased frequency and intensity of heatwaves in Prague may exacerbate air pollution episodes across the city, and air pollution, in turn, increases the health and mortality risk from extreme heat on many individuals vulnerable to heat (EEA, 2023).

On the CARMINE project, the Prague CSA will focus on the local-scale indoor and outdoor thermal comfort, and long-term mortality associated with heat stress. It will consider the effectiveness of three aspects of the Prague 2030 Climate Plan (Prague City Hall, 2021) including the role of NbS. Specifically:

- How will large-scale tree planting reduce heat stress within the city; by 2030 the city aims to plant at least 1.5 million new trees in its parks and streets.
- How can the local authority adapt to reduce the urban heat island (UHI) effect and improve local-scale thermal comfort.
- How and where can the city increase the proportion of blue-green infrastructure to improve the local-scale thermal comfort and improve sustainable water management.

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2.1.2 Leipzig, DE

Leipzig is in Saxony, central Germany and has a population of circa 630,000. It is located within the Leipzig Metropolitan Area, comprised of the city, and smaller towns and villages, which collectively have a population exceeding 1.1 million. The variety of urban and rural environments and different living conditions within the Leipzig Metropolitan Area provide a useful testbed for developing climate-resilient solutions. Under our changing climate, Leipzig is concerned about the increasing frequency and magnitude of heatwaves and the impact these will have on communities in the region, particularly to those who are vulnerable. There are also concerns about the increasing prevalence of wildfires under a future warmer climate.

Accordingly, via the CARMINE project, the Leipzig CSA will consider:

- How can NbS be used to mitigate heatwaves, reduce urban heat islands and improve indoor and outdoor thermal comfort.
- How will strategies to enhance energy efficiency and upgrade buildings protect residents during heatwave events.
- How can the Leipzig Metropolitan Area be prepared for future wildfire risk and what strategies can mitigate future wildfire risk.
- How will climate change impact the real estate sector.
- How can improved communication strategies and awareness raising increase public acceptance of climate change mitigation and adaptation measures.

2.1.3 Funen-Odense, DK

Odense is the third largest city in Denmark and the largest city on the island of Funen. The municipality population is circa 200,000. The broader Funen Metropolitan Area contains many small-to-medium coastal cities. The island is low-lying, and highly vulnerable to coastal flooding driven by storm surges that will increase in frequency and intensity as sea level rises (Laursen & Linderburg, 2017). The increased intensity of heavy rainfall events that cause flooding is a further concern, as are compound events, such as surges, heavy rainfall, and local stream flooding (NIWR, 2024).

The climate risks to low-lying Odense are well-known (Kaspersen & Halsnæs, 2017). This, combined with the strong engagement with local authority stakeholders, provides an excellent opportunity to implement research into action to deliver climate resilience. The CARMINE project will allow Odense to gain insight into the physical, economic and social risks of flooding events, and assess the effectiveness of different adaptation options to reduce risk.

2.1.4 Athens, EL

Athens is the capital of Greece and the Attica Region. The population of the Athens Metropolitan Area exceeds 3.7 million, and the city attracts over 6 million tourists each year. The frequency and duration of heatwaves and droughts is increasing, and there has also been an increase in

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the number of hot days – where daily maximum temperatures are greater than 35°C, and tropical nights – where daily minimum temperatures are greater than 20°C (Founda et al., 2022a). These are associated with poor thermal comfort (Founda et al., 2022b), and increased prevalence of heat-related illness and mortality, especially for vulnerable groups such as the elderly and low-income households living in old buildings in the dense city centre (Ziliaskopoulos et al., 2024; Paravantis et al., 2017). Over the last eight years, the Attica region has lost significant forested areas to wildfires that were ignited during heatwaves and came increasingly closer to the wildland-urban interface (Arianoutsou, 2024). Athen's aging population combined with the influx of tourists in summer months, the increased frequency of wildfires, and the dense urban environment is expected to place increasing strain on urban infrastructure and water resources, with consequences for public health.

Consequently, the Athens CSA will address the challenges associated with extreme heat, with a focus on public health. Specific considerations include:

- Developing a Digital Twin to monitor and reduce health and mortality risks associated with extreme heat.
- Assessing the potential of NbS to provide cooling.
- Gaining data-driven insights into the impact of heat on vulnerable groups, including children, the elderly, low-income households, and workers exposed to heat.

2.1.5 Barcelona, ES

Barcelona is located on the northeast Mediterranean coast of Spain and is the centre of a metropolitan area with a population of more than 3.3 million. The regional climate is characterized by hot, dry summers and increasingly variable rainfall, which has made the area particularly vulnerable to climate extremes. In recent years, the region has experienced heatwaves and droughts of increasing severity and duration (Serra et al. 2024; Coll et al., 2016) and these trends are projected to accelerate (Forero-Ortizet al., 2020; Barcelona City Council, n.d.). Wildfire risk is associated with hotter, drier weather, exacerbated by rural abandonment and expanding wildland-urban interfaces, which creates conditions for wildfire ignition and spread (Badia et al., 2019).

The CARMINE project will bring together scientific modelling with forestry management to:

- Analyze future climate projections from global/regional climate models and combine them with statistical and AI-based modelling tools, to understand how drought severity, heatwave intensity and fire danger will change in the future under different climate change scenarios.
- In collaboration with stakeholders and in the context of the Living Lab in Barcelona, co-create risk assessment tools to evaluate and map the heat, drought and wildfire risk.
- Provide suggestions and recommendations that will enable decision-makers to prioritize mitigation and adaptation measures.

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2.1.6 Bologna, IT

Bologna is the capital and largest city of the Emilia-Romagna region in northern Italy. It is the seventh most populous city in Italy, with about 400,000 inhabitants, however the Bologna Metropolitan Area is home to more than 1,000,000 people. Heatwaves are common and are increasing in frequency and magnitude. Heatwaves coupled with the UHI effect can exacerbate poor air quality by elevating the concentration of ground-level ozone (WMO, 2023), and these factors combined have negative health impacts on the aging population within the region. Indeed, 37% of families in Bologna include at least one elderly person, with individuals over 80 years comprising 9% of the population.

The CARMINE project will consider the impact of climate change on the UHI, now and in the future, and how NbS such as urban pocket parks, parkways, bioretention areas, and green shelters can be used to improve thermal comfort, especially for elderly residents, but also other vulnerable members of the population (disabled, chronically ill, low-income, etc.), as they undertake daily activities, such as grocery food shopping.

A phenomenon, *Food Desert* (FAO, 2019), exists where residents have limited access to affordable and nutritious food. These food deserts are often characterized by a lack of supermarkets or grocery stores within a reasonable distance, forcing residents to rely on convenience stores or fast-food outlets with fewer healthy options. Food deserts are commonly associated with low-income neighbourhoods, poor transportation infrastructure, and high reliance on processed or unhealthy foods. Vulnerable populations (elderly residents, individuals with disabilities, and low-income families) may struggle with food accessibility if they live far from well-stocked supermarkets: these conditions may lead to an increase in exposure to local climates and, subsequently, to an increase in individual health risks.

Bologna's case study will look to:

- Analyze the "most likely" market pathways, or the routes of the vulnerable population to reach fresh food markets, and determine the climate risks associated with these routes, and how these routes can be better improved (implementing NbS).
- Make policy suggestions/recommendations for improvements to public transportation infrastructure, especially as it affects the vulnerable population and their access to fresh food markets, lessening their reliance on unhealthy or processed food options.
- Enable the use of fresh food markets as points of community and/or socialization, especially for the elderly, as the risk of solitude and isolation increase with the heightened risks of heat waves (and the inability to leave home during the hottest periods of the day).

2.1.7 Brasov, RO

Brasov is located in Transylvania, central Romania and is the administrative centre of Brasov County. The city has a population of approximately 240,000; the population of the surrounding metropolitan areas is circa 370,000. Climate change is increasing the occurrence of extreme weather events in Brasov. Hot, dry periods, and extremely wet periods are increasing in frequency

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and magnitude. Climate change projections indicate both future water excess, and scarcity (Păcurar, 2018; Tudose et al., 2022). This is highly relevant, in the context of increasing attractivity of the city for new residents, investment and tourism. In Brasov, the CARMINE project will help stakeholders transition towards more sustainable water management decisions. The project will consider how NbS related to water management (e.g. rain gardens, bioswales, river conservation and restoration, permeable paving, constructed wetlands, rainwater harvesting) can improve water management (Mitincu et al., 2023a, 2023b) and address other challenges such as extreme urban heat (Ioja et al., 2019).

2.1.8 Birmingham, UK

Birmingham is the UK's second largest city, home to more than 1 million people. It is located within the West Midlands conurbation, a predominantly urban area of more than 2.9 million residents. Impermeable land surfaces predominate, and the region frequently experiences pluvial flooding during heavy rainfall events that can lead to gridlocking of roads, flooding of commercial and residential properties, sewage overflow to streets, event cancellation, among others (WMCA, 2024). These heavy rainfall events are projected to increase in frequency and magnitude under climate change (Met Office, 2022). Birmingham is a Biophilic City (since 2014), a Tree City of the World (since 2019), and was the first city in Europe to develop an Urban Forest Master Plan (BTP, 2021). Nature forms a key part of the future city vision and is considered a means to address historic social inequalities within the city (Sultan et al., 2023). The city also faces significant socioeconomic challenges, including housing shortages and widespread deprivation. In 2022, the city was declared bankrupt, and current local authority budgets are extremely stretched.

Via CARMINE, the Birmingham CSA explores the relationship between vegetation management and climate change. Specifically:

- How do different areas and characteristics of tree canopy change surface water runoff levels and extreme high surface temperatures.
- How will tree phenology alter under a changing climate, and what implications will this have for vegetation management.
- How can better tree establishment practices maximise the potential of trees to be a NbS for climate adaptation (e.g. shade, rainfall interception, carbon sequestration).

2.2 Data

Several sources of data were used to populate this report for D1.2, including:

- Existing research/practitioner information in each CSA, that was provided to the CARMINE project team before the LL workshops.
- A preliminary questionnaire that was issued before the LL workshops to each CSA to gain understanding of the climate risks and prospective stakeholders.

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- Information on climate adaptation policy in each CSA provided to support a systematic review of adaptation policy being undertaken as part of WP6.
- Reports written by each CSA following LL Workshop One, as also reported in the supplementary material for D1.9. The methodological approach is described in Section 2.2.2.

2.2.1 Data collection in Living Lab Workshop One

The CARMINE LLs provide a means for stakeholders in each CSA to input their perspectives and experience into the project tasks to jointly test, develop, and create climate-resilient solutions. This knowledge exchange and participatory approach is crucial to ensure that the project outputs are aligned with CSA needs, and therefore help the metropolitan communities become more climate resilient, in line with the Charter of the EU Mission on Adaptation to Climate Change by 2030. Deliverable 1.7 describes the creation of these LLs and their stakeholders.

The overarching aim of LL Workshop One was to create a comprehensive CC Challenge Systems Map that highlights key challenges, interdependencies and synergies within individual CSAs. This was facilitated by using a PESTLE framework (Political, Economic, Social, Technological, Legal, and Environmental) that structured the identification of risks and the underlying drivers of climate challenges and gained preliminary information on adaptation solutions and the barriers to implementation. The approach facilitated systems thinking among the stakeholders. Table 1 provides an overview of the LLs that took place in each CSA. Deliverable 1.1 of the CARMINE project provides more details on the aim and objectives of LL Workshop One (and future Workshops Two and Three). The Funen-Odense CSA is not shown in Table 1. This is because a validation workshop was conducted instead, as the CSA leads considered the climate risks, drivers, adaptation and mitigation measures, and barriers to be well known.

Table 1: Overview details of LL Workshop One in the CSAs

CSA	Date	Delivery mode	Stakeholders
Prague	20/11/2024	Hybrid (all day)	13
Leipzig	09/12/2024	Online (3 hours)	14
Athens	05/12/2024	In person (all day)	13
Barcelona	03/12/2024	In person (6 hours)	19
Bologna	25/11/2024	Online (3 hours)	24
Brasov	20/06/2024	In person (3 hours)	24
Birmingham	25/11/2024	In person (all day)	26

2.2.2 Qualitative analysis of data form Living Lab Workshop One

This report analyses the climate risks and their drivers that were reported in LL Workshop One by the stakeholders who attended the workshop. In each LL, the participants produced a series of risks associated with a climate challenge (e.g. extreme heat). These risks were discussed and

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recorded on sticky notes in the LL and attached to the PESTLE wheel. Where a risk could be classified into different PESTLE categories (e.g. insufficient cool spaces could be considered both and economic and social risk) it was listed once within each category. After the LL, the sticky notes were transcribed as written into tables and included in the submission of Deliverable 1.9.

D1.2 uses the information collected on sticky notes during LL Workshop One but applies two additional analytical steps. Firstly, the comments on the sticky notes (either describing risks) were recoded to use consistent terminology and therefore allow comparison across CSAs. For example, in response to the climate challenge “extreme heat”, three CSAs considered water scarcity to be a future challenge. However, the way each CSA described this challenge differed (Table 2) and so the raw data was recoded. Following the coding to ensure consistent terminology, a list of 43 risks across the eight CSAs was produced. These are discussed in Section 3.2 and enable a detailed examination of the risks associated with the climate challenge in each CSA within the context of the PESTLE framework.

Table 2: Example of recoding of environmental risks associated with extreme heat to create consistent terminology

CSA	Challenge	Risk	Recoding
Prague	Extreme heat	Water scarcity for the city	Water scarcity
Birmingham	Extreme heat	Greater water use with drought (water resource impact)	Water scarcity
Athens	Extreme heat	Drought	Water scarcity

Secondly, the risks were recoded to allow for thematic comparison across the CSAs to gain a preliminary understanding of the broader themes, and how these compared across the different CSAs (Table 3). This reduced the number of risks to 28 thematic codes; some risks appeared in more than one thematic code. The thematic codes are discussed and compared across the CSAs in Section 3.3.

To ensure analytical rigour, the recoding to create consistent terminology and thematic coding was repeated and checked by three members of the research team. Note that the outputs from the validation workshop that took place in one CSA (Funen-Odense) could not be analysed using this approach and therefore appear in Section 3.1 only.

Table 3: Example of recoding and thematic coding of water quality and supply risks from the Birmingham CSA

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Challenge	Type of Risk	Risk	Recoding for consistency	Thematic Coding
Surface water flooding and Extreme heat	Political	Access to potable/ drinking water	Water quality	Water Quality and Supply
Surface water flooding	Political	Water contamination	Water quality	Water Quality and Supply
Extreme heat	Economic	Water rationing - moving water between regions	Water scarcity	Water Quality and Supply
Extreme heat	Environmental	Greater water use with drought (water resource impact)	Water scarcity	Water Quality and Supply
Surface water flooding	Environmental	Water quality decrease	Water quality	Water Quality and Supply

3. Results from Living Lab Workshop One

3.1 Overview

Each CARMINE CSA considered one climate challenge in their LL workshop, except for Birmingham, which considered two challenges. These are summarised in Table 4. Figure 2 shows the number of risks documented for each climate challenge, and Figure 3 shows their classification within the PESTLE framework.

Table 4: Climate challenges in each CSA

CSA	Climate challenge
Prague	Extreme heat
Leipzig	Heatwaves
Funen-Odense	Flooding
Athens	Extreme heat
Barcelona	Wildfire
Bologna	Extreme heat
Brasov	Water scarcity
Birmingham	Extreme heat Pluvial flooding

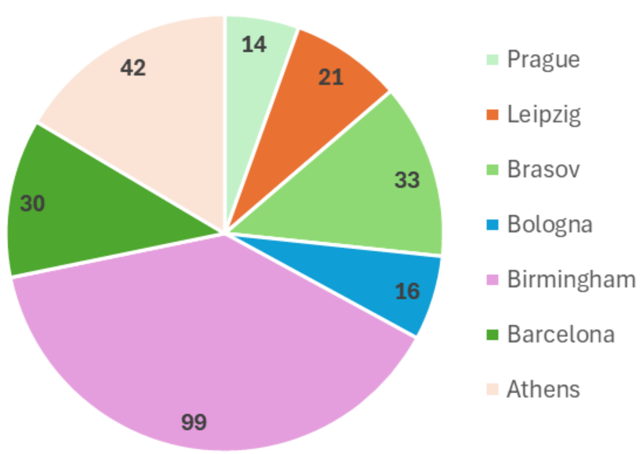

Figure 2: Number of risks documented in each CSA

Either extreme heat or heatwaves was the challenge in five CSAs; coastal and

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flooding is a challenge in Funen-Odense and pluvial flooding a challenge in Birmingham. Barcelona considered the challenge of wildfires, and Brasov, water scarcity. There were between 14 and 42 risks documented for each climate challenge, except in Birmingham, where 99 risks were recorded; 91 risks for extreme heat; 84 risks for pluvial flooding (many risks were duplicated for both climate challenges). Indeed, Birmingham accounted for a disproportionate amount (39%) of risks. This was likely because of various reasons, including: Birmingham's workshop being a full day, therefore longer than most other CSAs, coupled with some of the most participants present; the consideration of two climate challenges compared to one in the other CSAs; and the potential overlap or similarity of risks (or components of risks), written in slightly different ways.

Figure 3 shows the PESTLE classification of each risk. Social, Economic, and Environmental classifications generally had the greatest number of risks for each CSA, whereas Legal and Technological have the fewest risks. In Brasov (water scarcity), 42% of risks were classified as Environmental; this is double the average for the other CSAs. In Leipzig (heatwaves), 57% of risks were classified as Economic; this is nearly triple the average for the other CSAs. Another outlier was Bologna (extreme heat), where 38% of risks were classified as Social, but only 6% were considered Economic.

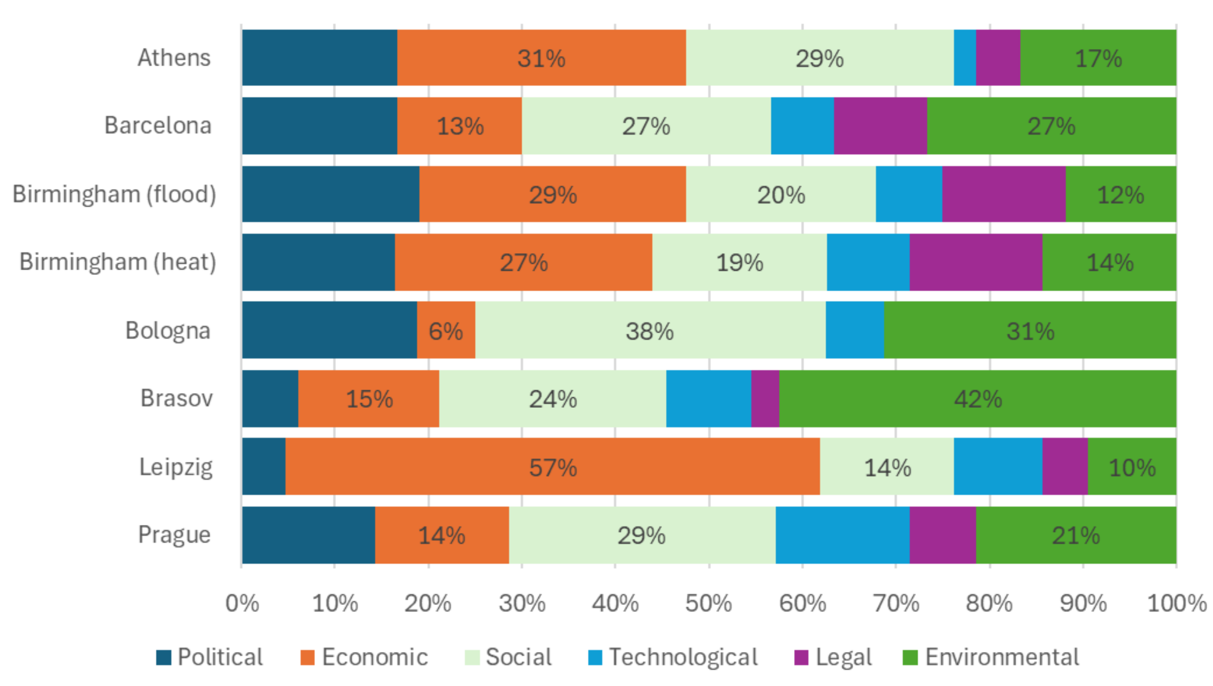

Figure 3: PESTLE classification of the risks documented for the climate challenges in the different CSAs. Data labels are given for the classifications with the greatest number of risks: Economic, Social and Environmental. Note Birmingham has two climate challenges. Percentages are used given ~40% of total risks were recorded in Birmingham.

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3.2 Risks by Case Study Area

3.2.1 Prague: extreme heat

The Prague LL focused on the challenge of extreme heat and identified 14 associated risks. The attending stakeholders included: Ministry of Regional Development; City of Prague; Operator ICT; Prague Emergency Service; The Prague Institute of Planning and Development; Czech Hydrometeorological Institute; Universities and Research Institutes; and National Public Health Institute. The LL workshop was part of a day-long event, "*Resilience to Heat in Urban Environments*," hosted by the City of Prague and co-organized by the Institute of Computer Sciences and the Czech University of Life Sciences. The morning had 31 participants (8 online) and gave an overview of various climate projects taking place in the city, including Destination Earth, CROSSEU, Impetus 4 Change. In the afternoon, 13 participants completed the PESTLE wheel activities.

Figure 3 shows the distribution of risks across the PESTLE classifications and there were no overlaps or risks between different classifications. Social risks associated with extreme heat included increased mortality and morbidity, social isolation, lower food security, and low attractivity of the city for new residents. Water scarcity and quality were main environmental risks; missing legislation/policies and long-term planning were Political and Legal risks. Increased energy demands and lower productivity were Economical concerns.

3.2.2 Leipzig: heatwaves

The Leipzig LL focused on heatwaves and identified 21 associated risks. The LL was held online, lasting approximately three hours, and had 14 participants. Stakeholders included: Leipzig Mobility; Leipzig City Department for City Planning and Development; University of Freiburg; Leipzig City Office for Urban Greenery and Waters; Leipzig City Department of Environment Protection; Leipzig Water Utilities, L-Group (student group); and Furtwangen University of Applied Sciences.

The majority (57%) of risks documented in the Leipzig CSA LL workshop were Economic. Several related to health concerns, such as: higher healthcare costs, production losses due to increased sick leave, additional support measures such as cooling rooms and emergency care. Other Economic risks included decline in visitor numbers at outdoor events, increased costs for water supply, higher energy costs, increased repair and maintenance costs, and high costs and uncertainties associated with NbS, but also economic impacts from loss of ecosystem services (e.g. cooling) provided by NbS. Social risks included increases in heat-related illnesses, and unequal access to air conditioning and green spaces. Environmental risks were loss of street trees and vegetation, and higher water demand for irrigating green spaces. Stringent regulation and lengthy approval processes were considered a Legal risk; citizens rejecting action on climate adaptation leading to civil unrest was considered a Political risk. There were no overlaps of risks between PESTLE classifications.

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3.2.3 Funen-Odense: flooding

Unlike other CSAs, Odense undertook a validation workshop, as the CSA leads considered the climate risks, drivers, adaptation and mitigation measures, and barriers to be well known. In this approach, the CSA leads (Danish Technical University) provided input to the reporting template based on previous a workshop (11/09/24) and conversations (January 2025) with stakeholders in the CSA. The risks identified by target groups concerning storm surge flooding are listed below. These were not categorised using the PESTLE framework and are not included in the analysis in Sections 3.2, 3.3, and 3.4.

- Buildings including permanent houses, summer houses, industrial buildings
- Health impacts
- Infrastructure and transport impacts
- City life
- Cultural values
- Nature values

3.2.4 Athens: extreme heat

The Athens workshop, "*Living Lab Athens Urban Heat Resilience: Pioneering Solutions for a Cooler Athens*", took place in person and explored the challenge of extreme heat. The research team aimed to explore how regional heatwaves are managed in relation to mortality and health risks, and to gain diverse perspectives and experiences of participating stakeholders, including their functions, responsibilities, and actions. Attendees of the LL workshop included: SOS Children's Villages (non-profit organization, NPO); Kifissia Municipality; Ministry of Climate and Energy; Design Clips studio (architecture and participatory urban design); Common Space (participatory urban design); Youth Initiative; Athens Primary Education Directorate; Organization Earth (NPO); UN Habitat; Harokopeio University; New Metropolitan Attica S.A; University of Dresden; and University of Thessaly.

The Athens LL identified 42 risks in the different categories of the PESTLE framework (Figure 3). Several (32) of these risks were duplicated as they appeared in more than one PESTLE category. For example, rising sea levels was both an Environmental and Economic risk and therefore appears twice. Food insecurity was considered an Economic, Social, and Environmental risk.

The Economic and Social risk categories included nearly 60% of documented risks in Athens, and there was strong overlap between these categories. For example, extreme heat creates mobility challenges, increases overheating risks in buildings, especially within older housing stock, and for vulnerable groups such as the young, older people, pregnant women, or those with pre-existing health conditions. Food insecurity was also considered a Social and Economic risk associated with extreme heat. Moreover, vulnerability factors such as energy poverty, language barriers, and the availability of information in appropriate formats can exacerbate these risks. Other Social risks included negative impacts on physical and mental health, increased violence, including domestic violence, and risks to pets.

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Extreme heat may impact worker safety, tourism and other aspects of the economy. Other climate challenges such as droughts, wildfires, rising sea levels, and negative impacts on biodiversity were considered Economic and Environmental risks linked to extreme heat. Concerning risks that overlapped Legal and Environmental categories, the delegates indicated that there are not enough partnerships between civil society, academia, and the state, and that there was not enough advocacy for environmental rights and protections. For the Political category, the implementation of climate policy was considered a risk. Power outages were a Technological risk associated with extreme heat.

3.2.5 Barcelona: wildfires

The Barcelona LL workshop focused on the challenge of wildfires and identified 30 risks, with no overlaps between PESTLE categories. Attendees included: Barcelona Supercomputing Centre; Catalan Civil Protection; Barcelona Metropolitan Authority; Catalan Wildfire prevention; Catalan Forestry Service; Ecological Research Centre; Sant Climent de Llobregat local council; Pompeu Fabra University; Collserola Natural Park; Ametller Origen (food sector); Garraf Forest Owners Association; and Barcelona local council's mountain neighbourhoods' office.

In Barcelona, most of the risks identified by the stakeholders fall into the Social and Environmental categories. Social risks associated with wildfires included: negative impacts on physical and mental health, including loss of life; impact on houses and communities; loss of cultural landscapes; and abandonment of rural areas. As noted in Athens, inequalities exacerbate impacts for those with economic precarity, while those with more economic capacity can recover more quickly. Environmental risks were: loss of biodiversity and habitat; soil erosion; loss of natural heritage, and emissions of greenhouse gases and other pollutants. Political risks were the third highest scoring category, and risks included: inefficient emergency management; unplanned reactive response; accountability; loss of confidence in public institutions; and political instability. Lack of policy coherence and reactive legislation were considered the Legal risks. Infrastructure damage was a Technological challenge.

3.2.6 Bologna: extreme heat

The Bologna online LL workshop focused on extreme heat, with a particular focus on elderly residents of the city. Attendees included: AIAS (disability services); AUSL (health protection); AMPRO (meteorological and climate services); AESS (sustainable energy); ANCI National Association of Municipalities; AUSER (services for elderly); Extinction Rebellion (civil movement group); COTABO (taxi cooperative);mobility freelancer; Academia dei Georgofili (agriculture, food and environment); University of Bologna (public research institution); Regione Emilia-Romanga (regional authority); Comune di Bologna (Bologna City Hall); ; Legambiente Association (non-partisan association); Consumerismo Association (consumer association); and Clust-ER GreenTech.

The workshop identified 16 risks, and there was no overlapping between categories. Nearly 70% of the risks were categorised as Social or Environmental. Social risks associated with extreme heat included mobility of frail individuals; exposure of delivery personnel; solitude of individuals;

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energy cooling costs; and the lack of recognition of the needs of vulnerable groups. Environmental risks were: amplification of the UHI effect; lack of space to create green spaces; and increased exposure to air pollution and heat on hot days. Under the Political category, participants believe the risks are that the current city model is not conducive to social relations; extreme heat can increase the risk associated with seeking food in urban environments; and that there is a lack of social or community-oriented spaces that provide protection from heat. The current complexity in home delivery services and varying policies for delivery costs was considered an Economic risk, and the loss of artisan mechanics who repair bicycles was considered a Technological risk associated with extreme heat. The Bologna LL did not identify any Legal risks associated with extreme heat.

3.2.7 Brasov: water scarcity

Water scarcity was the focus of the LL in Brasov. There are 24 active stakeholders involved in the LL, including: Brașov City Hall (public administration); Râșnov City Hall (public administration); Ghimbav City Hall (public administration); Romania Water Administration (public institution, water management); Brașov Environmental Protection Agency (public administration, environment); National Agency for Natural Protected Areas (public administration, institution); Kronstadt Forestry Company (public company, forestry); National Agency for Land Improvements (public institution, land management); Inspectorate for Emergency Situations (public institution, emergency management); Department of Social Assurance Brașov (public administration, social); Academia (members of three universities); National Council of college students – Brașov (Non-governmental organization, NGO, youth engagement); Water Company Brașov (public company, water supply and sewage management); Agency for Energy Management and Environmental Protection (NGO, environment and energy efficiency); WWF (NGO, environment), PROPARK (NGO, environment); Metropolitan Agency for Sustainable Development Brașov (NGO, metropolitan management); County Statistic Department Brașov (public institution, statistic); National Center for Cartography (public institution); National Institute for Research and Development in Forestry – ICAS (research, forestry); National Meteorological Administration (public institution). Although other representatives from the public administration of Brasov Metropolitan Areas (17), NGOs (8) and other relevant public institutions (3) were invited to the LL, they were absent. Additional meetings were organised for youth participants (4 meeting, having in total 101 participants), older people (1 meeting with 32 participants), farmers (online meeting, one participant), and planners (online meeting, one participant).

The LL workshop in Brasov identified 33 risks associated with water scarcity; 42% of these were Environmental (Figure 3).These risks included: drying up of rivers; drought risk to trees or vegetation impacting the quality of green space; soil degradation; biodiversity loss and environmental degradation; a reduction in natural and agricultural resources; increasing fire risk; amplification of the UHI; and decreased air and water quality. The workshop documented Social risks, such as: limiting the access to drinking water (because of water availability, price and quality); reduced well-being and quality of life; impacts to food security; and emergence of new pests and diseases. Potential Economic risks were: increased cost of living; decreased profitability of agriculture or winter tourism; and a general reduction in the regions' attractiveness for investment. Technological risks discussed by the participants centred on the need for new

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technologies to reduce water consumption and costs; and the need to improve water infrastructure, including storing rainwater. Political risks were pressure to promote policies involving more responsible water management, and increased risk of protests. Increasing environmental crimes was considered a Legal risk associated with the challenge of water scarcity.

3.2.8 Birmingham: extreme heat and pluvial flooding

The Birmingham LL considered the risks associated with two climate challenges, extreme heat and pluvial flooding. Attendees included: Local Resilience Forum; Youth Volunteer; Birmingham City Council; West Midlands Combined Authority; Civic Square (NGO); Academia; Met Office; Birmingham TreePeople; Natural England (government); Birmingham Voluntary Services Council (NGO); Birmingham & Black Country Wildlife Trust (NGO); and Severn Trent Water. This LL captured the most risks (99) from the participants. Many of the risks were associated with both climate challenges and was overlapping in the classification of risks using the PESTLE framework. There were 6 overlapping risks. For example, “transport delays/cancellations” was considered both a Political and Economic risk. However, many other risks overlapped in meaning. For example, “higher priced food” was a Political risk; “increased household bills” was an Economic risk.

Most of the risks from Birmingham for both pluvial flooding and extreme heat were categorised as Economic (Figure 3). These included: Infrastructure damage or disruption; increased household bills; food shortages; negative impacts on the economy (e.g. lost working days, lower productivity, cancellation of events,); and costs associated with negative impacts on health. Social risks for both climate challenges were: impacts on mental and physical health, and increased hospital admissions; challenges to livelihoods (work, education, wellbeing); social instability; isolation caused by transport disruptions; and risks associated with inequity (i.e. most vulnerable suffer disproportionate impacts), which further compound injustice. Political risks also mention climate justice, civil unrest and frustration, loss of confidence in government, increased pressure on health and legal services, and higher costs.

Environmental risks varied with climate challenge. Risks associated with extreme heat were: Failed crops and tree mortality; wildfires; increased outbreaks of pests and diseases in the natural environment; greater water use and impact on water resources; and poor air quality. For pluvial flooding, risks included: reduced water quality; nutrient leaching; and bacterial pollution from sewage overflow. Technological risks related to: Increased infrastructure costs or damage (e.g. data centres overheating); power outages; damage to building fabric and quality, with historic buildings at greater risk; and closure of centres that provide community services. Legal risks related to upholding human rights and civil liberties and increased insurance claims.

3.3 Comparison across Case Study Areas

Figure 4 shows the 28 thematic codes produced from the analysis of the risks within the seven CSAs (excluding Funen-Odense). It should be noted that the data from the Birmingham LL made up nearly half of all the material on risks, and as such issues specific to Birmingham may be

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overrepresented in analysis that considers data from all seven CSAs (for the possible reasons discussed in Section 3.1). Infrastructure damage, negative economic impacts, health, regulatory gaps, and transport and mobility were the most common themes from the risks discussed in the seven LLs.

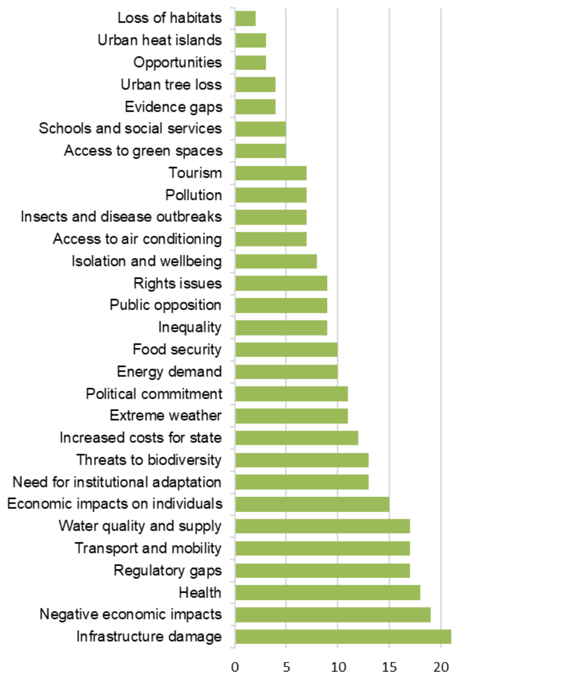

Figure 4: Frequency of the thematic codes in all CSAs

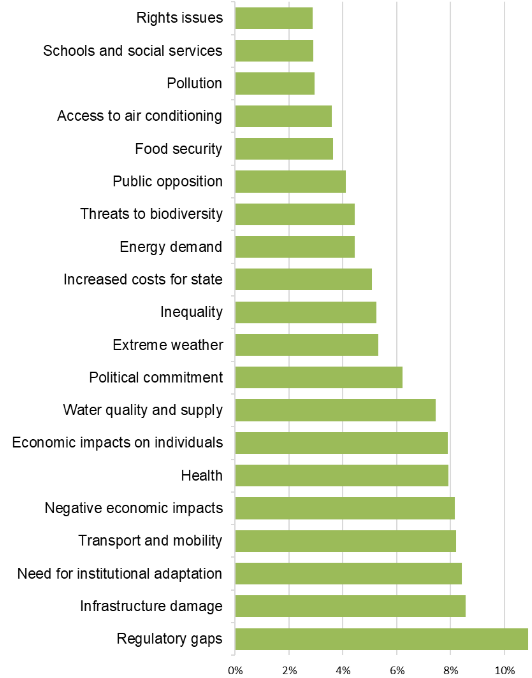

Figure 5: Percentage coverage of thematic codes in all CSAs

Figure 5 shows the percentage coverage of the codes across the seven CSAs. Here, regulatory gaps, infrastructure damage, need for institutional adaptation, transport and mobility, and negative economic impacts have greatest coverage across the CSAs. These thematic codes provide important insights into the challenges that the CSAs will face on their mission to adapt to climate change. Moreover, they provide important steer for other tasks that are part of the CARMINE Project, and the second and third LL workshops (see Section 5).

Table 5 shows the outcome of Jaccard Similarity testing, which shows the amount of overlap between codes in different CSAs. The Jaccard's Similarity coefficient ranges between 0 (no similarity) and 1 (complete similarity). As such, it appears that Birmingham-Athens, Birmingham-Barcelona and Birmingham-Brasov are the most similar CSA pairs in terms of the issues that were identified as risks. Birmingham-Brasov and Birmingham-Leipzig also show high similarity coefficients, and the predominance of Birmingham may (as previously mentioned) be due to the higher number of risks documented in this CSA. Of the remaining CSAs, Brasov and Bologna are most similar. Figure 6 shows the similarities between the CSAs and their most similar partners.

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Table 5: Jaccard's Similarity coefficients for the CSAs. This ranges between 0 (no similarity) and 1 (complete similarity).

CSA	Prague	Leipzig	Athens	Barcelona	Bologna	Brasov	Birmingham
Prague		0.44	0.38	0.35	0.35	0.27	0.37
Leipzig	0.44		0.38	0.35	0.35	0.33	0.52
Athens	0.38	0.38		0.42	0.43	0.40	0.63
Barcelona	0.35	0.35	0.42		0.27	0.43	0.62
Bologna	0.35	0.35	0.43	0.27		0.45	0.36
Brasov	0.27	0.33	0.40	0.43	0.45		0.59
Birmingham	0.37	0.52	0.63	0.62	0.36	0.59	

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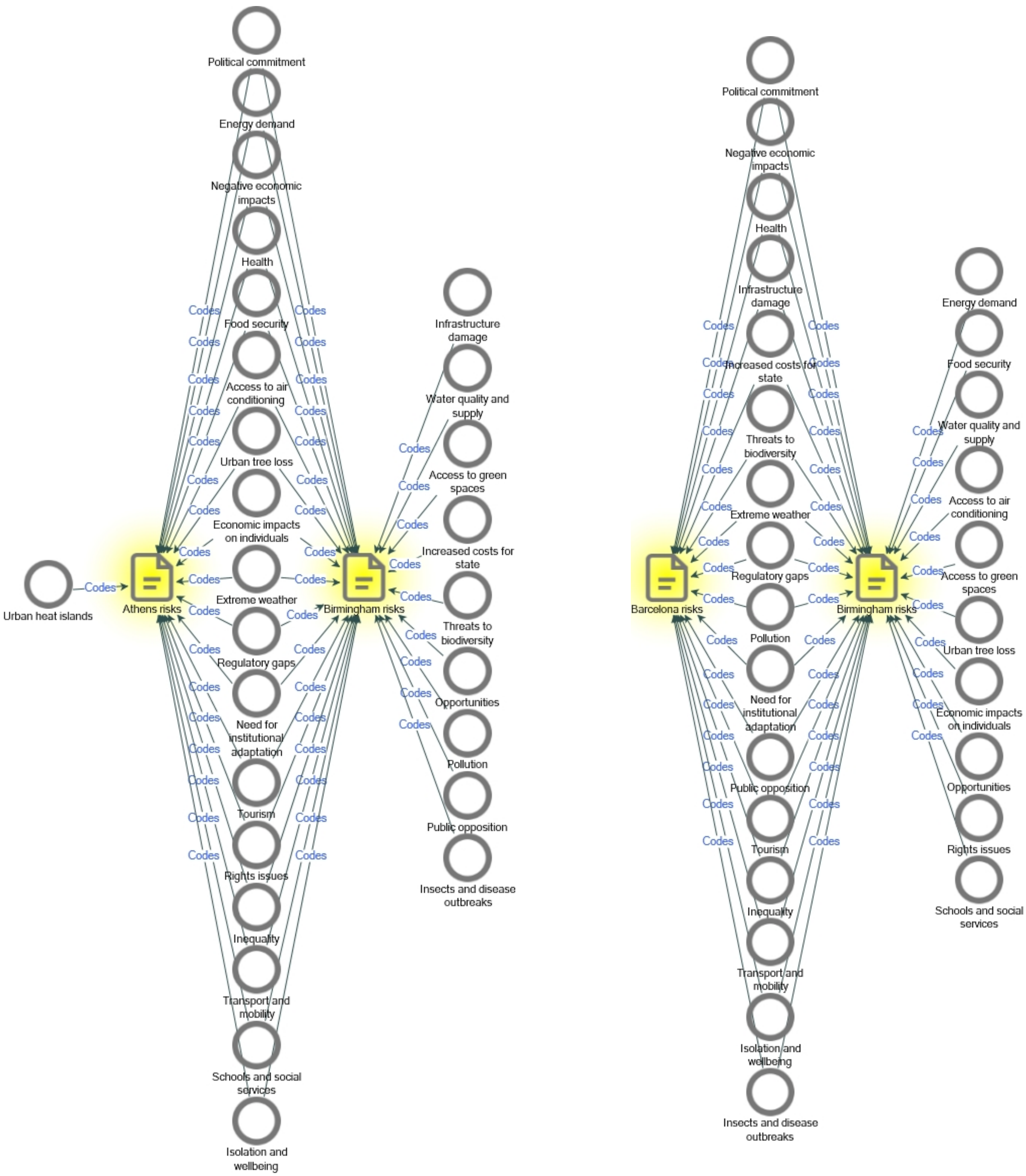

Figure 6: a) Similarity between Athens and Birmingham (0.63; left); and b) Barcelona and Birmingham (0.62; right). Jaccard's Similarity coefficients shown in Table 5.

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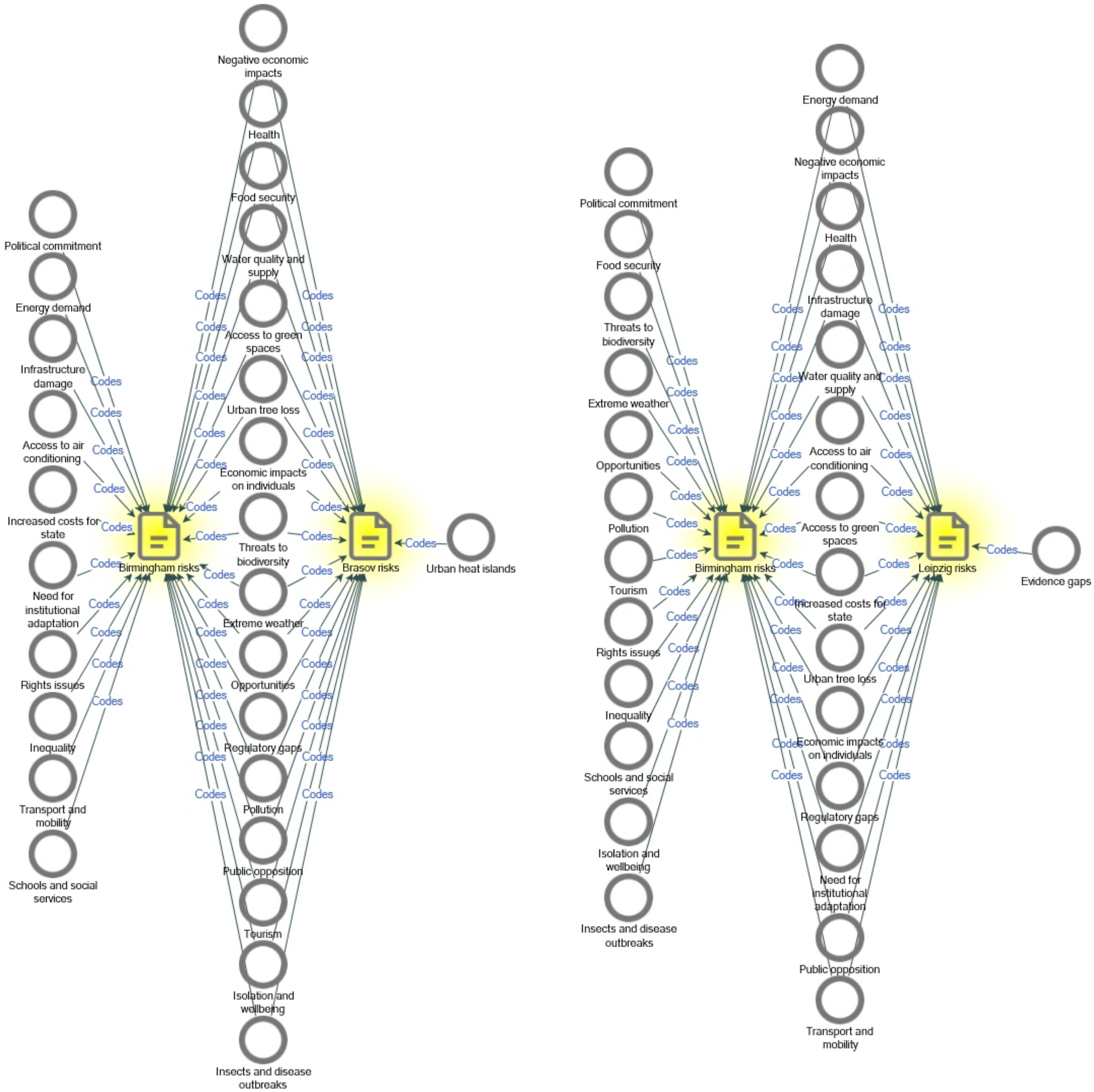

Figure 7: a) Similarity between Birmingham and Brasov (0.59; left); and b) Birmingham and Leipzig (0.52; right). Jaccard's Similarity coefficients shown in Table 5.

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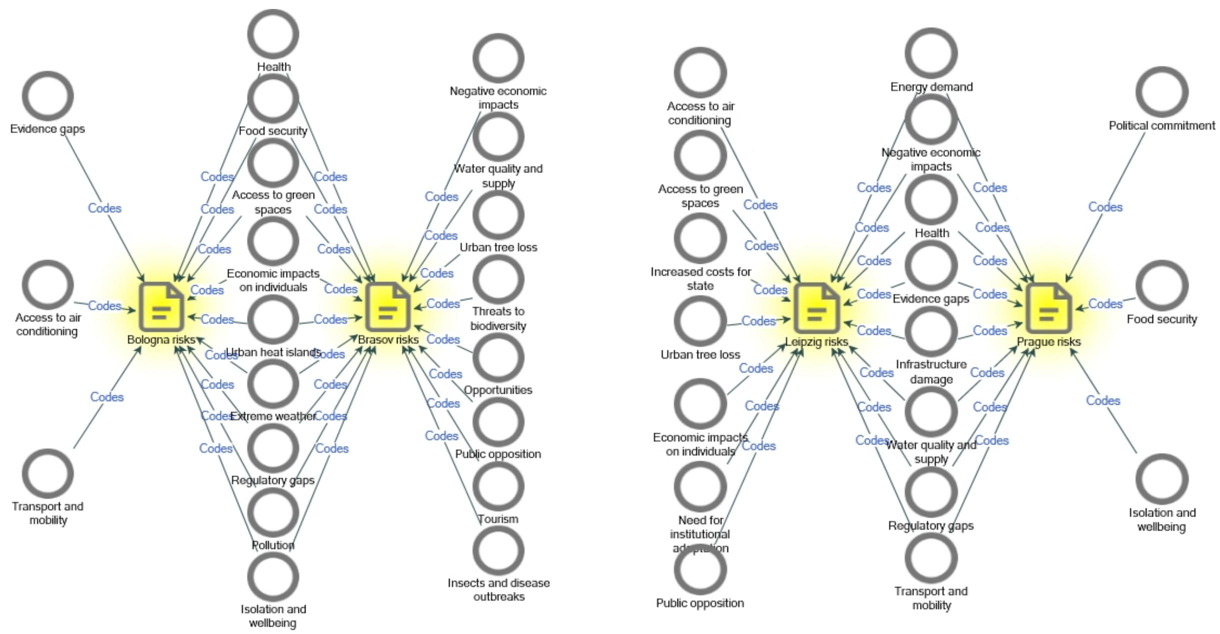

Figure 8: a) Similarity between Bologna and Brasov (0.45; left); and b) Leipzig and Prague (0.44; right). Jaccard's Similarity coefficients shown in Table 5.

4. Discussion

This report presents a preliminary and rapid analysis of the risks documented in LL Workshop One. The preliminary findings provide a foundation for LL Workshops Two and Three, and provide input into future CARMINE tasks, particularly WP1, WP2, and WP6.

4.1 Preliminary high-level findings

LL Workshop One facilitated the participatory documentation of risks associated with the climate challenge in each CSA. The PESTLE framework structured the identification of risks and encouraged a systems thinking approach that will support the visioning of climate goals (Workshop Two) and the development of adaptation and mitigation pathways (Workshop Three).

Many of the CSAs face the same or similar climate challenges, e.g. Athens, Bologna, Birmingham, Prague, and Leipzig all consider extreme heat or heatwaves; Barcelona considered wildfires and Brasov considers water scarcity, which are both the consequence of hotter, drier weather (e.g. extreme heat). Moreover, many of the risks associated with these climate challenges were the same across CSAs, such as negative impact on health, higher energy demand, unequal access to air conditioning or cooler spaces, loss of biodiversity, and water scarcity. The impact on the economy, tourism, and the attractiveness of the city for investment were other shared risks.

However, there are particularities such as geographies, economics, governance structures, or other vulnerabilities that make some risks in each CSA unique. For example, the older population

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demographic in Bologna makes this city more vulnerable to the negative impacts of extreme heat than those in cities with a younger population demographic. Other issues such as loneliness and reduced mobility may exacerbate climate risks, and the adaptation solutions must take these individual factors into account. Brasov stakeholders reported risks that had a strong focus on the sustainable management of water resources. Birmingham was declared bankrupt in 2022, and the fiscal pressure and restructuring within the local government creates challenges for service provision.

However, despite differences in climate challenges and contexts, broad risk themes across multiple CSAs were identified such as regulatory gaps, infrastructure damage, the need for institutional adaptation, transportation and mobility, negative economic impacts, and more (Figure 5). This provides opportunity for collaboration across the CSAs to discuss and develop solutions to address these shared risks (See Section 4.2).

4.2 Consideration of the risks within the changing climate

This deliverable should *include the specific challenges derived from climate change in each CSA in different climate scenarios*. Accordingly, we consider the risks reported in each CSA associated with the main climate challenge (Table 6) and provide a commentary of key points for consideration by WP2 (Integrating climate physical risk assessment models and earth system processes) that will undertake climate modelling in each CSA. In considering these, the model outputs are tailored for optimal use for stakeholders, decision-makers, and planners in the CSAs.

Table 6: Considerations when modelling the specific challenges in each CSA for future climate scenarios

CSA	Climate challenge	Considerations
Prague	Extreme heat	Stakeholders noted risks related to increased mortality and morbidity, social isolation, food security, water scarcity/quality, and energy demands. T2.1 (modelling framework) notes indicators related to air temperature, thermal comfort, and the inclusion of epidemiological models, which will provide information on health impacts. Target periods are future scenarios (2020-2050), extending to 2100 for some projections. Some risks (e.g. water scarcity) are not in the modelling framework; this is relevant as the city aims to plant 1.5 million new trees. The modelling approach also has a strong focus on air quality, which was not documented in the risks produced by the LL workshop. This discrepancy should be cross-checked with the CSA leaders.
Leipzig	Heatwaves	T1.2 notes modelling target periods for historical data (last 10 years, 2014-2024) and future scenarios for 2020-2050. Indicators are used for wildfires, heatwaves, and floods. Risks associated with floods and wildfires were not documented by LL Workshop One, and this discrepancy should be cross-checked with the CSA leaders. The Leipzig LL noted heat risks related to health and thermal comfort, but also increased costs for water

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CSA	Climate challenge	Considerations
		supply, higher energy costs, increased repair and maintenance costs. It should be considered how the heatwave indicators noted in the modelling framework (temperature extremes, heatwave length, and seasonal warming trends) can be used to understand how the risks documented in the LL will change for future scenarios.
Funen-Odense	Flooding	WP2 will model flooding; flood indicators include elevation, slope, maximum storm surge height, duration of high-water levels, maximum wind speed, and storm direction. Target Periods are mid-century (2041-2070) and end-century (2071-2100) for different climate scenarios. The scenarios of interest are SSP1-2.6, SSP2-4.5 and SSP3-7.0. Risk areas provided by the validation workshop include buildings, health impacts, infrastructure and transport impacts, city life, cultural values, and nature values.
Athens	Extreme heat	The risks from the Athens LL related to increased mortality and heat stress, particularly among vulnerable populations, and there were many socio-economic dimensions (e.g. energy poverty, food insecurity, violence, mobility challenges). WP2 modelling focuses on extreme heat, using a range of heat indicators. Target periods are historical (1970-present) for modelling previous heatwave events (2021/23), and future projections under RCP8.5 scenarios and selected periods (intense heatwave cases) for testing NbS deployment. It should be considered how the indicators can be used to understand how the risks (e.g. mortality and heat stress for different groups) change for future climate scenarios, and under different scenarios of demographic profile changes and built environment adaptation levels.
Barcelona	Wildfire	Stakeholders noted social risks related to negative impacts on physical and mental health, including loss of life; impact on houses and communities; loss of cultural landscapes; and abandonment of rural areas. Environmental risks included loss of biodiversity and habitat; soil erosion; loss of natural heritage, and emissions of greenhouse gases and other pollutants. Modelling includes indicators for heatwaves, wildfires, and drought, as well as wildfire danger indicators. . Target periods are near-term (2025-2050), and scenarios of interest are: RCP2.6, RCP4.5, RCP8.5. It should be considered how the indicators can be used to understand how the risks documented in the LL Workshop One will change as wildfires change under future CC scenarios. Changes in land use based on selected NbS will be considered in the modelling of wildfire danger indicators.

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CSA	Climate challenge	Considerations
Bologna	Extreme heat	Modelling focuses on how extreme heat or UHI indicators (including thermal comfort) change for the target periods: mid-century (2030-2050) and potentially end-century (2070). The risks documented in Bologna related to the impact of heat on elderly and vulnerable communities, and the indicators from the modelling process should inform how these documented risks will change for future climate scenarios. It is worth noting that the current demographic profile of Bologna is skewed towards the elderly, with individuals over 80 years comprising 9% of the population. This may not be the case in 2050 or 2070, and whether the demographic profile is changing should be considered as part of the modelling framework.
Brasov	Water scarcity	WP2 modelling considers drought and water scarcity, flash-flooding, and heatwaves. Flooding was not a documented risk from the LL Workshop One, and this discrepancy should be cross-checked. The workshop identified many social and environmental risks associated with drought and water scarcity. The modelling framework includes indicators for water supply/demand balance and the target periods are near-future (2020–2050), with historical baselines (2010–2020). It should be considered how the indicators can be used to infer how the environmental and economic risks noted in the LL Workshop One will change for future climate scenarios.
Birmingham	Extreme heat Pluvial flooding	The Birmingham LL workshop produced 99 risks over a range of sectors associated with extreme heat and pluvial flooding. The modelling framework and indicators considers pluvial flooding and extreme heat, with a focus on the vegetation-climate modelling. The target periods are a historical baseline of 1991–2020, and future projections: 2020–2050, potentially extending to 2070. It would be challenging to consider how 99 risks alter for different climate scenarios, so the CSA leads should cross-check if the modelling framework supports the general findings of the LL. For vegetation modelling, particularly trees, a longer time period is preferable as most trees begin providing maximum ecosystem services as they reach maturity.

4.3 Insight for CARMINE tasks

This report is delivered in M15 of a 48-month project, and therefore the findings reported here can inform other CARMINE project tasks. Linkages to WP2 are discussed in Section 4.2.

- T1.3 has created the online Stakeholder Community Hub. Findings from this deliverable can be shared on the community hub to promote discussions between different CSAs, especially those that have shared climate challenges (e.g. extreme heat) or shared risks (e.g. regulatory gaps) and share ideas and approaches for adaptation actions.

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- T1.4 is geo-designing adaptation and mitigation pathways, including NbS scenarios. Many of the CSAs noted risks related to NbS, such as loss of biodiversity and habitats, water scarcity and drought, soil degradation, and an increase in pests and diseases. These risks should be considered as part of the geo-design process.
- T3.1 is undertaking a socioeconomic vulnerability assessment to CC. The vulnerability factors noted in the CSAs such as elderly frailty and vulnerability (Bologna), or energy poverty and language barriers (Athens) should feed into this process.
- The risks noted in LL workshop feed forward into WP4 that is developing digital twins. For example, the Athens digital twin focuses on health risk, and should consider how to include the social risks noted by the LL stakeholders, such as mortality among seniors, emotional harm for citizens, increase in violence (including domestic violence), and more. Another example, in Birmingham, loss of biodiversity and tree mortality risks should be considered in the development of the digital twin to support vegetation management strategies.
- Several CSAs raised political and legal risks related to regulatory gaps, accountability, long-term planning and more. These can be considered within T6.1 that is assessing the implementation of EU policy in CSAs and developing a framework for vertical and horizontal governance systems necessary for efficient policy- and decision-making to tackle a trans-boundary climate risk. The risks also feed into the R&I roadmaps to help communities and individuals become more climate-resilient (T6.2) and policy recommendations (T6.3).

4.4 Limitations and forward look to Living Lab Workshops Two and Three

The analysis undertaken for this report revealed challenges and limitations to applying the PESTLE approach in the seven different CSAs. For example, the Birmingham CSA documented more than twice the number of risks than other CSAs, which led to risks from this CSA being over-represented in the CSA comparison (Section 3.3), and this may have led to their high similarity scores between themselves and other CSAs (Table 5).

Related to this, feedback from the LL Workshop One included how the stakeholder mix in terms of experience and expertise may have led to overrepresentation as well as underrepresentation of specific risks. There was also mention of some stakeholders' difficulties in understanding the definition of risk, which may have contributed to the representation challenges outlined, as well as increased volumes of risks as they may instead describe a risk component (a hazard, vulnerability, or exposure). Future participatory approaches should consider how to create greater consistency and balance in the volume of outputs across CSAs given the stakeholders' range of experience and expertise. It would also be beneficial to scope and define key terms to maximise stakeholders' contribution potential. These topics can be discussed in upcoming LL Workshop Two training in May 2025.

Additionally, there were some methodological differences; the Athens and Birmingham CSAs mapped risks to multiple PESTLE categories, but this approach was not applied in other CSAs. Birmingham also had several similar risks, which may have been recorded as one risk in other

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CSAs. Methodological approaches can be discussed in LL Workshop Two training to be held in May 2025.

Lastly, the outputs from the validation workshop in Funen-Odense were not compatible with the analytical approach applied here, which has limited the analysis of the risks from this CSA within the PESTLE framework and prevented the comparison of this CSA with others. It would be beneficial for CARMINE if Funen-Odense participates in LL Workshops Two and Three, so other CSAs can learn from their stakeholders, and vice versa, and so that this CSA can be included within comparative analyses undertaken by WP1.

5. Conclusions

This report, Deliverable 1.2, presents a preliminary and rapid analysis of the risks documented in LL Workshop One that took place in the CSAs throughout November and December 2024. The risks are described, compared, and discussed within the context of the climate modelling framework. The preliminary findings provide input into future CARMINE tasks, particularly WP1, WP2, and WP6.

Many of the CSAs face the same or similar climate challenges, and common risks, including adverse health effects, biodiversity loss, as well as economic impacts on tourism and investment appeal. However, unique factors like geography, demographics, and governance create specific vulnerabilities within the different CSAs. Despite these differences, common risk themes—such as regulatory gaps, infrastructure damage, economic and health impacts, and the need for institution adaptation, and transportation challenges—are evident across CSAs. This convergence presents opportunities for collaboration to develop effective strategies to tackle these shared climate-related issues, enhancing resilience and adaptability in the face of climate change.

Task 1.2 runs until M48, and in 2025 and 2026 there will be two further LL workshops in the CSAs. These workshops will vision future climate change goals (Workshop Two) and develop adaptation and mitigation pathways (Workshop Three). These LL workshops will build on the learnings from LL Workshop One, in terms of improving the methodological approach. The future LL workshops will allow for a deeper exploration of the climate challenges within each CSA and consider how the Metropolitan Areas can work together to enhance adaptation and mitigation efforts in accordance with the EU Mission on Adaptation to Climate Change by 2030.

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