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Application Programming Interface (API)
Copernicus Climate Change Service (C3S)
Copernicus Atmosphere Monitoring Service (CAMS)
Copernicus Land Monitoring Service (CLMS)
Copernicus for Urban Resilience in Europe (CURE)
Data Information Access Service (DIAS)
Copernicus Emergency Management Service (EMS)
Drivers, Pressures, States, Impacts, responses (DPSIR)
European Environment Agency (EEA)
Health Impacts (HI)

Information and communications technology (ICT)
Local Scale Surface Temperature Dynamics (LSSTD)
Nature-based Solutions (NBS)
Sustainable Development Goals (SDG)
Surface Urban Heat Island Assessment (SUHIA)
Urban Flood Risk (UFR)
Urban Heat Storage Monitoring (UHSM)
Urban Subsidence, Movements And Deformation Risk (USMDR)
Urban Heat Emissions Monitoring (UHEM)
Urban Air Quality (UAQ)
Urban CO2 Emissions Monitoring (UCO2EM)
Urban Thermal Comfort (UTC)
Work Package (WP)
Web Map Service (WMS)
Web Feature Service (WFS)

1 INTRODUCTION

1.1 Requirements Overview

This document presents CURE (Copernicus for Urban Resilience in Europe) stakeholder needs and requirements to shape the development of CURE cross-cutting applications. This deliverable is based on CURE Tasks 1.1 and 1.3, and is informed by state-of-the-art specifications of user requirements in urban resilience and spatial planning, supported by general requirements from a wider stakeholder group, all providing prime focus on requirements gathering from the CURE front-runner pilot cities. The aims here are to identify various user needs and requirements to develop an understanding of different user expectations of Coperninus based data and to identify commonalities that can be useful for the development of generic products applied to other European cities. This will provide basis to explore limitations in existing available data and methods to lay the foundations for future research directions.

Land use planning aims to manage the territory in order to address sustainability, resilience and the key political concerns of European cities, including climate change, urban health, economic development and biodiversity loss etc. This management is specified in a variety of policy strategies including mitigation and adaptation actions that enhance the resilience of cities, and support the definition of transition pathways to sustainable and carbon neutral cities. These policy strategies seek sound understanding and quantification of the drivers of urban transition, to support effective policy responses concerning urban vulnerability, and climate change, as defined in various policy commitments including the Urban Agenda [0] for the EU, and the Sustainable Development Goals (SDGs) [1].

All of this presents major challenges for land use planners and politicians as cities are extremely complex systems and the various drivers of change, impacts and responses are strongly interrelated, supporting and competing with each other. Indeed the effective governance of the cities and city-regions of Europe today is fundamentally undermined by this urban complexity, whereby the high degree of interconnectedness and multiple interactions between socio-economic and environmental factors in a territorial context create major barriers to the effective implementation of sustainable urban development [2].

Previous pan-European research and innovation project experience has demonstrated the deficiencies in respect of both urban planning process and technology enabled decision support tools, that aim to enhance urban planning [3]. Effective solutions are therefore required that define a major opportunity for the Earth Observation (EO) community to promote the innovative exploitation of underutilized Copernicus derived data, tools and methodologies in dealing with the multi-dimensional problem of urban sustainability. Copernicus service evolution is now mostly organised in thematic silos, and the potential for new products and services, especially as regards cross-cutting cases, is not yet realised and needs to be further exploited. Central to this aim is the need for cross-cutting tools, methods and Intelligence linking the complex socio-economic and environmental dimensions of urban sustainability in planning the spatial context of the city-region [4][5][6].

In particular there is a need to assimilate EO data into urban monitoring for a wide range of applications, including the definition of hot spots for heat/energy loss, developing urban climate/air quality models, flooding scenarios, as well as adapting scientific models into operational products and services. These actions can improve the accessibility, and the usage of geo-spatial products including spatially disaggregated environmental information at local and city scales by city planners.

1.2 CURE Urban Plan Applications

CURE Information and Communications Technology (ICT) enabled governance applications are a direct response to the opportunities identified above in regard to the requirements of cities. Requirements for the application of enhanced intelligence in urban management at city-wide local (neighbourhood) scale, to promote sustainable development. These are the prime targets for the CURE applications including:

- Local Scale Surface Temperature Dynamics (LSSTD) – AP01
- Surface Urban Heat Island Assessment (SUHIA) – AP02
- Urban Heat Emissions Monitoring (UHEM) – AP03
- Urban CO2 Emissions Monitoring (UCO2EM) – AP04
- Urban Flood Risk (UFR) – AP05
- Urban Subsidence, Movements and Deformation Risk (USMDR) – AP06
- Urban Air Quality (UAQ) – AP07
- Urban Thermal Comfort (UTC) – AP08
- Urban Heat Storage Monitoring (UHSM) – AP09
- Nature-based Solutions (NBS) – AP10
- Health Impacts (HI) – AP11

CURE 11 cross-cutting applications address challenges arising from user requirements to more effectively plan sustainable cities. CURE will demonstrate the technical operational feasibility of this “umbrella” of cross-cutting applications on urban resilience, consisting of 11 specific but interlinked applications. CURE application areas are based on related state-of-the-art EO techniques and methodologies, developed by the industry, research and academic project partners. These applications use Copernicus Core products from at least 2 Core Services each as main input information and as relevant to user needs. As a result, the CURE cross-cutting applications aim to cope with the required scale and granularity by also integrating or exploiting third-party data, *in-situ* observations and modelling, as well as socio-economic data.

CURE proposes to develop cross cutting applications creating urban planning decision-making products from 4 different Copernicus Core Services (CLMS, CAMS, C3S, EMS)[1] based on tools and methods developed via Pan-European Research and Innovation projects. CURE aims to demonstrate the technical operational feasibility, level of maturity and scientific value for downstream applications built in 4 "front-runner" European cities (Berlin, Sofia, Copenhagen and Heraklion), as well as wider application and replication to European and global cities via engagement with 5 "follower" cities (Bristol, Munich, Basel, San Sebastian and Ostrava).

CURE will complete development of the technological concept, provide experimental proof, validate and demonstrate the cross-cutting applications, and develop the system in the front-runner cities which will act as pilots to set the basis for further transferability and downstream services development. This process will also assist in filling existing gaps in the current Copernicus offer in relation to urban areas, and identify to what extent new observation requirements for spaceborne instruments are needed to realise or improve the specified applications.

CURE responds to this challenge by exploiting the under-utilized Copernicus cross-disciplinary data originating from different Core Copernicus services CLMS, CAMS, C3S and EMS through Data and Information Access Service (DIAS). This response in developing CURE applications focuses on user requirements for decision-making aids for urban planners, climate change and environmental experts, citizen health experts and policy makers in the management of the territory, as well as for the associated responsibilities in political negotiation, and wider stakeholder engagement regarding the future development of the city.

CURE applications will support the delivery of spatially disaggregated intelligence for decision makers operative at different city scales from neighbourhod to city-region. CURE will result in information capacity presenting the current state of cities against drivers (climate change and economic transformation), pressures (pollution and emissions), addressing the overall impact (quality of life, social cohesion) that will enable cities to prepare an evidence and knowledge based response (better plans, local actions and policies) for urban resilience and carbon neutral cities.

1.3 CURE Cross-Cutting Solutions

The CURE challenge in developing applications is the complex interconnectedness of socio-economic and environmental issues in the urban context that define the decision-making frameworks for urban management seeking sustainable development. These complex problems require a holistic approach to urban development, together with an integrated assessment of urban policies supported by a comprehensive set of economic, social, and environmental sustainability indicators, seeking "win-win" integrated solutions.

[1] Copernicus Core Services: https://www.copernicus.eu/en/services

Integrated urban planning solutions, promoted via the CURE applications include **nature based solutions (AP10)**, that generate increased understanding of a wide range of socio-economic, and environment co-benefits arising from, for example, the green roof potential and performance (roof size and slope, orientation, use, shadowing etc) of individual buildings for energy conservation with co-benefits of city scale water run-off regulation, thermal comfort, air quality improvement, and contribution to urban heat island moderation.

Urban heat island temperature is one of the most important parameters in climate monitoring, and in response the CURE **surface temperature dynamics application (AP01),** monitors the spatio-temporal behaviour of cities' surface temperature. Additional heat related CURE applications provide frequent local scale surface temperature estimations for cities related to **surface urban heat island (AP02), urban heat emissions (AP03), thermal comfort (AP08) and heat storage (AP09).** All assist urban planners to optimize their adaption strategies with regard to heat stress, and sustainable development optimisation.

Combined with other CURE applications, benefits related to key resilience challenges such as **CO2 emissions reduction (AP04), and flooding mitigation (AP05)** are also created. The multi-scale aspect of flood risk assessment contributes to the main elements of the risk equation: hazard, vulnerability, exposure and resilience capacity. This urban flood risk service aims to support urban planners both during city preparedness and climate adaptation activities, as well as during emergency situations supporting city response activities. Additionally, **subsidence risk, deformation and movement risk (AP06)** assessment couples hazard monitoring with up-to-date assets information (land cover/land use at building block level). Such accurate assessment of threats and identification of vulnerabilities is critical for urban planners to understand and manage subsidence or deformation risks.

CURE applications also address the critical issue of **urban air quality (AP07),** which in combination with the specific cross-cutting **health impacts application (AP11)** support the creation of healthy cities, where air quality remains below critical levels and where health promoting aspects, such as walkability, bike-ability and access to green areas are prioritised in urban planning.

2 Requirements Development Process

At the start of the project the CoReS method [7] was adopted and as part of the process planned a Bristol Stakeholder Workshop on 27-28 April, 2020 in Bristol. Due to Covid-19 pandemic and lockdowns in different countries, the requirements gathering methodology was necessarily revised. The revised methodology included literature review, online questionnaire for wider stakeholders and focused group online dialogues with CURE cities, Climate-KIC and EEA. The revised requirements development process is depicted in Figure 1.

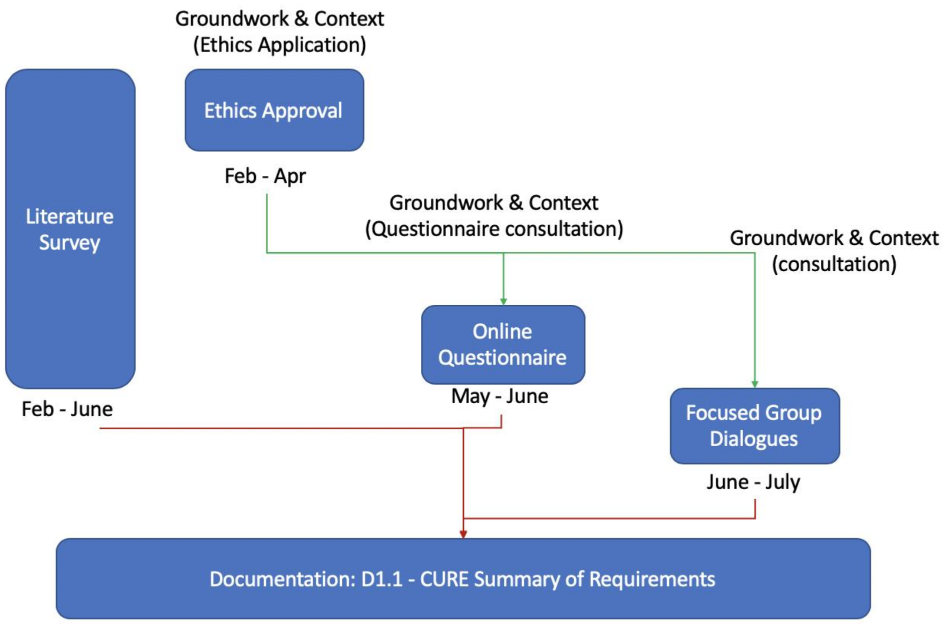

Figure 1: Requirements Gathering Process

A comprehensive ethics application was prepared and was submitted to Faculty Research Ethics Committee (FREC), UWE, Bristol, that was later approved. Requirements were derived from the relevant literature, online questionnaire and focused group dialogues. CURE service/application providers and UWE collaborated in preparing groundwork and context i.e. documentation including introduction to the applications, voice over presentations, questionnaire and organizing the dialogues.

3 Requirements Analysis

3.1 City-Regional Spatial Planning – Policy Co-Benefits

Citizens are more likely to support government action on climate change if the wider co-benefits of those actions are defined. An integrated approach that looks at complementarities and trade-offs across multiple policy objectives in urban planning and land use and transport, can take full advantage of potential synergies and co-benefits. Complex and interconnected urban ecosystems require such integrated assessment of spatial impacts in terms of socio-economic and environmental factors to secure the essential "win-win" policy co-benefits that are central to the delivery of the transformation agenda adopted by city politicians globally [8].

Policies targeting climate resilience, compact cities and enhancing urban quality of life can lead to major climate co-benefits e.g. reduced greenhouse gas emissions. Clear co-benefits arise, for example, in improving air quality by reducing fossil fuel emissions creating accompanying positive health and environmental impacts. As air pollution leads to 420,000 premature deaths a year in Europe, the health impacts of improved air quality represent a potentially powerful argument creating the political will to simultaneously reduce carbon emissions. Other policy areas present opportunities for co-benefits that go beyond contributions to climate change mitigation.

Despite the co- benefit potentials governments have typically failed to develop comprehensive co-benefits frameworks for policy decision making. Governmental process and silo structure generally inhibit the effective assessment of complex, multifaceted issues that cut across departmental priorities. Co-benefit frameworks supporting policy decision making have also failed to develop due to the lack of urban data, indicators and tools that cities can deploy to measure and monitor co-benefits [9].

Data helps assess the efficacy of policy actions and causation between the policy action and the climate co-benefits. These tools allow local authorities to test 'what if' scenarios, for example, concerning the reduction of air pollution to estimate the health cost savings of low-carbon transport policies. Similar tools for other co-benefits assessment can aid the incorporation of co-benefit considerations in the decision making process e.g. tools to quantify the estimated health benefits and savings associated with active travel and nature based solutions [10].

The following section (Section 3.2) addresses the first critical issue in relation to promotion of enhanced urban planning strategies for sustainable and carbon neutral cities, that of policy co-benefit definition. The aim is to identify typical challenges for urban policy development and implementation in the plan making process, and to support the specification of integrated cross-cutting user defined policy co-benefit scenarios. These provide the bases for connecting the various CURE applications. Here the focus is at the city-regional where the co-benefits are most clearly manifest, and where interventions can have the most immediate impact in supporting the specification of CURE enabled data, indicators and tools. These user specifications for urban policy and strategic planning intervention are informed by state-of-the-art research and Innovation projects supported by Horizon 2020, JPI Urban Europe and the European Environment Agency [11] [12] [13].

3.2 CURE Integrated Urban Planning and Cross-cutting Applications

CURE cross-cutting applications provide the basis for the creation of information, intelligence, methodologies and tools supporting integrated urban planning, and the delivery of policy co-benefits. The relationship between CURE applications and urban planning policy objectives as a basis for specification of the requirements of the CURE pilot cities and subsequent application development, is presented in the following Table 1, Table 2, Table 3, Table 4, Table 5 and Table 6. These Tables 1 to 6 identify policy themes, planning strategy and scenario responses as well as cross-cutting policy co-benefits associated with each policy theme. This builds on the DPSIR (Drivers, Pressures, States, Impacts, responses) methodology of the European Environment Agency [14], and is informed by literature review [15], [16], [17] [18], [19] [20] and engagement with CURE pilot cities forming the framework for the subsequent specification of CURE applications in the following section 3.3 and 3.4.

CURE related policy themes are:

- **Climate Resilience**
- **Compact Cities**
- **Nature Based Solutions (NBS)**
- **Health and Well-being**
- **Mobility and Quality-of-life**
- **Active Travel Cycling/Walking**

DPSIR is a framework to examine and analyse the important and interlinked relationships between socio-economic and environmental factors in the context of urban plan decision-making. The DPSIR model provides an analytical framework for assessing the urban ecosystem and its various relationships in relation to the spatial planning of the city-region. The framework highlights the indicators which are needed to enable feedback on the resulting impacts of current and future policy choices, providing an effective gauge for the usefulness and success of responses provided by policy makers to the pressures states and impacts evident in the urban context as a result of the drivers of change.

DPSIR provides a conceptual frame through which the urban planning policy themes are operationalised in relation to the CURE cross cutting applications, so supporting the development process. Accordingly, drivers of climate change create pressures and impacts for which overarching plan strategies of Climate Resilience are formulated. Plan implementation strategies are developed via plan policy plan cycles concerning problem definition, plan formulation, political engagement and implementation. In this respect, **the general requirement (Requirement G.0) is that the CURE applications should provide monitoring capabilities and integrated impact assessment that drive specific policy initiatives** including Compact Cities, Nature Based Solutions and others. Similarly, Health and Well-being as a political target is operationalised in a plan process that generates policy initiatives concerning Mobility and Quality-of-Life as well as Cycling and Walking. Integrated appraisal and assessment of DPSIR relations in plan making and implementation offer the essential focus as well as an opportunity for CURE application development, piloting, testing and the delivery of urban planning policy co-benefits. These principles provide the necessary foundations for the CURE cross-cutting application development during as well as beyond the CURE project lifetime.

Table 1: Climate Resilience Theme

<table>
<tr><th colspan="2">Climate Resilience</th></tr>
<tr><td>Drivers/Pressures</td><td>State /Impact</td></tr>
<tr><td>Prime climate change impacts include:
increasing temperatures (Urban Heat Island Effect)
increased precipitation and extreme precipitation events (pluvial and fluvial flooding, as well as increased storm damage).</td><td>Direct impacts - for urban systems leading to a range of secondary impacts on the economy, human health, social wellbeing, and quality of life.
Indirect impacts - compounding effects of climate hazards e.g., flood related urban subsidence, and unsustainable urban development (development on flood plains and coastal areas).</td></tr>
<tr><td>Response – Plan Strategy</td><td>Cross-Cutting Co-Benefits</td></tr>
<tr><td>Climate adaptation long-term planning strategy across different sectors and policy areas, to enable issues to be tackled in an integrated manner with vision.

Multilevel strategic spatial planning and urban development planning need tools to respond to the complex challenges of climate change and support multilevel strategic cross-cutting urban adaptation.

Urban regeneration to address specific challenges e.g. energy efficiency, affordable housing, liveability and public health, and also enhancing land-use and social mix as well as public transport, walking, and cycling, and more efficient utility and infrastructure provision.

Mitigating Urban Heating
Green infrastructure can help mitigate urban heating influencing evapotranspiration, albedo and solar reflection,heat storage capacities, and provision of shade. Reduces air temperatures in adjacent areas.

Maximising co-benefits and limiting trade-offs requires coordination of the different interventions between land use planning, built and Green infrastructure policy areas. Land use planning can promote trees, green roofs and facades to facilitate cooling.

Managing Flood Risk
NBS use the features and complex system processes of nature, such as its ability to regulate water flows, to mitigate flood risk.</td><td>Potential co-benefits from coordinated policy actions include: enhancement of quality of urban life from multifunctional green spaces; protection/enhancement of biodiversity (urban greening policies); transformation of transportation patterns from increased spaces for cycling and walking; and improvement of air quality.
Challenges of predicting the timing, scale, frequency, intensity and impact of climate change highlights the importance of informed, coordinated planning with a long-term perspective.
Need for coordinated action between policy areas to maximise co-benefits and minimise the trade-offs.
Green infrastructure integrates green space into spatial planning e.g., through strategically planned network of natural and semi-natural areas, including ecological reserves. Direct benefits include strengthening the functionality of ecosystems for delivering goods and services, mitigating and adapting to climate change effects.</td></tr>
</table>

NBS have the potential to provide multiple co-benefits beyond enhancing resilience to urban flooding. For example, the use of green infrastructure (e.g. wetland areas and floodplains) will also have human health benefits by improving air quality, environmental benefits by providing a buffer for habitats and species and climate mitigation benefits by carbon sequestration. NBS also potentially avoid the potential trade-offs with implementing traditional grey infrastructure solutions to flood protection, such as increased greenhouse gas emissions during construction or operation.	• Mitigating urban heating, Green infrastructure can result in health and quality of life benefits for surrounding areas. • Green infrastructure also offers a range of environmental and social co-benefits including: health benefits by providing green spaces for people; biodiversity benefits by providing habitats; broader climate resilience benefits such as flood risk reduction and carbon sequestration; environmental benefits through reduced pollution.

Table 2: Compact City Theme

Compact Cities	
Response – Plan Strategy	**Cross-Cutting Co-Benefits**
Transition to green, compact, resilient and energy-efficient cities has the capacity to make a key contribution to sustainable growth. Finding the balance between compactness and achieving high standards of quality of life in a healthy urban environment is a major challenge pursued via social, economic and physical regeneration of urban neighbourhoods through the compact city model. Compact but green cities, with key amenities within walkable distances or mobility systems designed to reduce travel distances and times, or a Green infrastructure network that connects all natural areas.	• Long term impacts on the quality of life of all – so uncontrolled urban expansion incompatible with a sustainable urban future • Urban design, good land use planning and a focus on high-quality urban green spaces can mitigate negative externalities of living at high density, and make compact cities attractive, safe and sustainable places to live. • Living at higher densities if not carefully planned also leads to congestion, pollution and noise exposure, and insufficient access to green space.

Table 3: Nature-based Solutions Theme

Nature-based Solutions	
Response – Plan Strategy	**Cross-Cutting Co-Benefits**
NBS approach emphasises maintaining and enhancing natural capital, as it forms the basis for solutions. For example, improving green spaces has many co-benefits beyond the immediate amenity value it provides to people. It can enhance urban biodiversity, improve air quality, act as a carbon sink, reduce urban heat island effect, and absorb storm water. NBS by default involves the increased presence of green/blue spaces and infrastructures within the city, thus mitigating issues such as urban heat islands, hydrological risks due to soil sealing, air pollution, loss of ecological heritage, etc. NBS are associated with the use of healthy ecosystem functions to tackle urban challenges, such as pollution, efficient transport and housing, water management, while protecting the environment and providing sustainable socioeconomic benefits.	• NBS are essential in the context of the Quality of Life since they strengthen the relationships between biodiversity, land use planning and urban design and enable multifunctionality that provides diverse benefits. Both enhance and restore biodiversity while offering efficient solutions to combat the effects of climate change. • Green infrastructure is integrated into various policy sectors: including land use and spatial development planning; water management; climate change mitigation and adaptation; environmental protection and biodiversity conservation.

Table 4: Health and Well-Being Theme

Health and Well-Being	
Response – Plan Strategy	**Cross-Cutting Co-Benefits**
Addressing urban health and well-being is a multi-dimensional challenge. Requires prioritising issues such as improving air quality, increasing mobility and access and increasing the quantity and quality of green spaces in ways that benefit urban health. Need to focus on cross-cutting policy approaches that deliver sustainable outcomes for issues - environmental quality, transport, and green infrastructure. The strong connection between mobility and environmental quality contributes effectively to reaching agreed limit values e.g., climate, air quality and noise. Reducing air pollution is one effective means of improving environmental quality and it can have widespread benefits for human health and well-being by reducing concentrations of air pollutants like particulate matter, nitrogen dioxide and ozone.	• A number of policy interventions can be made to increase the health and well-being of urban populations. When health and well-being is established as a top priority in urban areas, the resulting policy actions can create co-benefits that contribute to this goal. • Green infrastructure among many NBS that are currently being designed and managed to deliver both health benefits and a wide range of ecosystem services higher quality urban environments can provide for residents.

Attractive layout may encourage walking or cycling modal choice. Likewise, sustainable use of energy, waste treatment, etc. have a direct impact on air quality. Behaviour is a crucial factor influencing urban air quality. Urban planning, e.g. availability of good public transportation can influence the modal shift. These themes are assessed as of major importance for achieving better urban air quality.	• Green roofs, for example, promote sustainability in European cities by increasing habitat for insects and birds, enhancing climate change adaptation through storm water retention, and mitigating of air pollution by reducing particulates.

Table 5: Mobility and Quality of Life Theme

Mobility and Quality of Life	
Response – Plan Strategy	**Cross-Cutting Co-Benefits**
Urban mobility challenge and response to forces determining development of transport and mobility in Europe - congestion, air and noise pollution, climate change. Transport generates more than 80% of the air pollution in cities in developing countries. Reducing conventional vehicle use can reduce carbon emissions whilst also reducing outdoor air pollution. Challenge is to deal with the increased demand for mobility whilst developing a resilient mobility system, which can meet future needs. Urban planning and mobility development form two sides of the same coin as transport and mobility are variables dependent on settlement structures and land use. Urban mobility concepts connecting suburban areas, metropolitan areas and cross-border traffic. Measures, including demand side e.g. congestion charges, low emission zones or parking management and supply-side e.g. mass transit service, cycle routes and cycle-share programme actions. Transport offers a wide portfolio of policies needed to support car-free cities, such as improved frequency and availability of public transport, infrastructure for bicyclists and pedestrians, shared car and bicycle programs and access for emergency vehicles and delivery vehicles.	• Mobility is a highly interlinked topic. Important issues of integrated urban development, such as sustainable urban development, urban climate change, innovative mobility, cut across sectors and departments to involve a wide range of stakeholders. • Important links between mobility and health aspects. Motorised traffic in particular can have a negative impact on the health of local residents, while individual mobility behaviour, especially the active modes, can offer a wide range of cross benefits. • Transporting people around the cities of the future is a public-policy challenge, but also an opportunity to improve the health of urban populations. Regional authorities have a range of policy options available to them to encourage active transport. • Increase in the share of active transport would also have positive impacts with regards to congestion, noise pollution and road safety,

Policy areas that contribute to the achievement of the urban quality of life given the framing of quality of life within the wider EU policy context including nature and biodiversity, land use planning, and urban design. Together, the natural and built environment create the framework conditions that either help or hinder the promotion of social, economic and cultural elements of quality of life, and which can be promoted by a variety of sustainable development policies including active travel.	helping to increase the quality of life in urban areas.

Table 6: Active Travel Theme

Active Travel – Cycling /Walking	
Response – Plan Strategy	**Cross-Cutting Co-Benefits**
Urban areas have the highest potential to shift from motorised to more active modes of transport such as walking and bicycling. This can improve the health and safety of travellers and bring benefits to other urban residents through reduced air and noise pollution and fewer traffic accidents. A comprehensive network of active mobility infrastructure which is well-designed and safe is a basic requirement for making cycling or walking a viable and attractive option in daily travel. To develop the full potential of the active modes of transport, cycling and walking have to be taken into urban mobility policies. In the long-term, traffic-related emissions can only be reduced in a meaningful way if car journeys are reduced and people switch to active forms of transport such as cycling and walking. This illustrates the importance of the integration of active transport into urban and transport planning to make it as easy as possible for members of the public to walk or cycle. Promoting active transport providing co-benefits to promote walking, biking, and other forms of active transport can also contribute to improved health and well-being and reduced emissions of air pollutants and greenhouse gases.	• New approaches to urban mobility planning are emerging as local authorities seek to develop strategies that can stimulate a shift towards cleaner and more sustainable transport modes, such as walking, cycling, public transport, and new patterns for car use and ownership. • Policies to reduce motor vehicle traffic in cities, either by reducing speeds, restricting vehicle access to certain areas, or reallocating road space to other uses all can play a significant role when it comes to improving quality of life. • Actions with potential to reduce air pollution and noise and can also free up spaces previously used for cars to increase green space, which can increase urban biodiversity and climate resilience. • Creating safer and more walkable streets with more opportunities for exercising and socialising, such actions also tend to lead to significant health and social cohesion co-

Efforts to reduce vehicular emissions through the promotion of public transport can also have co-benefits for levels of environmental noise pollution. Active forms of travel have a multiplier effect in terms of benefits to public health – they help to reduce local air pollution while improving the physical and mental health and wellbeing of those adopting active forms of transport.	benefits that may not be immediately apparent but can have far reaching positive impacts on quality of life.

3.3 Requirements through Online Questionnaire/Survey

The CURE online requirements questionnaire was launched in May 2020 with a deadline of 31st May 2020. In total 62 responses from domain experts were received. The questionnaire consisted of eight questions in total. There were five multiple-choice questions and three open-ended questions. The complete questionnaire is shown in Appendix A. The first two questions are used to provide context by identifying the interest to different CURE applications and respondents' domain of expertise. The other questions are more related to deriving specific requirements. Overall **34 generic requirements** are derived from the questionnaire responses. The results for each of the questions along with their analyses is presented below:

3.3.1 Q1: Interest in Applications

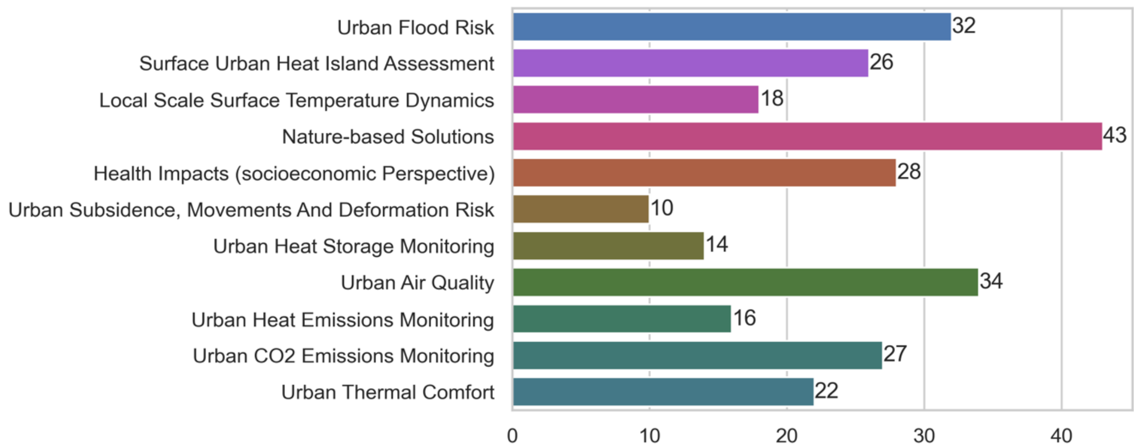

Figure 2: Responses to Question 1

The first question asked the respondents to choose the applications that they were interested in. Applicants were allowed to choose multiple options. Figure 2 shows that the overall NBS garnered the most interest with 43 votes, followed by UAQ with 34 votes and UFR with 32 votes. The applications with the least amount of interest were USMDR with 10 votes and UHSM with 14 votes. The results most likely reflect the nature of the applications themselves, as NBS, UAQ and UFR are applications that target areas that are high priorities for most city administrations.

3.3.2 Q2: Domain Expertise

This question asked the respondents to identify their domain of expertise. Respondents could choose multiple options as well as specify their own options. Figure 3 shows the distribution of responses for this question. Most respondents self-identified as urban planners (23), followed by GIS experts and data analysts (13). These three groups together comprise the primary end users of the proposed CURE apps, and thus it is significant that most respondents belonged to these three categories. This helps increase the confidence in the validity of the responses.

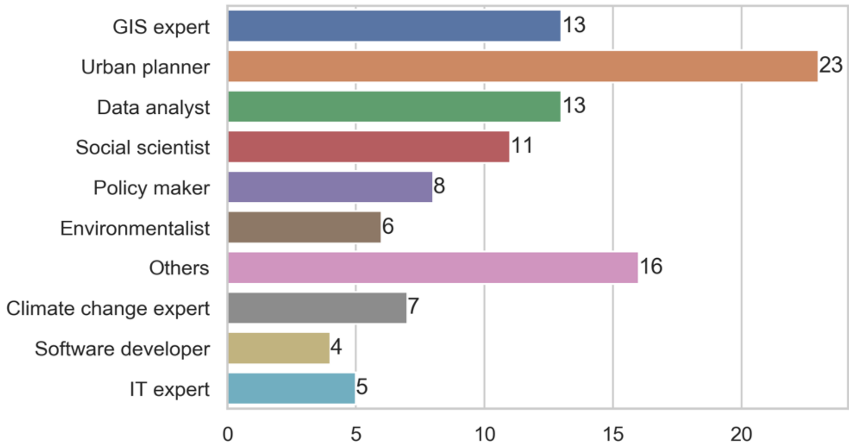

Figure 3: Distribution of responses for Q2.

3.3.3 Q3: Additional specific data and/or information

This open-ended question asked respondents to specify any additional data / information that they would like to receive from the CURE applications. We applied an automated keyword analysis technique to generate a wordcloud that indicates frequency of various keywords such as information, building, climate, energy, planning, heat, green, emissions, transport, area, risk, air, quality etc. Figure 4 shows the most commonly occurring words in responses to Q3. In order to understand the significance of the above keywords, below we present a summary of key data/information features identified by the respondents as requirements.

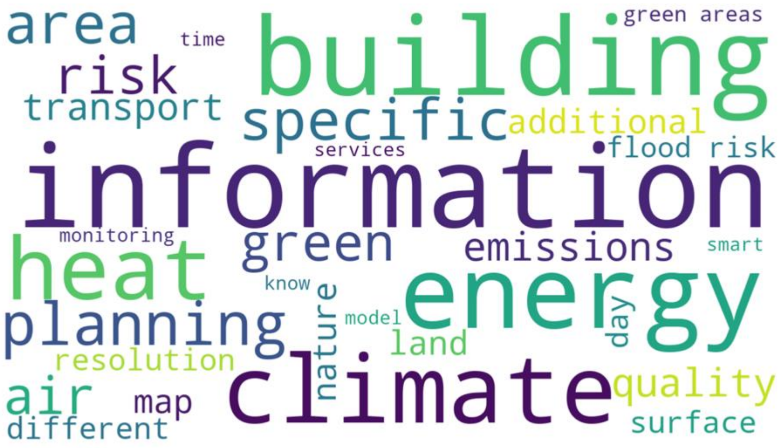

Figure 4: Commonly-used words in responses to Q3.

All the raw responses are shown in the **Appendix – B** where responses are associated with specific CURE applications. Due to varying nature of these responses it is not straightforward to derive common requirements. Here we summarize the generic requirements from the responses:

- **Requirement G.1:** CURE should use and provide access to the most recent data for different applications

- **Requirement G.2:** CURE should provide single point of access for various datasets of different applications through one map

- **Requirement G.3:** CURE should provide the possibility to extract timeseries at specified coordinates through APIs

- **Requirement G.4:** CURE should provide high resolution data and high frequency data e.g., hourly dynamics of heat emission

- **Requirement G.5:** CURE should be able to use and provide data combination of satellite-based, EU databases (e.g., risk behind natural events – earthquakes or other adverse events caused by climate change) and local data (i.e., sensors data, transport data including transport conditions, social activity data such as walkability, etc), smart city

- **Requirement G.6:** CURE should compare and/or validate CURE application outputs with other existing data sources such as local climate zones from wudapt database

- **Requirement G.7:** CURE should provide data outputs including soil (impervious soil detection / soil permeability (sub-surface zone)), land conditions, 2D/3D city model, cultural heritage data, nature protection data, building heights, surface elevation data, land cover, land use, energy performance data, traffic flow (multi-modal), cartographic maps (buildings, streets), digital elevation maps, albedo of urban surface, imperviousness and percentage of green areas, wind, temperature and emissions, NO2, PM10, PM2.5 particulate measurements, green areas (and proximity to green areas) and blue corridors, noise, social data

- **Requirement G.8:** CURE should do coupling of different applications e.g., NBS combating climate change risks, AQ/NBS and HI – with cause effect analysis, etc.

- **Requirement G.9:** CURE should provide various simulations including climate protection and adaptation measures, mitigating climate change by reducing CO2 emission, intelligent heat and cooling control based on weather forecast, building refurbishments based on energy consumption

- **Requirement G.10:** CURE applications should identify big polluters and should monitor seasonal air pollution

- **Requirement G.11:** CURE should perform change detection of specific land use classes and index green volume in urban areas

- **Requirement G.12:** CURE should provide early warning system e.g., issuing an alert when a threshold is reached such as floods, urban heat, air quality, etc.

- **Requirement G.13:** CURE should provide interoperability i.e. ability to interface with existing or future information systems in cities

Please refer to Appendix - B for more detailed responses.

3.3.4 Q4: Third-party or In-situ Data

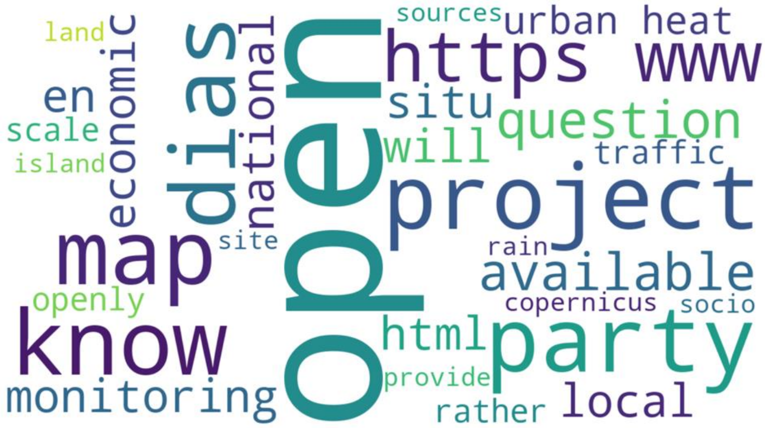

Figure 5: Commonly-used words in responses to Q4.

Figure 5 shows the wordcloud for responses to Q4, which asked respondents to specify any third-party or in-situ data that they would like to see integrated in the CURE services. Figure 5 indicates very prominently the use of 'open' data, economic data, urban data and data from national databases, etc. The aim of this question is to make CURE products more customized and/or relevant to a specific city/country. The detailed raw responses are provided in the Appendix B where responses are associated with specific CURE applications. Here we summarize the generic requirements from the responses:

- **Requirement G.14:** CURE should be able to use open data from cities, National (statistics, meteorology and mapping) agencies and EU databases and other applications but this requires careful mapping to access data through APIs – few data source examples from different EU states (Portugal, Netherland, Italy, Germany etc) and Pan-European cities (Antwerp, Berlin, etc) are provided.

- **Requirement G.15:** CURE should be able to use local urban heat islands (data) with satellite data

- **Requirement G.16:** CURE should be able to use traffic monitoring in anticipation for managing urban air quality

- **Requirement G.17:** CURE should be able to use socio-economic and energy related data to understand usage/data patterns

- **Requirement G.18:** Other datasets which CURE should use are: CORINE land cover and land use data, Open street map data, Eurostat data, World Urban Database, Citizen science data

Please refer to Appendix - B for more detailed responses.

3.3.5 Q5: Preferred Resolution Scales

For this question the respondents were asked to specify what resolution scales they would prefer for the different applications. The overall results are shown in Figure 6. Most respondents expressed interest in up to 100s of meters squared resolution, follow by 10s of meters and a few meters. This can be attributed to strategic applicability of a specific CURE application. That being said there was considerable variation in the results, and the application-specific breakdown is given in Appendix A. **Requirement G.19** covers resolution scale requirements which are listed in the Table 7 and have been identified for the various apps.

We applied MoSCoW method (Must have, Should have, Could have, Would not have) to indicate the importance of each requirement. **Must have**: represents non-negotiable features or needs that are essential for the success of the project. **Should have**: represent important needs or requirements that are not vital, but add significant value in short and long term. **Could have**: are nice to have features that will have a small impact if not implemented. **Will not have**: represent low priority features or needs for the project specific timeframe.

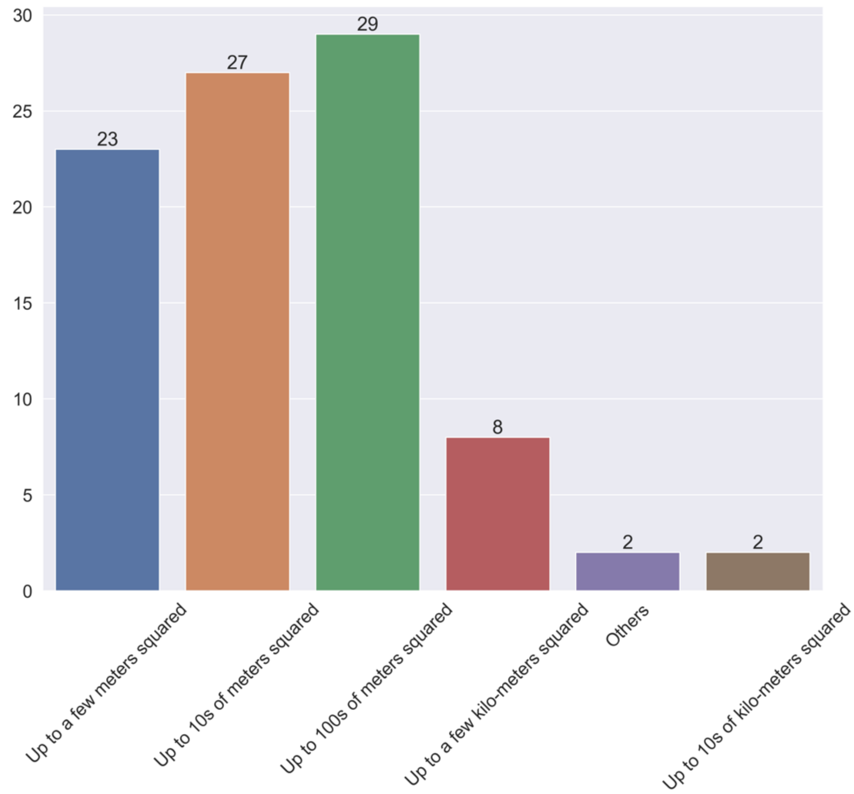

Figure 6: Overall results for Q5.

Table 7: Requirements for resolutions scales for various applications.

Application	Resolution scales				
	Few meters	10s of meters	100s of meters	Few kms	10s of kms
HI	S	C	M	M	C
HSM	S	M	M	C	S
LSSTD	S	M	M	C	W
NBS	M	M	M	S	C
SUHIA	S	M	M	C	W

UAQ	S	M	M	C	C
UCO2EM	M	M	M	C	C
UFR	C	M	C	S	W
UHEM	M	S	S	C	C
USMDR	M	C	S	W	W
UTC	M	S	S	C	W

3.3.6 Q6: CURE Applications Data Access Methods

In this question the respondents were asked to identify the methods in which they would prefer the CURE applications to be accessible. Respondents could choose multiple methods or specify their own. The overall results for Q6 are shown in Figure 7 and the application-specific results are shown in Appendix A. The analysis indicate that the Web map services were by far the most common methods respondents preferred (44 votes) while data APIs and file download were less common. For **Requirement G.20**, Table 8 lists the application-specific access requirements by priority.

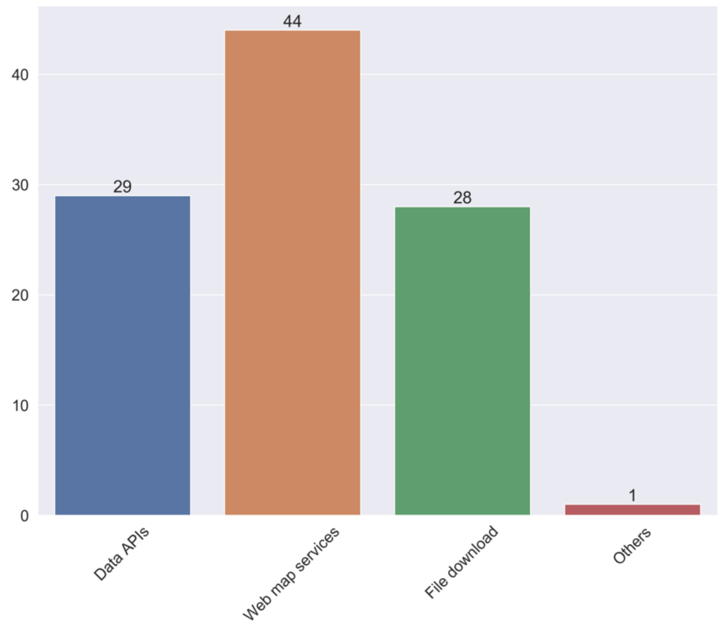

Figure 7: Overall responses for Q6.

Table 8: Requirements for data access methods for various applications.

Application	Data Access Methods		
	Data APIs	File Download	Web map services
HI	S	C	M
HSM	S	C	M
LSSTD	C	S	M

NBS	S	C	M
SUHIA	S	C	M
UAQ	S	C	M
UCO2EM	S	C	M
UFR	S	C	M
UHEM	S	C	M
USMDR	C	S	M
UTC	S	C	M

3.3.7 Q7: Importance of Temporal Scales

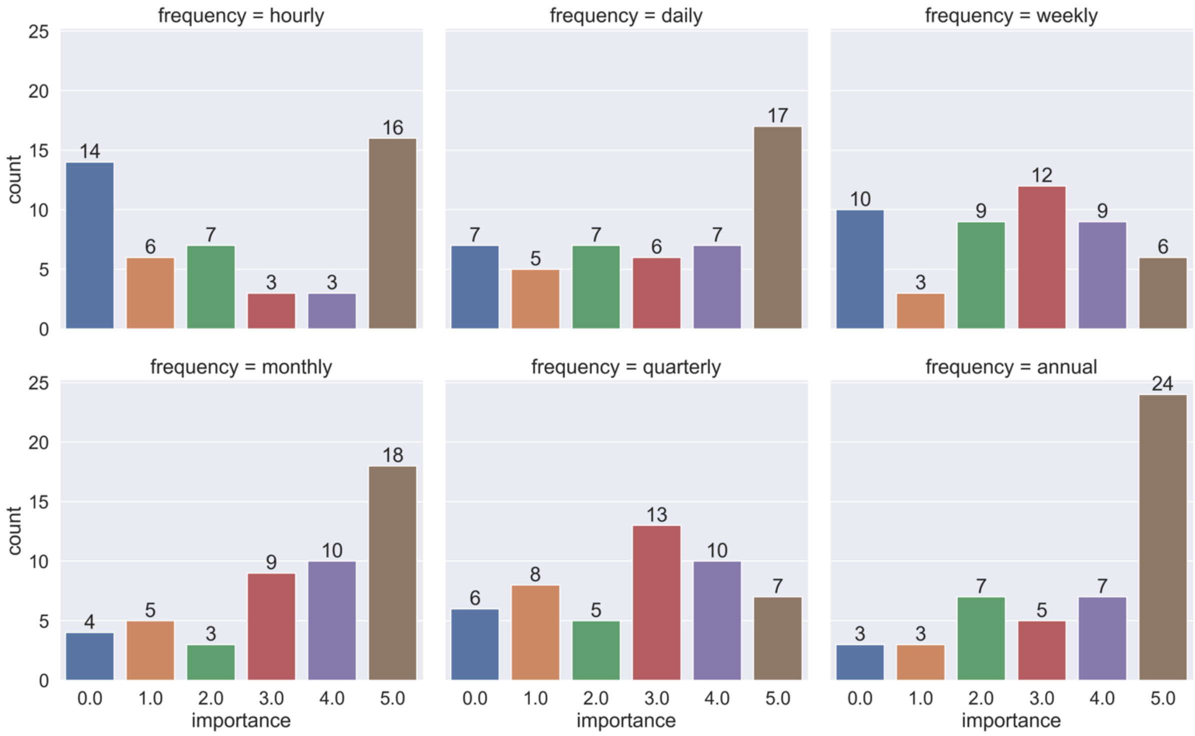

Figure 8: Overall responses for Q7.

Respondents were asked to rate various temporal scales in order of importance, 0 being not important at all and 5 being the most important. Overall results are shown in Figure 8 and application-specific results are shown in Appendix A. Overall most people rated hourly, daily, monthly and annual as the most important temporal scales. Weekly and quarterly scales were not considered important by most people. For **Requirement G.21**, Table 9 lists the application-specific temporal scale requirements by priority.

Table 9: Requirements for temporal scales for various applications.

Application	Temporal scale					
	Hourly	Daily	Weekly	Monthly	Quarterly	Annual
HI	M	S	S	M	C	M

HSM	M	S	C	C	C	S
LSSTD	M	M	C	S	C	M
NBS	S	S	C	M	C	M
SUHIA	S	S	C	M	C	M
UAQ	S	S	C	S	C	M
UCO2EM	S	S	C	S	C	M
UFR	S	C	C	S	C	M
UHEM	S	M	C	S	C	M
USMDR	S	S	C	M	S	M
UTC	M	S	C	S	C	M

3.3.8 Q8: Additional Comments

This question asked the respondents to specify any other needs which are not covered by the previous questions. The aim of this question is to give the end users the opportunity to indicate additional needs or features which can make CURE products more customized and/or relevant to a specific city/country. The detailed raw responses are provided in the Appendix B.

Here we summarize the responses which define general requirements applicable to the most of CURE applications:

- **Requirement G.22:** CURE should provide information on day vs night peaks

- **Requirement G.23:** CURE should provide access to data when it is needed rather than too often

- **Requirement G.24:** CURE applications could be combined with gamification and behaviour change interventions which can be useful to improve quality of life in cities & communities

- **Requirement G.25:** CURE should consider medium sized and small towns for implementing the topics such as air quality and air pollution can also be problematic in smaller cities

- **Requirement G.26:** CURE should build a user community of the involved cities/region for internal exchange of knowledge and questions

- **Requirement G.27:** CURE applications should be easy/comfortable to use, reachable (accessibility) and usable as urban services are crucial for the implementation in the daily work of the city administrations

- **Requirement G.28:** CURE should provide hourly data as it allows integration in smart city systems

- **Requirement G.29:** CURE should provide 24/7 data and all data must be geo-referenced

- **Requirement G.30:** There must be integrated and harmonized metadata (considering INSPIRE directive) and interpretation

- **Requirement G.31:** CURE should consider ground motion service by EEA as input to USMDR application

- **Requirement G.32:** CURE should provide high frequency temporal variation of the data on urban floods

- **Requirement G.33:** Timeseries data are highly welcomed as it will help to evaluate the trend of each variable in relation to climate change

- **Requirement G.34:** CURE should consider application on Moravian Silesian region to prepare an adaptation strategy

3.3.9 Summary of requirements analysis and conclusions

Overall, the following key points can be concluded from the preceding discussions about the responses to the various questions.

1. NBS is the most sought-after application followed by UAQ and UFR. This is perhaps not surprising since these apps target areas that are high priorities for climate resilience for most city administrations. However, it is essential to note that the scope of the NBS in CURE is only limited to green roof potential.
2. Most respondents consisted of urban planners followed by GIS experts and data analysts. This is significant because these categories constitute the primary users of the proposed CURE services.
3. CURE should also provide the most recent data for different applications as well as serve as a single point of access for various datasets. The CURE application outputs also need to be cross-validated with other data sources.
4. The true power of CURE can be unleashed through cross-cutting applications that couple various CURE applications together, e.g. AQ / NBS and HI working in tandem providing cause-effect analyses.
5. CURE should integrate data from various sources such as open data, economic data, urban data and data from national databases etc.
6. Overall there is quite a significant demand for high-resolution data output from the CURE services; from a few meters to 100 of meters.

7. Most respondents requested that the CURE outputs be available through web map services, followed by the ability to access them through data APIs as well as through file downloads.
8. Most CURE applications should support hourly, daily and annual monitoring information. Furthermore, it was also suggested that the CURE applications should provide information on day / night peaks and should be easy-to-use and accessible.

3.4 Requirements through Dialogues with Cities

The process consists of organizing series of mini dialogues with representatives of relevant departments/agencies of different cities. A number of teleconferences were organized followed by exchange of queries or questions and responses that led to identifying: interest in different CURE applications, specific needs including resolution scale, temporal scale and specific features which can benefit the cities and specific needs where CURE applications can play an important role.

In order to structure the mini dialogues a questionnaire framework was designed with the objective to gather requirements consistently and identify commonalities which will help in developing the generic applications for different cities. The questionnaire frame is in Appendix-C.

Please note that a preliminary requirements analysis indicates that not all of the user needs are within the scope of the CURE project as these needs go beyond mere cross-cutting of Copernicus DIAS data services. The outcomes of the process identify various areas of investigation or further research from Copernicus to downstream applications and it can be considered as a gap in the existing data needs and methods. Here we present a summary of those requirements.

As we know that cities administrations have many departments and/or agencies who look after various planning, environment, social, financial, health, security aspects, please note that the views and requirements presented by the representatives in the dialogue teleconferences represent views from a small sample from a diverse city administration. To avoid any confusion, protect privacy and to simplify representation of a city in the stakeholder engagement process, in the following text we'll use city name as synonym to the representatives. This means instead of saying Mr. Sanders from the department of Urban Planning of the City of Madrid, we'll simply refer it to as Madrid. In CURE four front-runner cities are involved: Berlin, Copenhagen, Heraklion and Sofia. Summary of their initial requirements is presented below:

3.4.1 Berlin

Berlin is interested in evidence based decision making and CURE can play an important role. Urban Climate change theme is the main focus related to CURE project. Berlin has rich data resources and most of the data is publicly available through the open data portal of Berlin. Berlin has an open-data-policy, so there are no limits for data access (see: https://www.govdata.de/dl-de/by-2-0).

Berlin expects following benefits from CURE applications:

- Evidence based decision making where existing data gaps can be filled by CURE applications
- Collecting actual data and compensating lack of detail with the higher frequency of data acquisition through satellite or CURE applications. One area where CURE applications can be particularly useful concerns the cycle of data review e.g., currently Berlin's model climate model is updated only every five years - whereas there is a need for a six-month review of data to address rapid change assessments– and so this can be an opportunity for CURE applications as well as rationale for supporting engagement with CURE products. So temporal frequency for half year would be useful from CURE. High frequency of the updated data (e.g., at least six months interval) that will potentially save costs of collecting data from other methods after few years.
- Harmonised view at district, city, region scale and change detection at high resolution scale (at least 10m grid) as this will be comparable with existing local data and justifiable to be used in Berlin
- Cross-validating or verifying or evaluating existing information or models with CURE applications. Getting detailed data through CURE can be used to evaluate results or compare outputs between CURE applications and Berlin's existing data as Berlin already has about 5000sqm data.
- For Berlin, appropriate CURE application could possibly support the monitoring / the evaluation of the instrument of Urban development plans (e.g. Urban Development plan Climate (https://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/index_en .shtml)) .
- Also different other specific planning instruments in the fields of the Berlin Clean Air Plan (https://www.berlin.de/senuvk/umwelt/luft/luftreinhaltung/luftreinhalteplan_2025/index.shtml) or the Implementation of the European Water Framework Directive in Berlin can be supported.

Below is a summary of requirements derived from the dialogue with Berlin:

- **Requirement B.1:** Berlin's main interest is in climate and energy related applications including *Local Scale Surface Temperature Dynamics, Surface Urban Heat Island Assessment, Urban Heat Emission Monitoring, Urban Thermal Comfort and Urban Heat Storage Monitoring.* Looking at the thematic areas relevant to Berlin and diversity of

CURE applications, other applications could also be applied in Berlin by engaging with other departments and stakeholders if needed. These applications are: Urban CO2 Emission Monitoring, Urban Flood Risk, Urban Air Quality, Nature based solution and Health Impact.

- **Requirement B.2:** Resolution scale is an important consideration for Berlin to make CURE application compatible with the existing information sources which operate at 10x10m scale. For example, Berlin has an existing climate model that uses 10m grid and has been quite successful so far. Therefore, CURE applications must be at least at 10x10m scale to adapt CURE applications and data across different departments resulting in improving the operational feasibility and sustainability over longer period of time.

- **Requirement B.3:** Temporal resolution is also identified as important requirement. Frequency of updated data or application output is expected to be at least 6 months.

- **Requirement B.4:** The scope of the application should be the whole city as it falls within the scope of the urban climate. It should consist of land-use mix, green areas and/or build-up areas. Nevertheless for the CURE applications which are looking for a specific study area of approximate size 5Km^2 in the inner S-Bahn-Ring in Berlin as shown in the following Figure 9.

Figure 9: S-Bahn-Ring: a potential study area for CURE applications

- **Requirement B.5:** Monitoring of increase of surface sealing is an important feature for Berlin and it would be useful to consider this in CURE applications. For Berlin, impervious surface ceiling data will be updated next year and this can be a very good opportunity for the CURE project to include surface sealing in one of the relevant applications e.g., Surface Urban Heat Island Assessment.

- **Requirement B.6:** Berlin uses different formats for their Web-services: Grids or ASCII via ATOM (satellite / airborne data e.g.), Vector data via WFS and CURE products should be compatible.

- **Requirement B.7:** The data access for Berlin could also be via WFS/ATOM and traditional downloads for maps with created layout, legend etc. are suitable. Outputs in the form of exclusively PDF-format is not sufficient enough.

- **Requirement B.8:** Berlin uses a metadata-profile according to ISO 19115 (https://www.iso.org/standard/26020.html); and they are committed to collect and edit all necessary metadata for each spatial dataset. For Berlin, metadata profiles of CURE applications should be compatible with ISO 19115.

3.4.2 Copenhagen

Integrated impact assessment is the main focus identified for Copenhagen. Their interest in different cross-cutting policy thematic areas is mainly based on: i) their existing initiatives which collect data from both local data sources as well as satellite data e.g., there are already other initiatives from where data related to Land Surface Temperature Dynamics, Urban Flood Risk, Air Quality, Urban Surface Heat Island Assessment, Health Impact, NBS (green roofs) are already being collected, and ii) possible gaps in data which can be used to investigate new insights. A lot of local data is available from the Copenhagen open data portal: https://www.opendata.dk/city-of-copenhagen

A requirement feasibility check was performed based on the initial requirements which identified various possible scenarios by using the cross-cutting themes and interest in different CURE applications. However, many of the requirements were beyond the scope of the CURE project and/or were not feasible to fulfil due to various reasons such as much needed local infrastructure such as flux towers in CO2EM application, limiting scope of NBS to green roofs only, lack of satellite data for a certain year, etc. Here we list the original cross-cutting aspects with the view that these are being verified and feasibility of implementation is being investigated.

1. Research suggests that correlation between different factors: such as air quality, urban heat and related diseases are expanding. For example, air quality, urban heat stress/comfort and noise are keys and are important issues to investigate. Air pollution together with heat are important contributors to deaths and diseases such as post-natal stress and looking at mental health issues in longer term. So new assessment of air quality impact on health should look at both short term and long term health impacts. For instance a research question can be that 'What are socioeconomic impacts of short as well as life-long diseases such as mental health, diabetes, stress?' Here the requirement **'Requirement C.1'** is 'CURE applications should

investigate the co-relation between air quality, heat island and health/economic impact for short term as well as long term illnesses.' This requirement is highly dependent upon the scientific research on air quality on long term illnesses which will provide basis for modelling the CURE HI application.

2. Similarly, correlation between air pollution and health (socio-economic) can provide other interesting insights. For instance, due to COVID-19 lockdown it would be interesting to look from satellite data perspective and assess the overall impact on World Health Organisation (WHO) targets. This can include health impact, socioeconomic impact, traffic congestion cost (e.g., time freed up/saved in journeys) etc. It is more like comparing the state of environment and socioeconomic factors with the original targets defined by WHO i.e. limits of NOx, PMx, etc. Copenhagen is committed to WHO targets. In short, the requirement **'Requirement C.2'** is 'CURE applications should investigate the impact of COVID lockdown from a satellite data perspective and find out what is required to implement the WHO guidelines? What are the associated socioeconomic impacts? and what are the impacts on congestion levels?' This requirement is highly dependent upon the availability of the most recent data from Copernicus.

3. Copenhagen is planning to plant 100.000 trees and cost of plantation in the city is tremendous i.e. approx. €20.000 per tree on average. So tree plantation assessment and correlation between CO2 emission monitoring (and reduction), air quality monitoring (and improvement) and health impact will be of much interest. In short, the requirement **'Requirement C.3'** is 'CURE applications should assess the environmental (e.g., CO2 emissions, air quality) and health (socio-economic) impact of tree plantation in Copenhagen'. This requirement is highly dependent upon the scope of the NBS application which mainly focuses on the green roofs. In addition, it requires necessary infrastructure for applying CO2EM application as indicated in the next requirement.

4. Like in other urban areas, controlling the CO2 emission is also a challenging policy requirement in Copenhagen. Copenhagen's goal is to be carbon neutral by 2025 and the main focus is on traffic emission. Other initiatives are already being developed. So one challenge or requirement **'Requirement C.4'** for CURE applications could be to investigate district based CO2 emissions at granular level (i.e. higher resolution) without compromising the GDPR privacy constraints. The implementation of this requirement is highly dependent upon availability of flux towers in Copenhagen because CO2EM application uses fluxes by applying Eddy Covariance method on local scale flux towers which are deployed based on expert local knowledge.

5. Urban heat, heat island assessment, noise and correlation with health can provide useful insights for planning and decision making. So requirement **'Requirement C.5'** for CURE applications could investigate the above correlation through satellite and local data.

6. As **'Requirement C.6'**, there may also be a possibility to apply USMDR application to assess the impact of Cloudburst from 2011 which had caused substantial damage to the city of Copenhagen e.g., building insurance claims reached to over EURO 800 millions[2] [21]. Fulfilling this requirement will be highly dependent upon the availability of local as well as satellite data prior to 2011. This application can also be applied on the assessment of major infrastructure development such as metro/train but it would require a specific use case – selected area for piloting.

Like in a typical requirements management process, we expect that these requirements will evolve in the upcoming weeks and these evolving requirements will be covered in the requirements living document (see Appendix – C).

3.4.3 Heraklion

Heraklion also collects lots of data (e.g., temperature, air pollution, etc) through local sensors. Their open data is accessible from https://smartcity.heraklion.gr/en/home/. Like other cities Heraklion has their local priorities and CURE applications based on local needs are identified by Heraklion. For instance, existing studies indicate that in Heraklion 70% of emissions are related to transport. Heraklion signed EU Covenant of Mayors agreement and for this CURE's Urban CO2 Emission monitoring application can be very useful.

In particular, Heraklion expects following benefits from CURE applications:

- A new data source that can be used for evidence based decision making
- Collecting actual data and compensate lack of detail with the higher frequency of data acquisition through CURE applications.
- Different CURE applications at varying scales contributing to policy making or planning challenges

Below is a summary of requirements derived from the dialogue with Heraklion:

[2] https://www.climatechangepost.com/denmark/flash-floods-and-urban-flooding/

- **Requirement H.1:** Heraklion is interested in the following CURE applications: Surface Urban Heat Island, Urban Heat Emission Monitoring, Urban CO2 Emission Monitoring, Urban Flood Risk and Urban Subsidence Deformation and Movement Risk.

- **Requirement H.2:** The scale of CURE applications, especially, heat related applications should be local to make it usable.

- **Requirement H.3:** Heraklion wants to use the most recent data i.e. from 2019 onwards, in the CURE applications.

3.4.4 Sofia

In general Sofia has interest in the final customized CURE products, but they also need the data behind this, in order to be able to reuse this data for forecast, impact assessment and follow up future changes. Sofia is interested in new data that can help them answering various planning questions by analyzing the correlation between various environmental and planning variables. Their thematic focus and challenges are related to sustainable development including issues concerning urban planning, mobility, green spaces, waste management, and others under the remit of Sofproect - https://sofproect.com/en/home/ .

In this respect, new data and assessment tools from CURE to tackle these challenges will be valuable. The city has committed to decrease emissions with 40% by 2030 (base year 2007). Currently, there are many environmental data gaps e.g., lack of systematic way of monitoring green spaces, groundwater quality, etc. So they are interested to know that to what extent the earth observation derived data can support assessments in relation to air quality (e.g., pollution from traffic and heating), soil pollution and groundwater quality? This also includes monitoring of current state, correlation and causal analysis and predictive futuristic analysis to support Vision Sofia 2050 https://vizia.sofia.bg/vision-sofia-2050. Some data is available through online platform such as air quality measurement stations: https://platform.airthings-project.com/ and other related data e.g., Green Sofia is shared with CURE.

Sofia expects the following benefits from CURE applications:

- Potential contributions to Sofia urban development plan if CURE outputs are available by Q1, Q2 of 2021 as these will serve the purpose to incorporate the results in the decision making during the update of the Sofia urban development plan. Current urban development plan is from 2009. Since 2014 it’s mandated to update the plan and this may result in amending the exiting plan or entirely renew the plan by the end of the year. Here, CURE evidence based data can play a useful role.
- Evidence-based decision making to identify the most acceptable and suitable decisions and alternatives. For instance, CURE based monitoring and assessment of land use e.g.,

commissioning/decommissioning industrial sites and impacts on air pollution, soil pollution, ground water, surface water, etc can help in planning. Similarly, it is hypothesized that traffic and households are main contributors of pollution and heat in Sofia and through CURE monitoring necessary evidence can be collected for decision making.

- There have already been some studies performed, e.g., urban health island, which can be used to cross-verify the CURE outcomes.
- Fulfilling the data gaps e.g., earlier last year there are only six official air quality monitoring stations and by the end of year 2019, 22 new stations were launched.
- Contributions to Sofproect initiatives https://sofproect.com/en/home e.g., Sofia green, and Vision Sofia 2050 - https://vizia.sofia.bg/vision-sofia-2050
- Use CURE data to combine/overlap with existing local data to come up with useful understanding with the different departments of the municipal about the environmental parameters e.g., eco-system and quality of life.

Below is a summary of requirements derived from the dialogue with Sofia:

- **Requirement S.1:** Sofia is interested in the following CURE applications: Local Scale Surface Temperature Dynamics, Surface Urban Heat Island Assessment, Nature Based Solutions, Urban Air quality, Urban Thermal Comfort and Health Impact.

- **Requirement S.2:** CURE applications usability (e.g., understandability) must be high as it can prove to be crucial in bridging the understanding gap between different users/stakeholders in different municipal departments.

- **Requirement S.3:** The geographical coverage should be for the whole territory of the municipality to identify areas for interventions with specific measures.

- **Requirement S.4:** Frequency of updated CURE data or application output is expected to be at least 12 months as long as it can be used to monitor effects of particular changes in the natural and built environment.

- **Requirement S.5:** Sofia identified 10x10m resolution scale as an ideal scale for the UAQ application. Other applications of interest, though vary in providing strategic and more focused views, would be ideal at the similar scale.

- **Requirement S.6:** CURE applications should provide vector data format as the preferred format. Other supported formats can be raster in TIFF files with Z volume and machine readable text format and shape files with attributive information.

- **Requirement S.7:** In terms of data access, CURE should provide file download access mechanism for Sofia.

- **Requirement S.8:** Sofia is primarily interested in the most recent data. CURE applications should use historical data to perform retrospective analysis where it helps in projections/futuristic analysis contributing to evidence based planning and policy making challenges such as change in the traffic will impact air quality, heat comfort, impact of existing green spaces or new ones, etc.

- **Requirement S.9:** CURE applications should provide futuristic analysis or projections i.e. what is the current state and how can it be improved in the future?

- **Requirement S.10:** CURE applications should support parametric planning e.g., a model for air quality, eco-system services by using simulations, predictive analysis, forecasting, cause-effect analysis etc. This will support development plan and modelling future city development – given inevitable trade-offs regarding conflict of interests and seeking the best solutions from all points of view in developing the future vision. So developing a model linking to parametric planning – with all indicators in the model - seeking balance between different parameters would be useful.

- **Requirement S.11:** A number of UHI and modelling studies have been performed in the past and these studies should be used for developing and cross-comparing with the specific CURE applications. Please see the list of published studies in Appendix – D.

4 ANALYSIS AND CONCLUSIONS

Different cities indicated interest in different CURE applications as summarized in the following Table 10. In some cases higher frequency of outcomes (e.g., six months) is the main motivation to get up to date state of by using CURE applications. In other cases the most recent and harmonized data as well as cross-cutting aspects are of high priority based on which futuristic analysis can be performed.

Table 10: CURE applications mapping to cities

Application	Front-runner cities			
	Berlin	Copenhagen[3]	Heraklion	Sofia
LSSTD – AP01	X			X
SUHIA – AP02	X	X	X	X
UHEM – AP03	X		X	
UCO2EM – AP04			X	

[3] The final list of CURE applications will be updated after further requirement analysis.

UFR – AP05			X	
USMDR – AP06		X	X	
UAQ – AP07				X
UTC – AP08	X	X		X
UHSM – AP09	X			
NBS – AP10				X
HI – AP11		X		X

Preliminary analysis of the requirements identified in the previous sections, indicates varying level of interest in different CURE applications. Furthermore, this analysis identifies a few common denominators which if followed will increase the replicability aspects of the CURE applications across other European cities. These common denominators are:

- CURE applications should consider past as well as the most recent data with higher update frequency e.g., day vs night.
- CURE applications should provide easy access to final products e.g., WMS, as well as the underlying data by applying various data access methods e.g., WFS, APIs, file downloads etc.
- CURE should act as an easy to use platform for the data search and access from different Copernicus services
- CURE applications should support varying resolution scales i.e. from strategic (city-region) to city and neighbourhood scale by investigating suitable downscaling methods
- CURE applications should consider functional urban areas of cities (city-region) for geographical coverage where it is appropriate
- CURE applications should provide basis to perform retrospective modelling and analysis to develop predictive and futuristic models for cities in addressing environmental issues.
- CURE should provide the necessary building blocks for the development of downstream cross-cutting applications for impact assessment, urban planning and policy making.

From CURE perspective it is important to find a right balance between harmonised solutions (including temporally and spatially consistent information) across various cities and more tailor made solution to fill specific needs i.e. involving use of data from cities and development of specific products for specific needs. There is always space for the developments of more effective solutions combining EO data with in-situ data e.g., socio-economic, mobility etc. However, the challenge is to identify common features so that generic solutions can be developed for wider market replicability. Furthermore the design of these solutions should be extendable and let researchers and cities extend and build innovative solutions which can further fulfil local policy and planning needs.

CURE city specific requirements identified above provide the basis for development of the technological concept, providing experimental proof, validation and demonstration of the cross-cutting applications in the front-runner cities. These CURE applications should be developed with reference to the specific requirements above, as well as general requirement that they should provide integrated impact assessment and implementation monitoring capabilities that secure policy co-benefits in relation to Compact Cities and Nature Based Solutions, Health and Well-being as well as policy initiatives concerning Mobility and Quality-of-Life and Cycling/Walking. These city-focused downstream applications also act as pilots to set the basis for further transferability and downstream services development. This process also assists in filling existing gaps in the current Copernicus offer in relation to urban areas, and aims to identify to what extent new observation requirements for spaceborne instruments are needed to realise or improve the specified applications.

Finally, it is essential to understand that the CURE project applications aim to integrate data from different CURE DIAS services and whilst there are some cross-cutting aspects considered for the development of CURE application, various coupling scenarios of CURE applications are beyond the scope of the CURE project. However, as stated in section 3, many user needs and requirements demand such downstream integrated approaches by coupling of different CURE applications. This is mainly needed to understand the impact of change of state of one or more variables (from application A) on the variables in another application such as health impact, heat or thermal impact, CO_2 or/and air quality impact due to increase of green infrastructure.

ACKNOWLEDGEMENTS

We acknowledge support of all CURE project partners – in particular FORTH, DLR, GISAT, VITO, ApHER and UNIBAS for providing the initial learning resources about the introduction to project and its cross-cutting applications and answers to specific queries from the cities, which played key role in the stakeholder engagement process. We also acknowledge support of both front runner and follower cities and advisory board members in the requirements dialogues and facilitating the requirements development process. Finally, we acknowledge useful contribution to our anonymous users who responded to the online questionnaire.

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APPENDICES

Appendix - A

A SURVEY QUESTIONNAIRE

A copy of the online survey questionnaire.

CURE Applications Questionnaire

Participant Information Sheet and Consent

You are invited to take part in the CURE Stakeholder Needs online questionnaire survey as part of the research taking place in the Horizon 2020 Copernicus for Urban Resilience in Europe (CURE) project.

Your participation will be anonymous and it is up to you to decide whether or not to take part in the survey. Before you decide whether to take part, it is important you understand why the study is being undertaken and what it will involve. So please read this information sheet carefully. If you do decide to take part, you will be unable to withdraw after submitting the questionnaire, as due to anonymity of the questionnaire, it will not be possible to identify your responses.

Who is organising and funding this research?

The CURE project (http://www.cure-copernicus.eu/) is funded by the European Commission under Horizon 2020 programme – Grant # 870337. The CURE consortium has 10 partners from 9 countries and it is led by Nektarios Chrysoulakis from IDRYMA TECHNOLOGIAS KAI EREVNAS (FORTH), Greece. David Ludlow, Zaheer Khan and Kamran Soomro from the University of the West of England, Bristol are leading the stakeholder engagement and requirements elicitation. They are responsible for the CURE Stakeholder Needs online questionnaire survey and analysing the responses.

What is the aim of the research?

The CURE project aims to develop 11 cross-cutting and integrated applications that can assist the decision-making processes concerning development and delivery urban of planning and sustainable development. Relevant policy frameworks and planning objectives include climate change adaptation/mitigation, energy and economy as well as healthy cities and social environments. To meet this challenge, information and intelligence is derived from a number of Copernicus Core Services (earth observation data), including the Land Monitoring Service (CLMS), Atmosphere Monitoring Service (CAMS), Climate Change Service (C3S) and Emergency Management Service (EMS) combined with in-situ and socio-economic data will be utilised. The ultimate aim of this research activity is support for the development of evidence-based policy options and strategies delivering integrated urban planning solutions that deploy new urban intelligence founded on Copernicus remote sensing data. The project therefore directly contributes to the specification and realisation of strategies for resilience planning at local and city scales, as well as the promotion of the New Urban Agenda for Europe, and the Sustainable Development Goals at the global level.

Why have I been invited to take part?

You are invited to take part in the survey as you have specific skills and expertise relevant to the development of the CURE applications, and may be a potential user of the applications. We are interested in understanding your experience, and views regarding the application specific requirements. If you take part, you will be helping us to gain a better understanding of the user requirements and co-designing the CURE applications which meet user community needs and applied across European cities.

Where will the results be published?

The results of the questionnaire survey will be analysed and used in a project deliverable including a summary of user requirements, that will be available as a public documents from the project website. The survey results may also be used in conference papers and peer-reviewed academic papers. Anonymous and non-identifying direct quotes may be used for publication and presentation purposes.

Who has ethically approved this research?

The CURE Online stakeholder questionnaire has been given ethics consent by the FET Faculty Research Ethics Committee. All the information that you give will remain confidential and anonymised. The results will be secured as per the UWE's and the Data Protection Act 2018 and General Data Protection Regulation requirements. Once all anonymised data analysed and report is finalised, the raw data from the questionnaire will be securely deleted by the end of the project i.e. Dec 2022. Any comments, questions or complaints about the ethical conduct of this study can be addressed to the Research Ethics Committee at the University of the West of England at: Researchethics@uwe.ac.uk

What if I have more questions?

If you have any concern, queries or would like any further information about the CURE research project please contact in the first instance:

CURE Project Coordinator:

Nektarios Chrysoulakis, Director of Research at FORTH / IACM
100 N. Plastira Str., Vassilika Vouton, GR 70013, Heraklion, Greece
Email: zedd2@iacm.forth.gr; Tel. +30 2810 391762; Mob. +30 6932 929775;

Stakeholder Engagement Lead:

David Ludlow, Associate Professor – European Smart Cities
University of the West of England, Coldharbour Lane, BS16 1QY, Bristol, United Kingdom
Email: David.Ludlow@uwe.ac.uk ; Tel: +44 (0)117 32 83223; Mobile: +44 (0) 7818 095327

What are the next steps?

In responding to the online questionnaire please:

- Review the participant information sheet to understand why this research is being organised
- Review the CURE applications to respond to the questions as far as you are able
- **Submit your responses by May 31 2020**

Consent

The submission of the questionnaire will be considered as your consent. This part should be read together with the Participant Information Sheet. Please ensure that you have read and understood the information contained in the Participant Information Sheet and asked any questions before you respond to questionnaire and submit your answers. If you have any questions please contact a member of the research team, whose details are set out on the Participant Information Sheet. The submission of your responses will assume that:

- You have read and understood the information in the Participant Information Sheet and consent to taking part in the CURE Stakeholders Needs Questionnaire;
- You agree that anonymised quotes may be used in the final report of this research;
- The responses will be anonymised, analysed and then grouped with other participants, so your answers are not identifiable to you.
- You understand that your participation is voluntary. Additionally, after submission of your responses to the questionnaire you will not be able to withdraw from the study, as the data collected will be anonymous and therefore cannot be identified for removal.
- You agree to take part in the research

If you haven't done so already, please read the CURE privacy notice by downloading it from here.

PrivacyNotice.pdf

Background

The CURE project exploits the Copernicus Core Services and develops 11 cross-cutting applications for urban resilience. These applications are:

- **Local scale surface temperature dynamics**
- **Surface urban heat island assessment**
- **Urban heat emissions monitoring**
- **Urban CO2 emissions monitoring**
- **Urban flood risk**
- **Urban subsidence, movement and deformation risk**
- **Urban air quality**
- **Urban thermal comfort**
- **Urban heat storage monitoring**
- **Nature-based solutions**
- **Health impacts (socioeconomic perspective)**

Integrated urban planning solutions, are promoted via the CURE applications including **nature based solutions**, that generate increased understanding of a wide range of socio-economic, and environment co-benefits arising from, for example, the green roof potential and performance (roof size and slope, orientation, use, shadowing etc) of individual buildings for energy conservation with co-benefits of city scale water run-off regulation, air quality improvement, and contribution to urban heat island moderation.

Urban heat island temperature is one of the most important parameters in climate monitoring, and in response the CURE **surface temperature dynamics application**, monitors the spatio-temporal behaviour of cities' surface temperature. Additional CURE applications provide frequent local scale surface temperature estimations for cities related to **surface urban heat island, urban heat emissions, thermal comfort and heat storage.** All assist urban planners to optimize their adaption strategies with regard to heat stress, and sustainable development optimisation.

Combined with other CURE applications, benefits related to key resilience challenges such as **CO2 emissions reduction, and flooding mitigation** are also created. The multi-scale aspect of flood risk assessment contributes to the main elements of the risk equation: hazard, vulnerability, exposure and resilience capacity. This urban flood risk service aims to support urban planners both during city preparedness and climate adaptation activities, as well as during emergency situations supporting city response activities. Additionally, **subsidence risk** assessment couples hazard monitoring with up-to-date assets information (land cover/land use at building block level). Such accurate assessment of threats and identification of vulnerabilities is critical for urban planners to understand and manage subsidence risk.

CURE applications also address the critical issue of **urban air quality**, which in combination with the specific cross-cutting **health impacts application** support the creation of healthy cities, promoting aspects, such as walkability, bikeability and access to green areas supporting an economically viable and sustainable urban development.

Questions

1. Which of the CURE applications are you most interested in – please choose one or more from the list below?

- ☐ Local Scale Surface Temperature Dynamics
- ☐ Surface Urban Heat Island Assessment
- ☐ Urban Heat Emissions Monitoring
- ☐ Urban CO2 Emissions Monitoring
- ☐ Urban Flood Risk
- ☐ Urban Subsidence, Movements And Deformation Risk
- ☐ Urban Air Quality
- ☐ Urban Thermal Comfort
- ☐ Urban Heat Storage Monitoring
- ☐ Nature-based Solutions
- ☐ Health Impacts (socioeconomic Perspective)

2a. Please select the option below that best describes your domain expertise

- ☐ Urban planner
- ☐ Policy maker
- ☐ Climate change expert
- ☐ Software developer
- ☐ Environmentalist
- ☐ Social scientist
- ☐ GIS expert
- ☐ Data analyst
- ☐ IT expert
- ☐ Geologist
- ☐ Others

2b. If you chose "Others", please specify

3. The application processes data from pre-selected multiple Copernicus services and provides new integrated information and intelligence for urban planning decision making. Please specify any additional

specific data and/or information you would like from CURE? Also please specify to which CURE application (s) your answer relates.

4. The application uses data from Copernicus DIAS (Direct Information and Access) services or 3rd party sources. Is there any 3rd party in-situ or local data that you would like to see integrated with the CURE application? Is this 3rd party in-situ or local data openly available? or can it be provided to CURE project for demonstration purposes? Please specify to which CURE application(s) your answer relates.

5a. The CURE applications apply different downscaling methods to translate Copernicus data from city-region to city and local scale. What resolution or scale best serves your needs? (you can choose more than one)

- ☐ Up to a few meters squared
- ☐ Up to 100s of meters squared
- ☐ Up to 10s of kilo-meters squared
- ☐ Up to 10s of meters squared
- ☐ Up to a few kilo-meters squared
- ☐ Others

5b. If you chose “Other”, please specify and also the CURE application to which your response relates.

6a. It is planned that the CURE applications will be deployed as cloud services. What other ways would you like to access CURE applications or its data? (you can choose more than one)

- [ ] File download
- [ ] Web map services
- [ ] Data APIs
- [ ] Others

6b. If you chose "Others", please specify

7. CURE applications will also use temporal data. Using a scale of 0 = Not at all important to 5 = Very important, what temporal scales are important for your organisation?

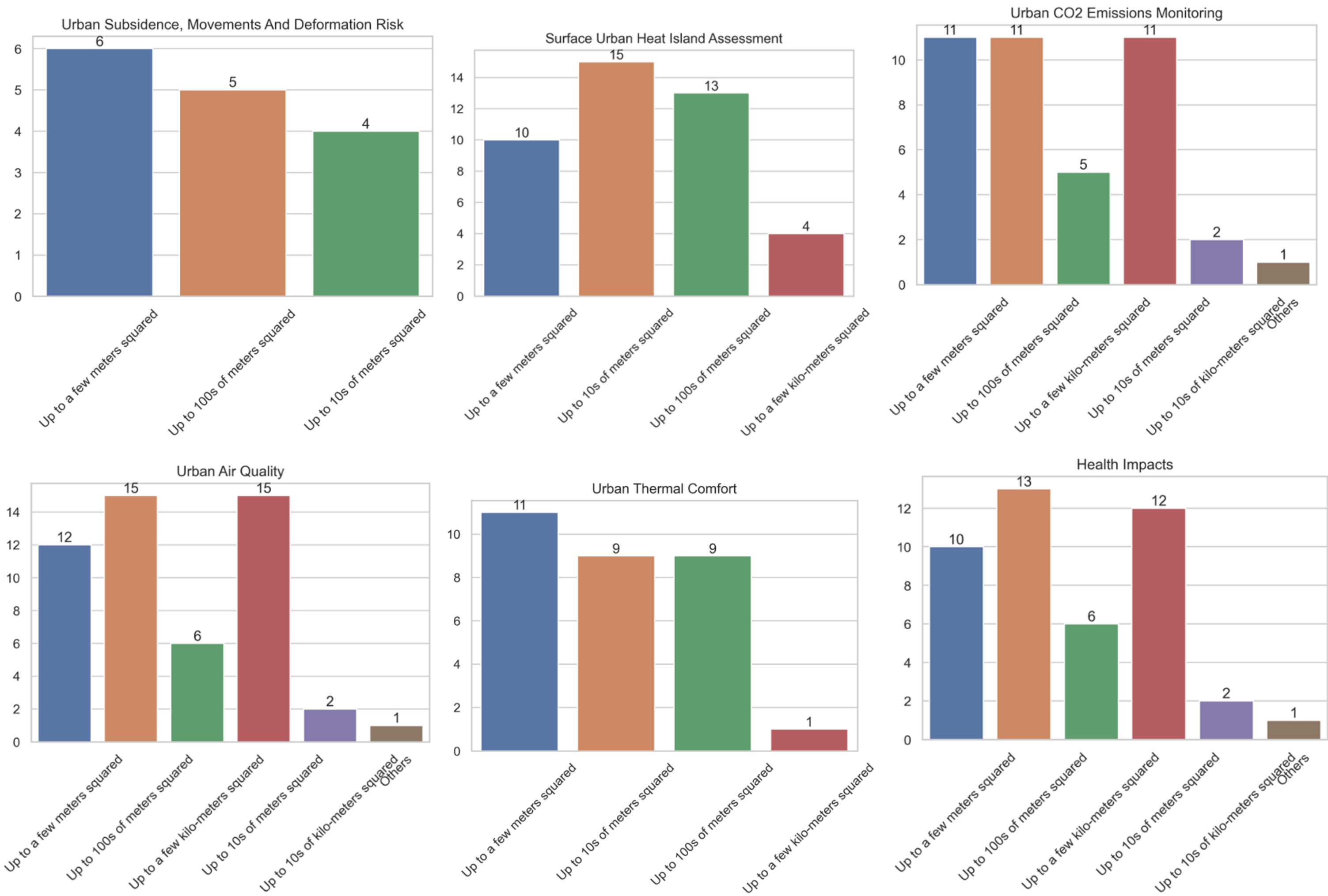
	0	1	2	3	4	5
Hourly data	○	○	○	○	○	○
Daily data	○	○	○	○	○	○
Weekly data	○	○	○	○	○	○
Monthly data	○	○	○	○	○	○
Quarterly data	○	○	○	○	○	○
Annual data	○	○	○	○	○	○

8. Please specify any additional needs or requirements not addressed by the above questions.

B Application-specific Detailed Analysis of the Responses to Various Questions

B.1 Question 5

Figure 10 shows application-specific responses to Question 5.


Urban Subsidence, Movements And Deformation Risk
6
5
4
Up to a few meters squared
Up to 100s of meters squared
Up to 10s of meters squared
Surface Urban Heat Island Assessment
10
15
13
4
Up to a few meters squared
Up to 10s of meters squared
Up to 100s of meters squared
Up to a few kilo-meters squared
Urban CO2 Emissions Monitoring
11
11
5
11
2
1
Up to a few meters squared
Up to 100s of meters squared
Up to a few kilo-meters squared
Up to 10s of meters squared
Up to 10s of kilo-meters squared
Others
Urban Air Quality
12
15
6
15
2
1
Up to a few meters squared
Up to 100s of meters squared
Up to a few kilo-meters squared
Up to 10s of meters squared
Up to 10s of kilo-meters squared
Others
Urban Thermal Comfort
11
9
9
1
Up to a few meters squared
Up to 10s of meters squared
Up to 100s of meters squared
Up to a few kilo-meters squared
Health Impacts
10
13
6
12
2
1
Up to a few meters squared
Up to 100s of meters squared
Up to a few kilo-meters squared
Up to 10s of meters squared
Up to 10s of kilo-meters squared
Others

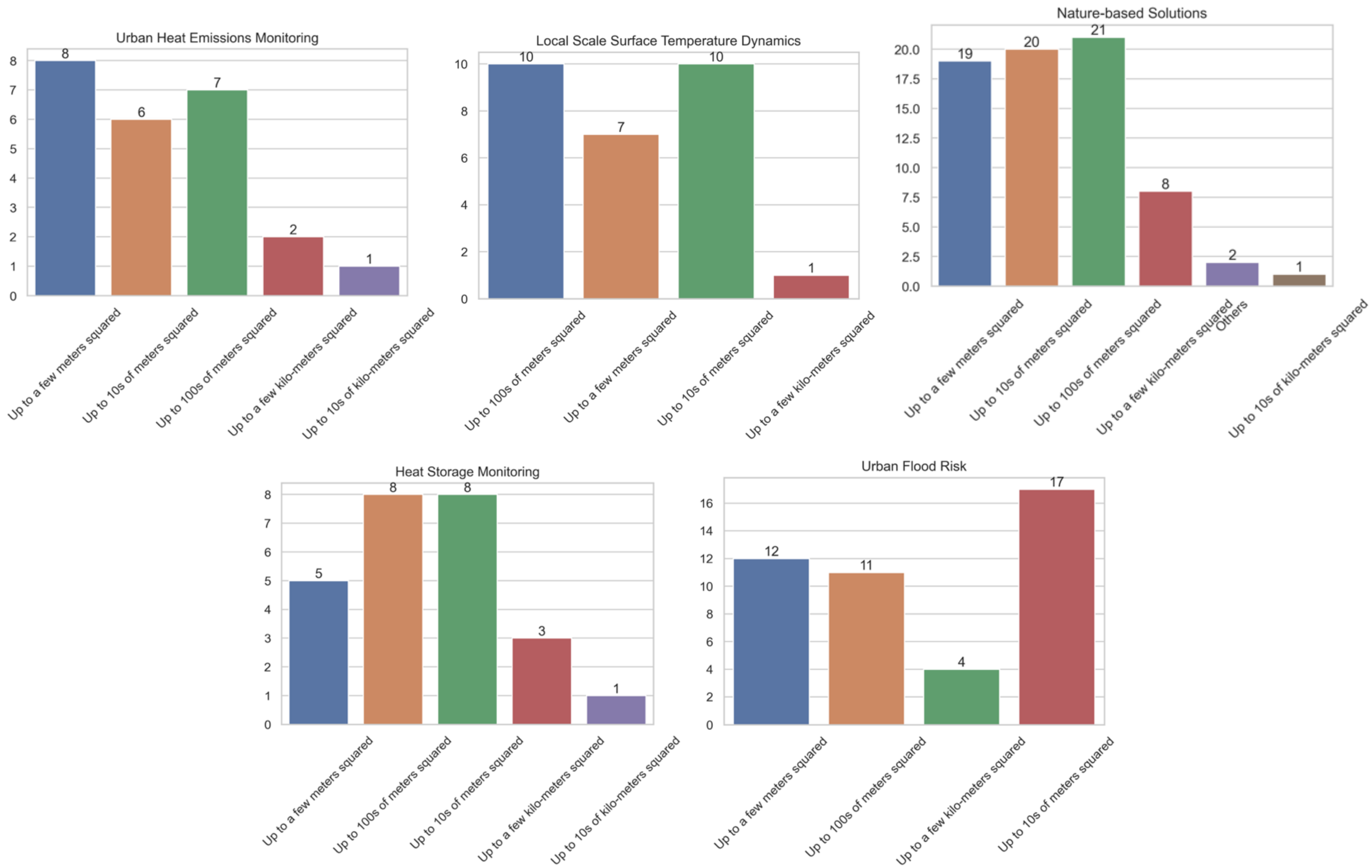
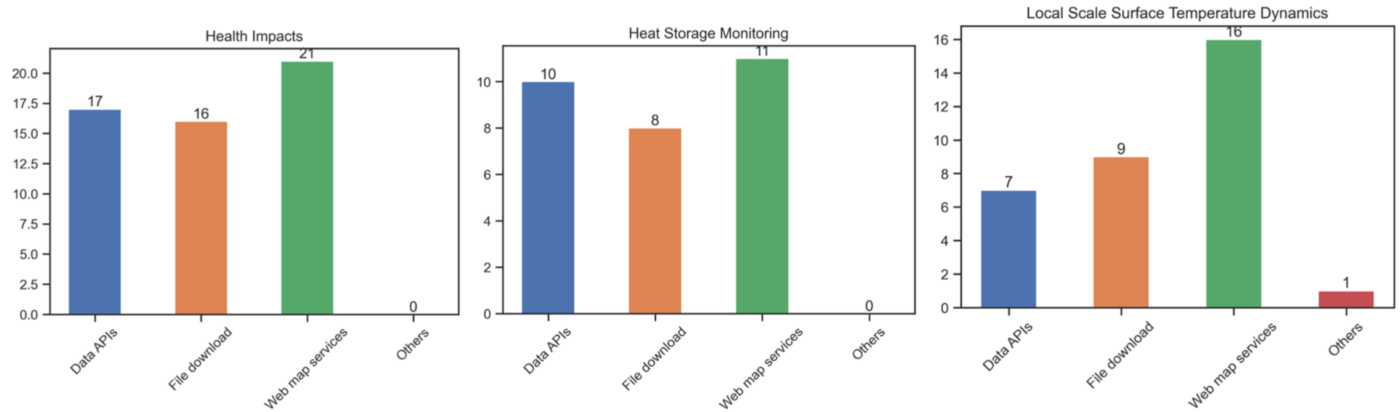
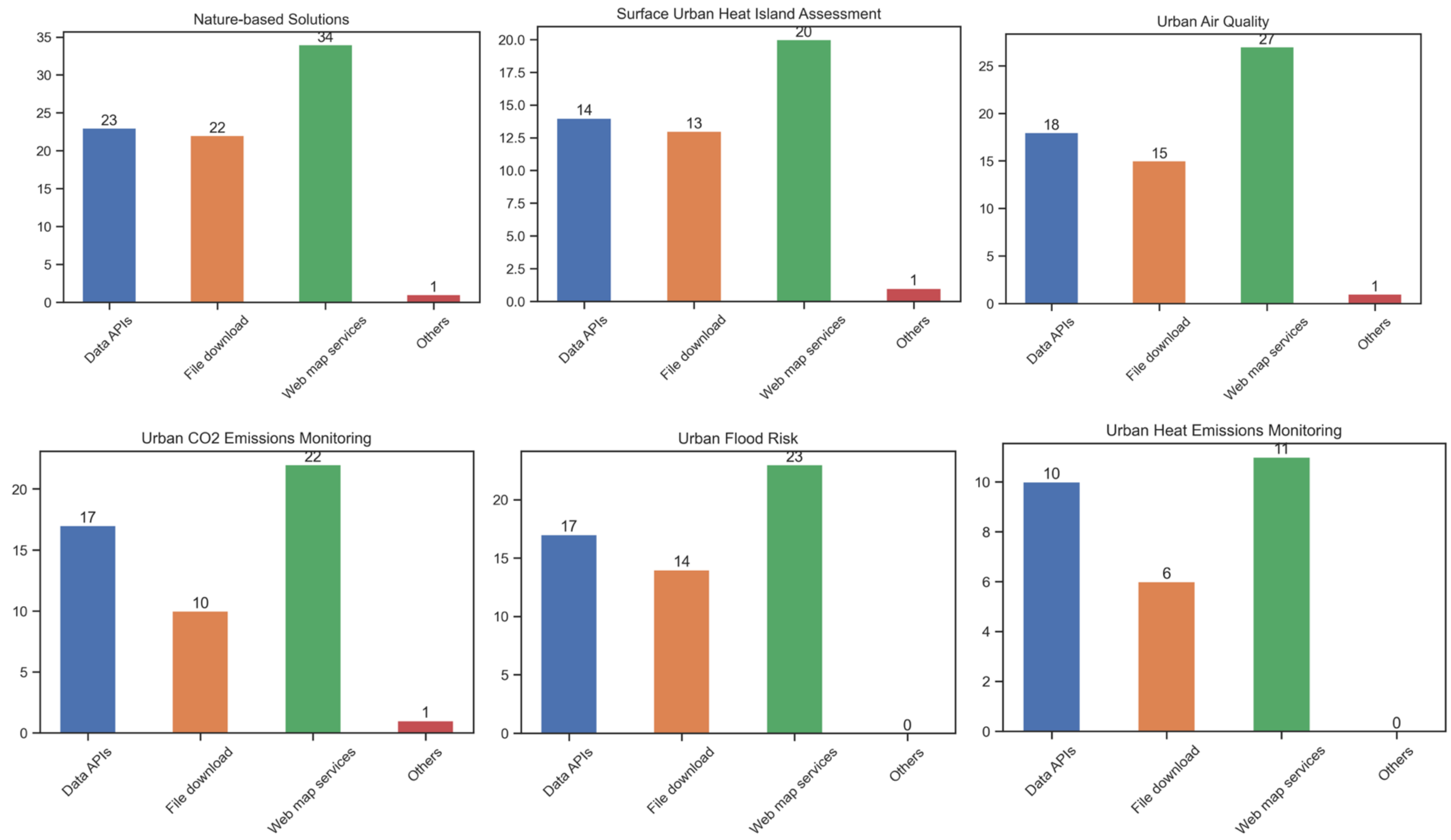


Figure 10: Application-specific responses to Question 5.

B.2 Question 6

Figure 11 shows application-specific responses to Question 6.




Nature-based Solutions
23
22
34
1
Data APIs
File download
Web map services
Others
Surface Urban Heat Island Assessment
14
13
20
1
Data APIs
File download
Web map services
Others
Urban Air Quality
18
15
27
1
Data APIs
File download
Web map services
Others
Urban CO2 Emissions Monitoring
17
10
22
1
Data APIs
File download
Web map services
Others
Urban Flood Risk
17
14
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Data APIs
File download
Web map services
Others

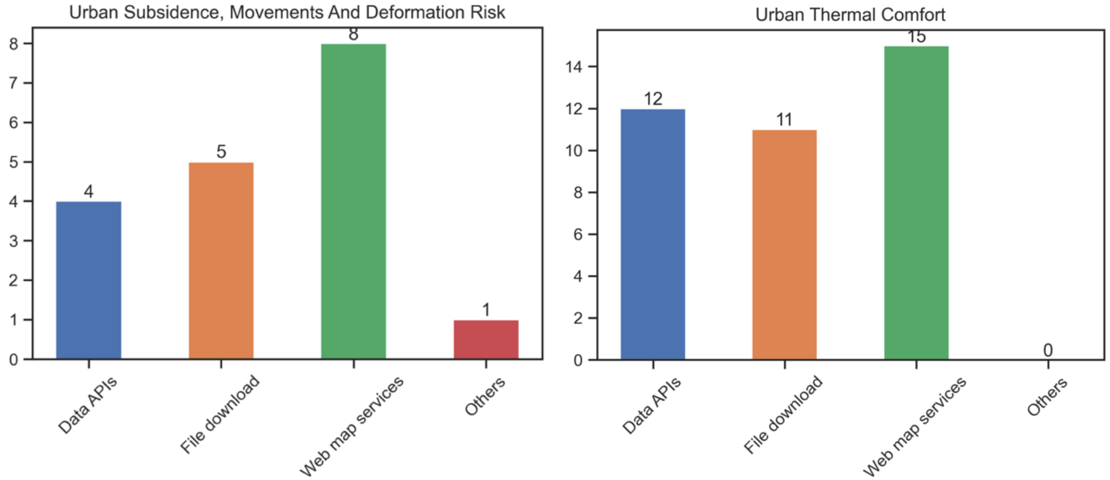
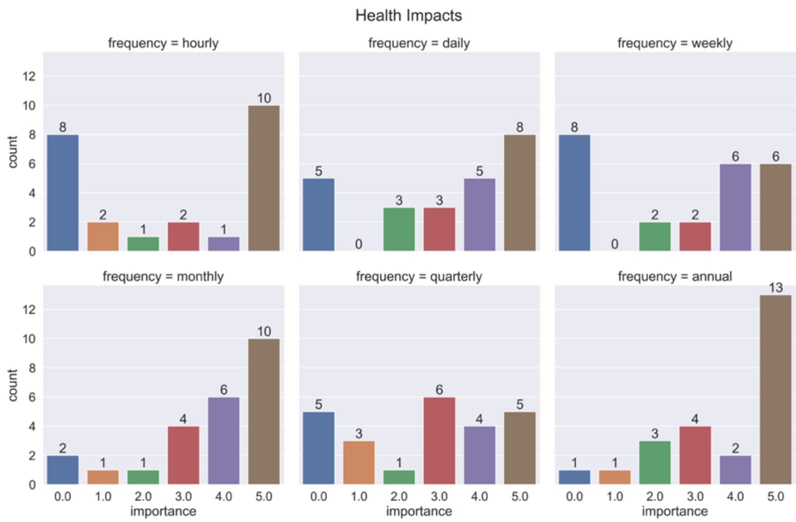
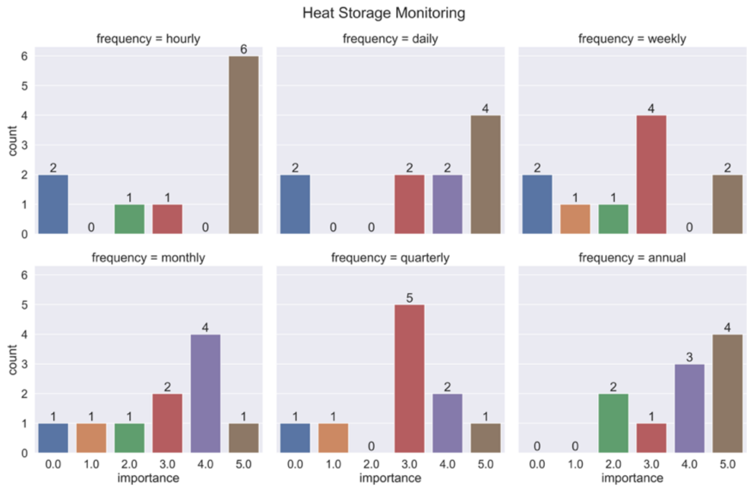


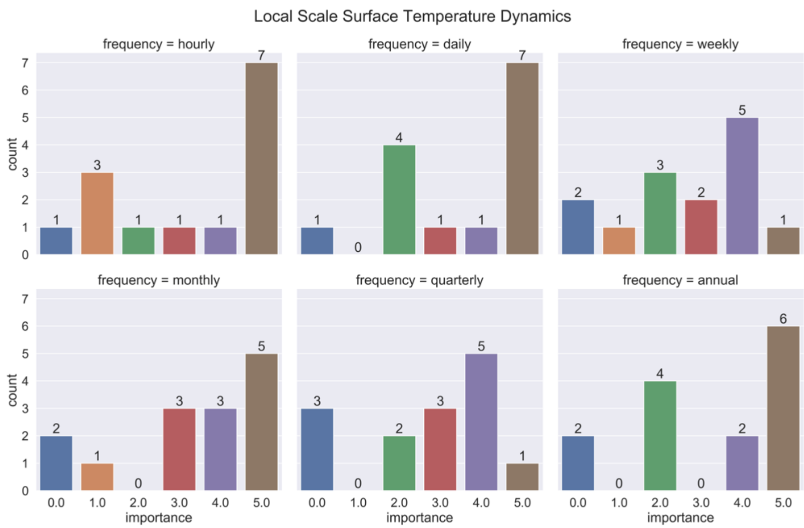
Figure 11: Application-specific responses to Question 6.

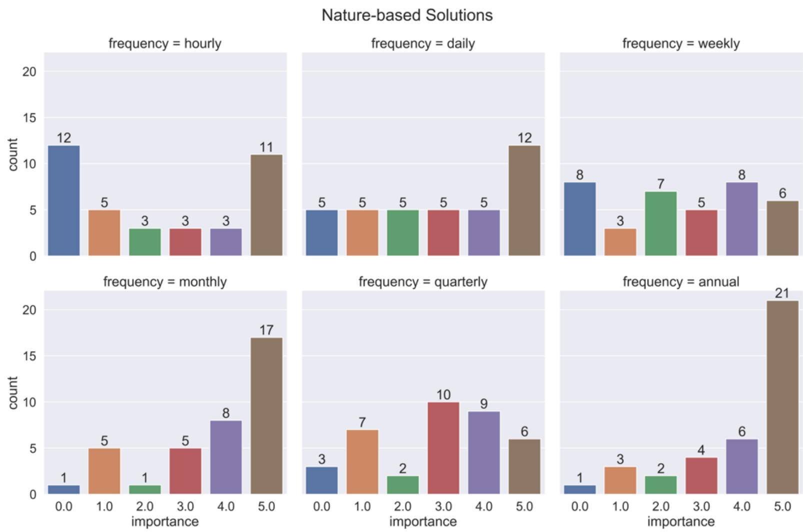
B.3 Question 7

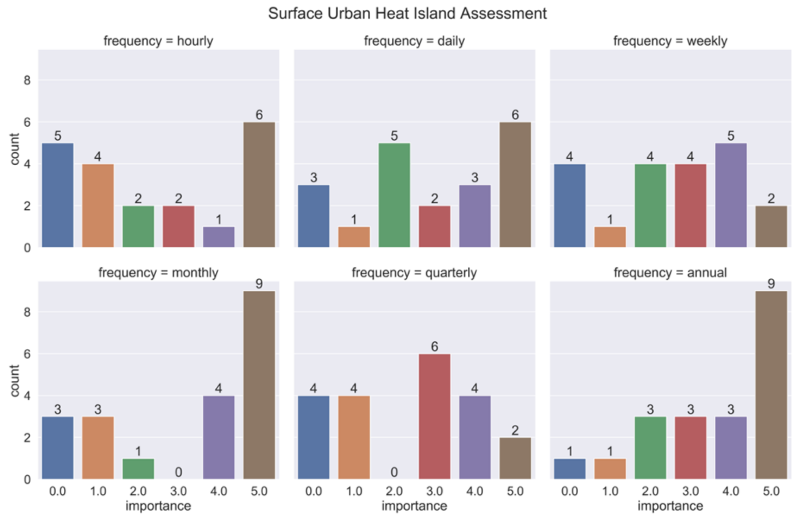
Figure 12 shows application-specific responses to Question 7.

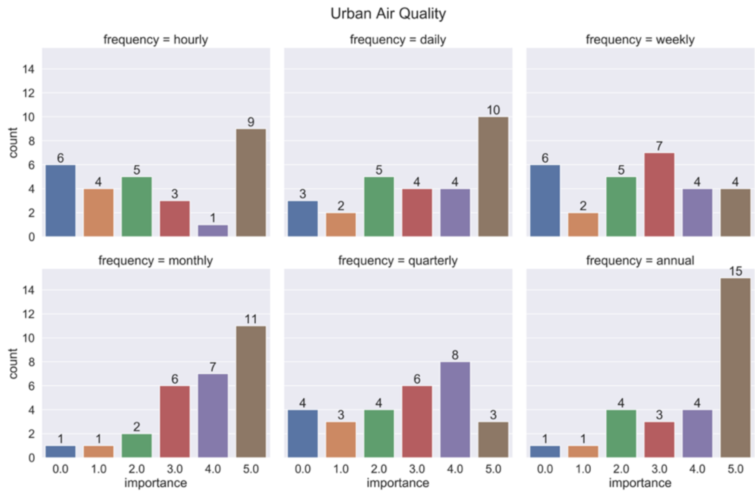

Health Impacts
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance


Heat Storage Monitoring
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance

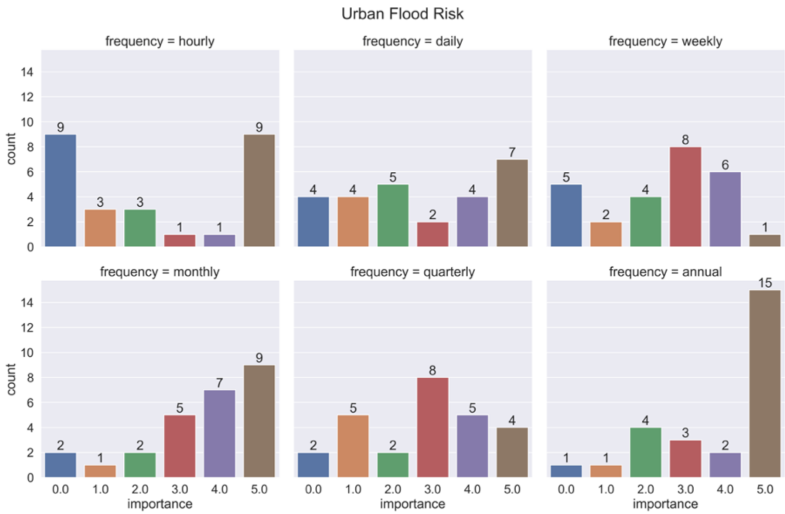

Local Scale Surface Temperature Dynamics
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance


Nature-based Solutions
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance


Surface Urban Heat Island Assessment
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance


Urban Air Quality
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance


Urban CO2 Emissions Monitoring
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance


Urban Flood Risk
frequency = hourly
frequency = daily
frequency = weekly
frequency = monthly
frequency = quarterly
frequency = annual
count
importance

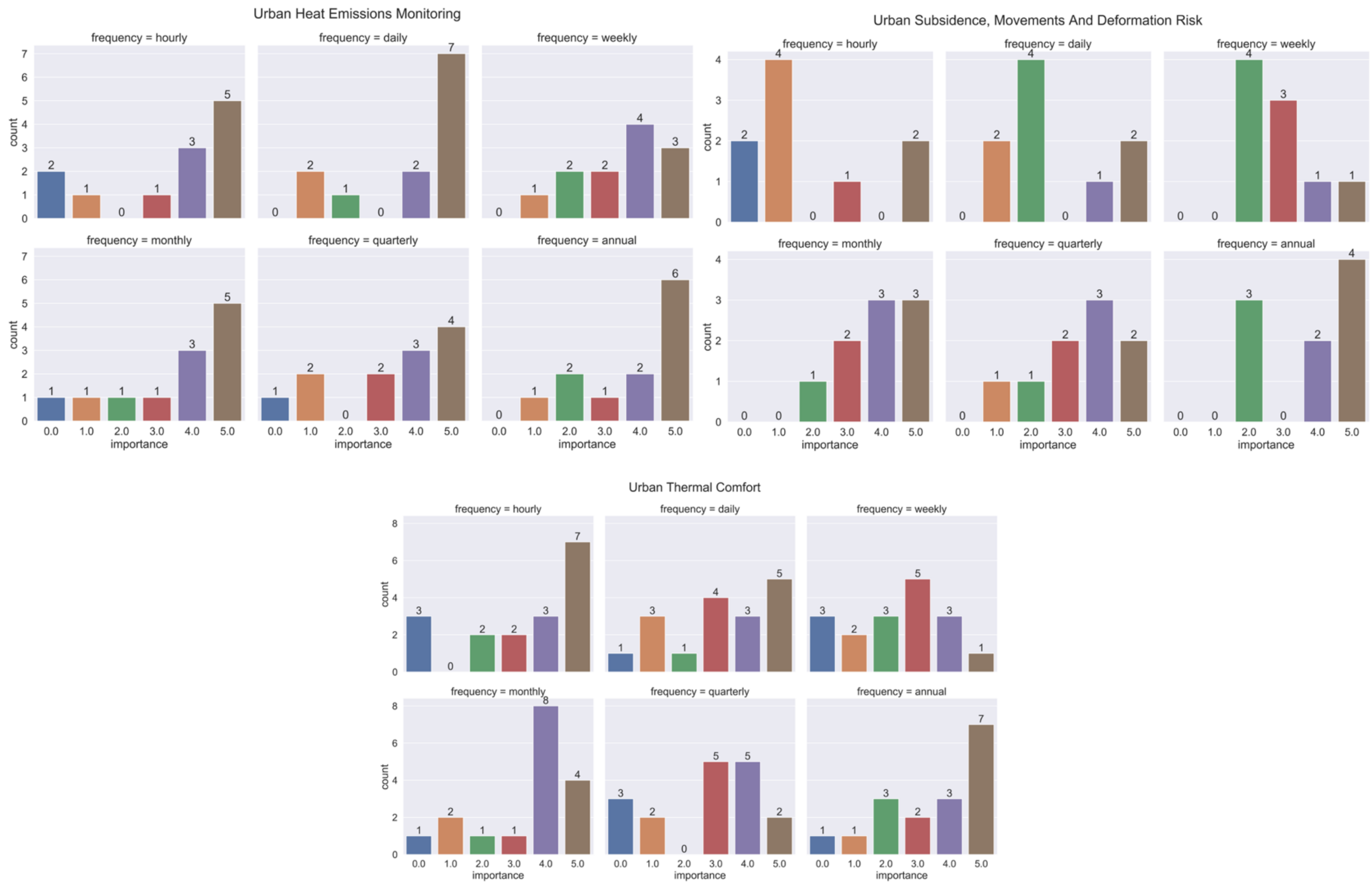


Figure 12: Application-specific responses to Question 7.

Appendix - B

Qualitative responses

Please note selected responses were slightly modified or removed to protect the privacy/anonymity conditions.

Q3 - Raw responses

Response	Specific CURE Applications or General*	Q1 CURE Applications
Green roof areas	NBS	UFR; UHSM; SUHIA; USMDR; NBS; UHEM; UAQ; HI; UCO2EM; UTC
Structured time series and possibility to extract time series at specified coordinates through APIs	All applications	UFR; UHSM; SUHIA; USMDR; NBS; UHEM; UAQ; HI; UCO2EM; UTC
Issuing an alert when a predefined threshold is reached	UFR, UAQ, Urban Heat related apps	SUHIA; NBS; UHEM; UTC
Ability to interface with existing or future information systems deployed in the city decision centres	All applications	SUHIA; NBS; UHEM; UTC
Data of building (Floors) and of wind for implementing monitoring temperature and emissions	General	LSSTD; UHSM; SUHIA; USMDR; NBS; UHEM; UAQ; HI; UCO2EM; UTC
Social data	General	UFR; NBS; UHEM; HI

Spatial structure of the urban and suburban areas – basis for transport policy	General	NBS
Urban planning - traffic data and data on social activity (visual methods through satellite picture) as additional source to more conventional sources	General	LSSTD; NBS; UAQ; HI; UCO2EM; UTC
Zustande transport, smart city, intelligent government	General	UFR; NBS; UAQ; UCO2EM
A Differentiation and reality check between UHI models and local Climate zones (LCZ) from wudapt	SUHIA, UTC	SUHIA, NBS, UTC
I would like to know more about soil and land condition	General	UFR; USMDR; NBS; UHEM; UTC
General: GIS data 2D and 3D urban: 3D City model data	General	UFR; NBS; UHEM; UAQ; UCO2EM
Spatial models for calculating urban heat islands	SUHIA	SUHIA, NBS, HI
Nature-based solutions in combating climate changes risks	NBS	SUHIA, NBS, HI
Simulation of Climate protection and Adaptation measures. Mitigating Climate Change by reducing CO2 emissions. Preventing intelligent heat and cooling Control based on weather forecasts. Building specific Energy consumption and supply map indicating where it is worth refurbishing the Buildings and renewing the Energy supply form.	General	NBS; UHEM; UAQ; HI; UCO2EM
Concentration of short-term air pollution (PMx, NOx, SOx) especially during winter season Would be especially useful if the map resolution was big enough to allow pinpointing of big polluters	UAQ	LSSTD; UAQ
soil permeability (sub-surface zone) i.e. Soil capacity to absorb water	UFR and NBS	UFR; NBS; HI
It would be interesting to have integration of the above CURE applications with other data bases of the EU collecting data about risks behind natural events such as earthquakes or climate adverse events that were caused by climate change such as typhoons or similar hitting the European continent.	General	LSSTD; UFR; UHSM; SUHIA; NBS; UHEM; UAQ; HI; UCO2EM; UTC

cultural heritage data (e.g. heritage zones) nature protection data surface elevation data building heights	General	NBS; UAQ; HI; UCO2EM
Land cover and land use mapping	UFR	UFR; SUHIA; NBS; UTC
Access to other frequency signals and resolution than those of Sentinel 1 and CAT´s technology	USMDR	UFR; USMDR
Additional specific data and/or information around energy performance of buildings as one of the policy areas of the European Green Deal	General	LSSTD; UHSM; SUHIA; USMDR; NBS; UTC
Another application providing data on (multi-modal) traffic flows	General	NBS; UAQ; HI
for my work as urban planner I strongly depend on data analysis for design & research as well as for decision making. What I now find very confusing that for every data I need I must know and visit different websites providing information about flood risk, location height, energy labels of buildings, heat island effect, biodiversity, % of houses with solar panels, it would be fantastic to have all this knowledge combined on one website where you are able to click different information on a map. If that would be standard for Europe it would be even more great since often you need to compare different cities with each other and like to use the same data. Now often data is varying in year of conduct, varying from methodology or not of the exact same location.	General	SUHIA; UFR; UAQ; HI
cartographic maps (buildings, streets etc) DEMs Access to local sensor data	General	LSSTD; UFR; USMDR; UAQ
Information about albedo of urban surface, imperviousness and percentage of green areas	General	LSSTD; UFR; UHSM; SUHIA; NBS; UAQ; HI; UCO2EM; UTC

Change detection of specific land use classes (green areas, agriculture, forest, rural areas, building development) as very important (monitoring functions of Copernicus services). To adopt this information for urban use, the scale of information must be useful for urban demands (appr. 10*10 m^2) and must be available a short time after detecting. Another very interesting theme should be the analysis and monitoring of the index "green-volume" in urban areas in addition to impervious soil coverage detection.	NBS and General	LSSTD; UFR; UHSM; SUHIA; UTC
Preferably for urban planning higher resolution of all applications. Planning changes from day to day. It is not necessary to dispose of several years old data. Consider some other part of Moravian Silezian region (Ostrava is a city in Moravian Silezian Region) for application (USMDR).	General	LSSTD; SUHIA; USMDR; NBS; UAQ; UCO2EM
Apart from the nitrogen dioxide other pollutants, ie. PM10 and PM2,5. Similar tool for assessment of the unsealed surfaces in cities (green areas), tools for assessment of the green and/or blue corridors cutting several neighbourhoods. Important factor - hourly dynamics of the emissions (especially related to the working - living urban patterns). Health problems are always complex. The data which would help to pinpoint the level of impact of specific factors would of great help, which mostly demands huge data basis to provide the cause-effect proof. Very interesting elements are: air pollution, acoustic quality (not only noise, but on the contrary - proximity of green areas which provide different soundscape), walkability.	UAQ NBS UHEM HI	LSSTD; NBS; UHEM; HI; UTC
The behavioural habits of the population mobility should and can change due to the improvement of mobility comfort matched with the mobility cost reduction.	General	UAQ; UCO2EM

The technology progress enables an efficient improvement of the quality of mass transport and can significantly contribute to a large reduction of environment pollution. Available data concerning the development of city mass transport systems can allow to assess their impact on the environment.		

* General represents a response where the participant did not explicitly indicate the CURE application to which the response relates to.

Q4 - Raw responses

Response	Specific CURE Applications or General*	Q1 CURE Applications
To exploit open data repositories available in different regions. But this means to map their full/relevant list and to check accessibility and API availability, etc. An example could be: https://opendatahub.bz.it/	General	UFR; UHSM; SUHIA; USMDR; NBS; UHEM; UAQ; HI; UCO2EM; UTC
Traffic monitoring and traffic anticipation data (e.g. for urban air quality)	(UAQ)	SUHIA; NBS; UHEM; UTC
It would be interesting to make Copernicus data (especially those on urban temperatures) interact with the development plans of cities	General	LSSTD; UHSM; SUHIA; USMDR; NBS; UHEM; UAQ; HI; UCO2EM; UTC
Local Urban Heat Island Maps of cities as overlays	(SUHIA, UTC)	SUHIA, NBS, UTC
Data from cities existing applications and sensors such as City of Antwerp has its own urban heat prediction data that could be incorporated. In addition, data from 8 rain sensors which provide the city with real time insights about rain intensities	General (SUHIA, UHEM)	UFR; USMDR; NBS; UHEM; UTC

CORINE data Data on land use and land cover	NBS and SUHIA	SUHIA, NBS, HI
Open city data e.g., https://smartcity.wien.gv.at/site/en/open-government-data-2/	General	LSSTD; SUHIA
Combine with other socio-economic and energy-related data to better understand data patterns.	General	NBS; UHEM; UAQ; HI; UCO2EM
Open street map data including point of interest data Population grid (e.g., from Eurostat)	General	NBS; UAQ; HI; UCO2EM
Free Digital Surface or Terrain Models from DGT (Direção Geral do Território in Portugal, Lisbon) from the orthophoto production.	General	UFR; USMDR
World Urban Database (http://www.wudapt.org/) for Surface Urban Heat Island Assessment	SUHIA	LSSTD; SUHIA; UHSM; USMDR; NBS; UTC
socio-economic data > CBS (Statistics Netherland) https://www.cbs.nl/en-gb/our-services/open-data/statline-as-open-data Potential of solar, wind, geothermal energy > https://www.nationaleenergieatlas.nl/ height maps > https://www.ahn.nl/ahn-viewer?origin=/common-nlm/viewer.html simulator of flood risk with sea level rise with data about population density, social vulnerability, > https://ss2.climatecentral.org/#9/40.7613/-73.5949?show=property&projections=0-K14_RCP85-SLR&level=10&unit=feet&pois=hide	SUHIA; UFR; HI; General	SUHIA; UFR; UAQ; HI
Data from national mapping agencies Meteorological datasets	General	LSSTD; UFR; USMDR; UAQ
Open geographical data with free access e.g., Berlin open data - https://daten.berlin.de/	General	LSSTD; UFR; UHSM; SUHIA; UTC

Possible integration of information from citizen-science. For nature-based solutions, it could be relevant to know existing alien species and to avoid favouring its expansion. There is already a monitoring scheme https://digitalearthlab.jrc.ec.europa.eu/activities/invasive-alien-species-monitoring-citizen-scientists/57833	NBS; General	UFR; SUHIA; NBS; HI
Data products from DLR (Deutsches Zentrum für Luft- und Raumfahrt, German Aerospace Center, (https://www.dlr.de/content/en/sites/braunschweig.html) and PTP (The National Metrology Institute of Germany, https://www.ptb.de/cms/en.html)	General	UAQ; UCO2EM

* General represents a response where the participant did not explicitly indicate the CURE application to which the response belongs to.

Q8 – Raw responses

Response	**Specific CURE Applications or General***	**Q1 CURE Applications**
Important for work is to access to data when it is needed, and not too often	General	UFR; NBS
High frequency temporal variation of the data on urban floods	UFR	UFR; SUHIA; NBS; UAQ; HI; UCO2EM; UTC
Day vs night peaks	General	LSSTD; UFR; UHEM; UAQ; UCO2EM
Applications could be combined with Gamification and behaviour Change interventions. Useful to improve Quality of life in cities & communities. Connect CURE to smart City developments.	General	NBS; UHEM; UAQ; HI; UCO2EM
Consider upcoming Ground Motion Service to be implemented by EEA in coming years as input to the Urban Subsidence, Movements and Deformation Risk - https://land.copernicus.eu/user-corner/technical-library/european-ground-motion-service	USMDR	LSSTD; UHSM; SUHIA; USMDR; NBS; UTC

These are also needed for medium sized and small towns - air pollution and air quality is not only a problem in large cities and agglomerations but can locally also problematic in smaller cities	General	UHSM; NBS; UAQ; HI; UCO2EM
In order to evaluate the trend of each variable in relation to climate change, time series as long as possible (depending of the data availability) are highly welcomed	General	LSSTD; UFR; UHSM; SUHIA; NBS; UAQ; HI; UCO2EM; UTC
Build a user community of the involved cities/regions for internal exchange of knowledge and questions	General	LSSTD; UFR; UHSM; SUHIA; UTC
Comfortable, reachable and usable Copernicus urban services are crucial for the implementation in the daily work of the city administrations	General	LSSTD; UFR; UHSM; SUHIA; UTC
Hourly data allows integration in smart city systems	General	UFR; UHSM; NBS; UAQ; HI; UCO2EM; UTC
Application on Moravian Silesian region (in addition to Ostrava) to prepare an adaptation strategy	General	LSSTD; SUHIA; USMDR; NBS; UAQ
Data must be accumulated 24/7. All data must be geo-referenced.	General	UFR; NBS; HI
Must have integrated and harmonised metadata and interpretation. Consideration of INSPIRE Directive.	General	UFR; NBS; HI

* General represents a response where the participant did not explicitly indicate the CURE application to which the response belongs to.

Appendix - C

City specific Requirements Question

A	B	C	D	E	F	G	H	I	J
Requirements / **Focus** / **CURE Applications**	**What is CURE offering to cities and do city participants see potential of other CURE applications in their cities?**	**Are there any specific needs of cities where CURE applications be useful? Do cities see benefits/added-value of these applications (policy benefits, efficiency, new source of data)?**	**Are there any relevant local or national (or EU) policies/agendas or specific uses where CURE applications can help cities? This will provide some context to rationalise use of specific CURE applications for cities.** **It would be useful to know which planning challenges and/or policy needs CURE applications can contribute to?**	**Who are potential local stakeholders of CURE applications? Who should we contact if we need to get additional information such as local data access points and/or clarification of requirements?**	**Are there any specific features which cities would like to see in CURE applications? This can be around cross-cutting application integration aspects and/or local issues where there is limited or no reliable data available.**	**Is there any real use case (or planning/policy challenges) where a CURE application can be applied and tested (validated)? Can cities suggest study areas/area of interest (e.g., district, neighbourhood or city-region) for the CURE application development and demonstration?**	**Is there any expectation on temporal and spatial resolution or projection (CRS - Coordinate Referencing System) from the CURE applications?**	**Once the CURE applications/platform is ready, what would be the preferred data format and access mechanism?**	**General comments**
To be filled based on the mini-dialogues and further communication			What are these policy/planning challenges where previously identified CURE applications can contribute? 2. Others?	Are there other data sources? Who should we contact if we need any other local data?	Is there any specific feature such as new data category or/and cross-disciplinary information city would like to see in a specific application? Are you expecting new data only or a final customised product (e.g., rerospective analysis, parameteric causual analysis, predictive analysis, etc.) from the CURE project? For later what should be included in the final product?	For each application, is there a specific user story/use case that can be used to develop and validate the outcome of the application? From this user story we should be able to know why a specific CURE application important for Heraklion?	What is an ideal expected frequency of updated data (daily, weekly, monthly, annually, etc.) for the city? CURE applications work at local scale e.g., 100x100m. What is an ideal expected spatial resolution scale for the city (e.g., 10x10m; 100x100m, 1Kmx1Km etc.)? Are there any other city specific constraints that CURE applications should adhere to?	**Format:** Which data format is appropariate for Heraklion? Raster images? Vector data? Others? **Data access:** What data access method is suitable for the city? e.g., APIs?, File download?, Others? **Metadata:** What Metadata standard suitable for the city? Are there any GDPR/local specific privacy related conditions to which CURE must adhere to?	Any other concern that is not covered in previous questions but is important for city's point of view e.g., application development timeline? Etc.
If answer(s) to above questions are specific to a particular CURE application then please use the following rows to add your answers:									
1. Local Scale Surface Temperature Dynamics									
2. Surface Urban Heat Island Assessment									
3. Urban Heat Emission Monitoring									
4. Urban CO2 Emission Monitoring									
5. Urban Flood Risk									
6. Urban Subsidence, Movement and Deformation Risk									
7. Urban Air Quality									
8. Urban Thermal Comfort									
9. Urban Heat Storage Monitoring									
10. Nature Based Solutions									
11. Health Impact (socioeconomic perspective)									

Please note that the detailed responses to City requirements questions are covered in separate confidential excel documents. These will be living documents and will be used to cover changes in requirements or evolving requirements.

Appendix – D

List of relevant publications for Sofia studies:

1. Lidia Lazarova Vitanovaa, Hiroyuki Kusaka, (2018), Study on the urban heat island in Sofia City: Numerical simulations with potential natural vegetation and present land use data, Sustainable Cities and Societies, Vol. 40, pp. 110-125. URL: https://www.sciencedirect.com/science/article/abs/pii/S2210670717317377
2. Rita Pongrácz, Judit Bartholy, Zsuzsanna Dezső, (2010), Application of remotely sensed thermal information to urban climatology of Central European cities, Physics and Chemistry of the Earth, Parts A/B/C, Vol. 35, Issues. 1-2, pp. 95-99. URL: https://www.sciencedirect.com/science/article/pii/S1474706510000197
3. Dimitrova, R.; Danchovski, V.; Egova, E.; Vladimirov, E.; Sharma, A.; Gueorguiev, O.; Ivanov, D. (2019). Modeling the Impact of Urbanization on Local Meteorological Conditions in Sofia. Atmosphere 2019, 10, 366. URL: https://www.mdpi.com/2073-4433/10/7/366
4. Nikolay Kolev, Plamen Savov, Evgeni Donev, Danko Ivanov, Tsvetina Evgenieva, Vera Grigorieva & Ivan Kolev (2011) Boundary layer development and meteorological parameters impact on the ground level ozone concentration over an urban area in a mountain valley (Sofia, Bulgaria), International Journal of Remote Sensing, 32:24, 8915-8933, DOI: 10.1080/01431161.2010.524679. URL: https://www.tandfonline.com/doi/abs/10.1080/01431161.2010.524679
5. DIMITROVA RENETA, DANCHOVSKI VENTSISLAV, EGOVA EVGENIA, VLADIMIROV EVGENI. MODELLING THE IMPACT OF VANISH GREEN AREAS ON LOCAL METEOROLOGICAL CONDITIONS IN SOFIA, BULGARIA. (Draft available).
6. Ivan Yanev, Lachezar Filchev, (2016), A COMPARATIVE ANALYSIS BETWEEN MODIS LST LEVEL-3 PRODUCT AND IN-SITU TEMPERATURE DATA FOR ESTIMATION OF URBAN HEAT ISLAND OF SOFIA, Bulgarian Academy of Sciences. Space Research and Technology Institute. Aerospace Research in Bulgaria. 28, 2016, Sofia. URL: http://journal.space.bas.bg/arhiv/n%2028/Volume_28.pdf#page=78