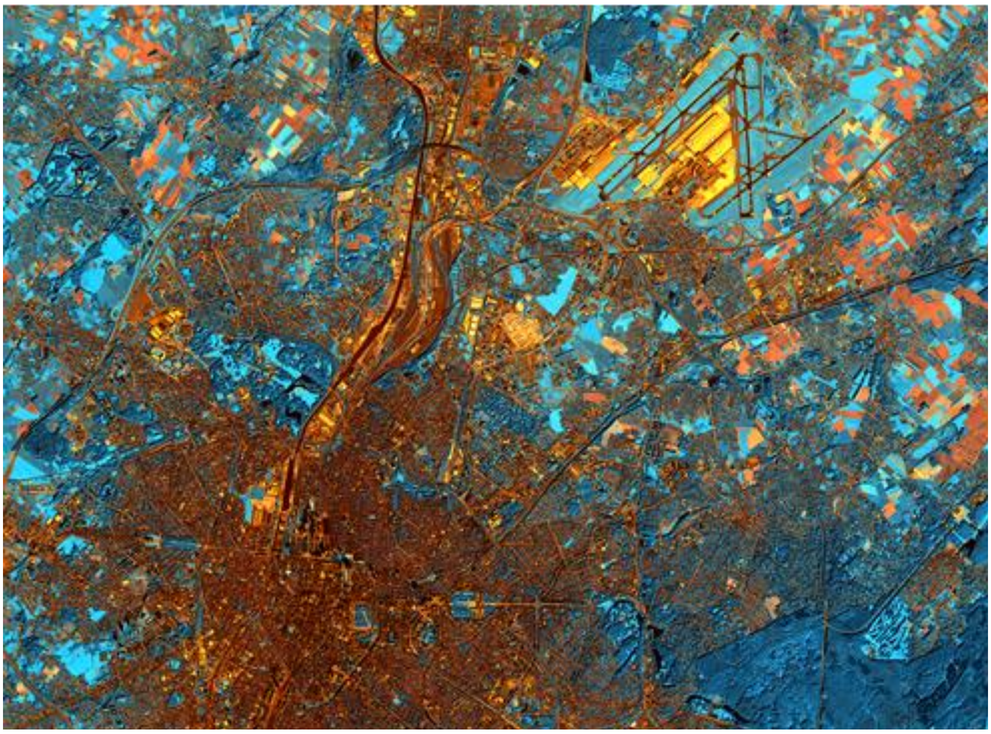

CURE

June 2022

COPERNICUS FOR URBAN RESILIENCE IN EUROPE

Editorial

by Nektarios Chrysoulakis

CURE (Copernicus for Urban Resilience in Europe) is one of the three projects that were funded from the Horizon 2020 Space call on Copernicus evolution (LC-SPACE-04-EO-2019-2020). It is a joint effort of 10 partners that synergistically exploit Copernicus Core Services to develop an umbrella application for urban resilience (CURE System) based on DIAS (Data and Information Access Services). This System consists of 11 Cross-cutting Applications, evaluated at several European cities, for climate change adaptation/mitigation, energy and economy, as well as healthy cities and social environments.

The CURE project attempts to innovatively deploy information from Copernicus Core Services concerning atmosphere, land, climate change and emergency; in order to address the multidimensionality of urban resilience. In parallel, it exploits spatially disaggregated environmental Earth Observation (EO) data and products, which are not directly available from the Copernicus Core Services, such as data from contemporary satellite missions and in-situ observations. All the above are combined with third-party EO modelling towards coping with the required local scale.

The main project's milestones for the first half of 2022 concerned the 2nd Review Meeting and the CURE Cross-cutting Applications evaluation and integration. More specifically, the 2nd Review Meeting was held in April 2022 and was related to the report of second-year activities and results of the project, while the 4th Progress Meetings was held at the beginning of 2022 and aimed at coordinating activities of the project partners for the fifth semester of the project. Moreover, the CURE Copernicus Core Services Interface was updated, the CURE Cross-cutting Applications development was completed and the CURE System was finalised, leading to the creation of a brochure including the key CURE outputs. Finally, a benchmarking, scenarios and economic feasibility analysis was conducted towards enhancing the project exploitation.

The 5th issue of the CURE Newsletter introduces three more CURE Cross-cutting Applications: a) Urban Heat Storage Monitoring Application (AP09), b) Nature-Based Solutions Application (AP10) and c) Health Impacts Application (AP11). Also, the main CURE project news during this period are described in this issue.

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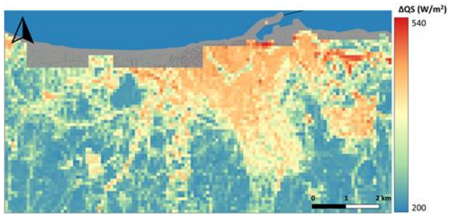

Urban Heat Storage Monitoring Application

This Application provides time series maps of the energy change rate, either stored in or released from the urban elements.

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Nature-Based Solutions Application

This Application provides green roof potential and priority at building scale considering the characteristics and challenges of each city.

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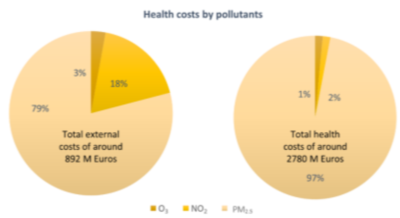

Health Impacts Application

This Application provides a detailed survey to indicate how many people die prematurely due to air pollution and the associated costs for society.

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Urban Heat Storage Monitoring Application

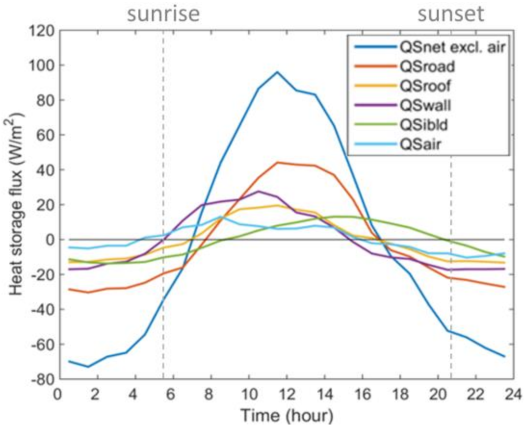
by Manolis Panagiotakis and Zina Mitraka

Cities Storing and Releasing Heat

Observations of global temperature evolution indicate a pronounced air temperature warming, since an increase in the occurrence of heat waves and the Urban Heat Island (UHI) effects tends to exacerbate such warming. Among all the effects caused by the substitution of natural ecosystems for urban land-use, the most pronounced is the increase in the amount of energy stored in the urban canopy (especially in buildings), which is approximately 2-6 times larger than in non-urban canopies. The slow release of this energy, stored mainly in the buildings and paved surfaces of cities, causes the UHI effect and it is related to the energy efficiency and consumption in cities.

The CURE AP09 deploys various EO data, such as land cover, geometry, radiation and air/surface temperature, towards monitoring urban heat storage change. The heat storage flux (ΔQS) is defined as the net flow of heat stored within an urban volume that includes air, trees, buildings and ground. The ability to absorb, store and release heat depends on the thermal mass and morphology of the urban surface.

The figure below shows example heat storage flux changes during the day for different materials. The distinct behaviour in terms of heat storage for different urban features is evident. For example, the roof and wall surfaces, illustrated with yellow and purple lines respectively, start the heat storing almost immediately after the sunrise (marked with dotted grey line). The street surfaces on the other hand, marked with the red line, start the heat storing later in the day, but with a much faster pace. Such analyses, quantifying the heat storage at local scale, are really useful for choosing the right materials and an optimum orientation of the urban surfaces. Moreover, they support a) identification of possibly problematic areas and b) monitoring changes in time, i.e. assessing the heat storage change after implementing a planning intervention, contributing to resilient urban planning.



Example heat storage flux changes during the day for different materials (adapted from Lindberg et al. 2016).

Quantifying Urban Heat Storage Changes in CURE

To quantify the urban heat storage flux at local scale, this CURE Application is using the so-called Objective Hysteresis Model (OHM). The hysteresis effect on energy flux storage indicates how quickly the urban surface responds to the input of energy and its association with the diurnal evolution of the boundary layer, varying according to area characteristics, such as the latitude, the cloud cover, the soil properties, the wetness, and the vegetation cover.

Land cover map for the city of Heraklion, Greece corresponding to 2019, as derived from very high resolution imagery from the Copernicus Contributing Missions (WorldView II).

Detailed surface information, along with net all-wave radiation information, air temperature, surface temperature and land cover dynamics information, is used to achieve the spatial representation of the urban heat storage flux using OHM. Several sources of data from the Copernicus Services and Satellites are used to achieve this.

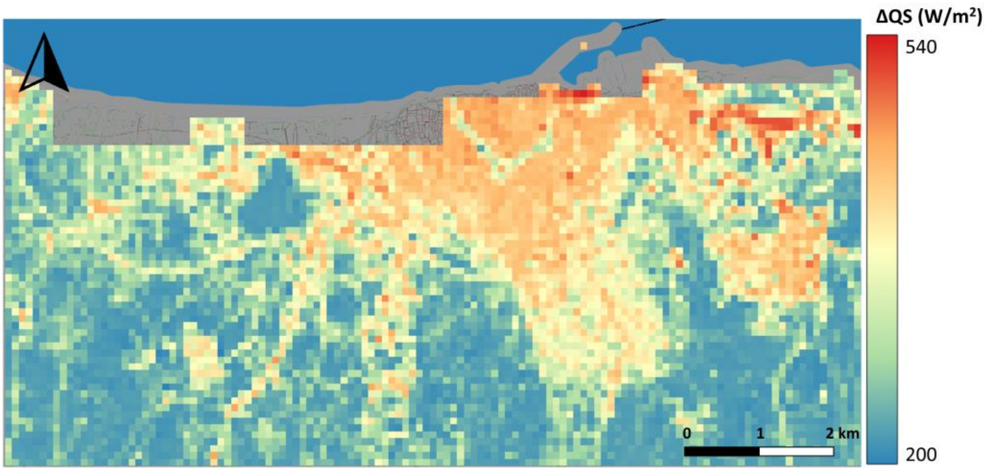
Short-wave incoming radiation information is available from the Copernicus Atmosphere Monitoring Service (CAMS), while water vapor and air temperature from the Copernicus Climate Change Service (C3S). The Land Surface Temperature (LST) is estimated for the time of satellite overpass at 100 m × 100 m spatial resolution from the CURE Local Scale Surface Temperature Dynamics Application (AP01). Information on the albedo is available from MODIS through the respective application of the RSlab. Finally, detailed surface cover fractions dynamics are estimated as a secondary product of AP01.

Information on urban surface cover dynamics are essential for the accurate monitoring of the storage heat flux due to the seasonal swift and the urban structure change. The importance of surface properties is crucial for calculating the amount of energy that is stored and released. Materials, with low albedo and high heat capacity for example, are energy storage tank/sinks (e.g. concrete) that trap the incoming radiation energy during daytime.

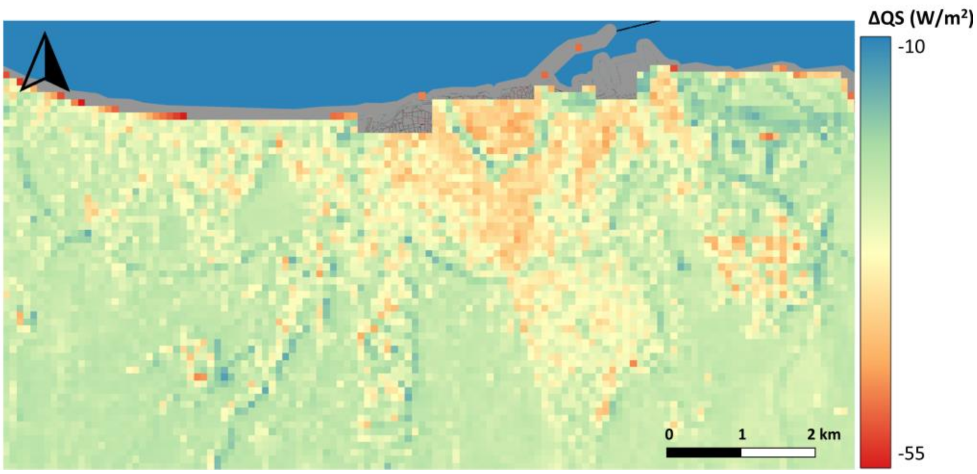
The products

The CURE AP09 provides time series maps at local scale (100 m × 100 m) of the heat storage flux at the time of the Sentinel-3 overpass that is twice per day, because of its dependence on the surface temperature products. This CURE Application operates for Heraklion, Greece and Basel, Switzerland. The maps represent the heat storage flux (W/m^2), which is the rate of the energy change, either stored in or released from the urban elements at the time of the satellite acquisition. The urban heat storage map values represent the rate of energy exchange between the atmosphere and the surface, with positive values indicating energy storage in the urban surfaces, and negative values indicating energy release from these surfaces.

The CURE System on DIAS may calculate heat storage flux maps for a given time range and provide the output as GeoTiff files with a spatial resolution of 100 m x 100 m. The frequency of the products depends on the availability of Sentinel-3 thermal imageries and the cloud cover over the area of interest. These can be viewed and analysed with any Geographic Information System (GIS) software, such as the open-source QGIS.



Daytime heat storage flux map for the city of Heraklion, Greece, corresponding to 28 April 2019 12:35 local time.



Night-time heat storage flux map for the city of Heraklion, Greece, corresponding to 28 April 2019 23:40 local time.

Example heat storage maps for the city of Heraklion are shown in the left figures for daytime and night-time. A land cover map is also presented for reference in the previous page. From these heat storage flux maps, it is evident that areas with different surface cover store and release energy at different pace during daytime and night-time. The city stores energy in a much faster rate than the surrounding agricultural, vegetated and bare soil or rocky areas at this time of the day, which is long after the sunrise. Particularly, the large open paved surfaces, such as the airport runaway and the port docks (black in the land cover map), appear to have maximum heat storage flux at this time of the day compared to all other surface cover types.

While such surface heat storage maps can directly provide quantitative information about the rate of heat storage and release for different urban surfaces, in order to have a comprehensive overview of the city's heat load, the combination of all CURE heat related Applications is needed. Only their combination can provide complete information regarding the heat load for different times of the day and different seasons, including the past and future, for monitoring reasons, but most importantly for supporting local strategies to reduce heat.

Nature-Based Solutions Application

by Alessandra Gandini, Daniel Navarro and Efren Feliu

Nature-Based Solutions (NBS) are actions inspired by nature, which use the features and complex system processes of nature, such as its ability to store carbon and to regulate water flows, helping societies to address environmental, social and economic challenges. NBS are gaining relevance for the enhancement of urban sustainability and resilience, considering the increased evidence about a wide range of co-benefits they provide.

Specifically, the deployment of green roofs in urban areas provides multiple benefits; as they reduce the risk of flooding by collecting rainwater, reduce the ambient temperature, improve the energy efficiency in buildings, and offer many social benefits associated with urban agriculture, well-being, noise reduction, healing, as well as environmental and air quality. Considering all these benefits, they represent a valid alternative to increase green areas, especially where available land for greening is limited.

The CURE AP10 contributes to expanding knowledge regarding the capacity of cities to host these types of solutions, improving the prioritization and the suitability criteria for the quantification of green roof potential and analysing alternative scenarios of green roof installation as additional decision-making information.

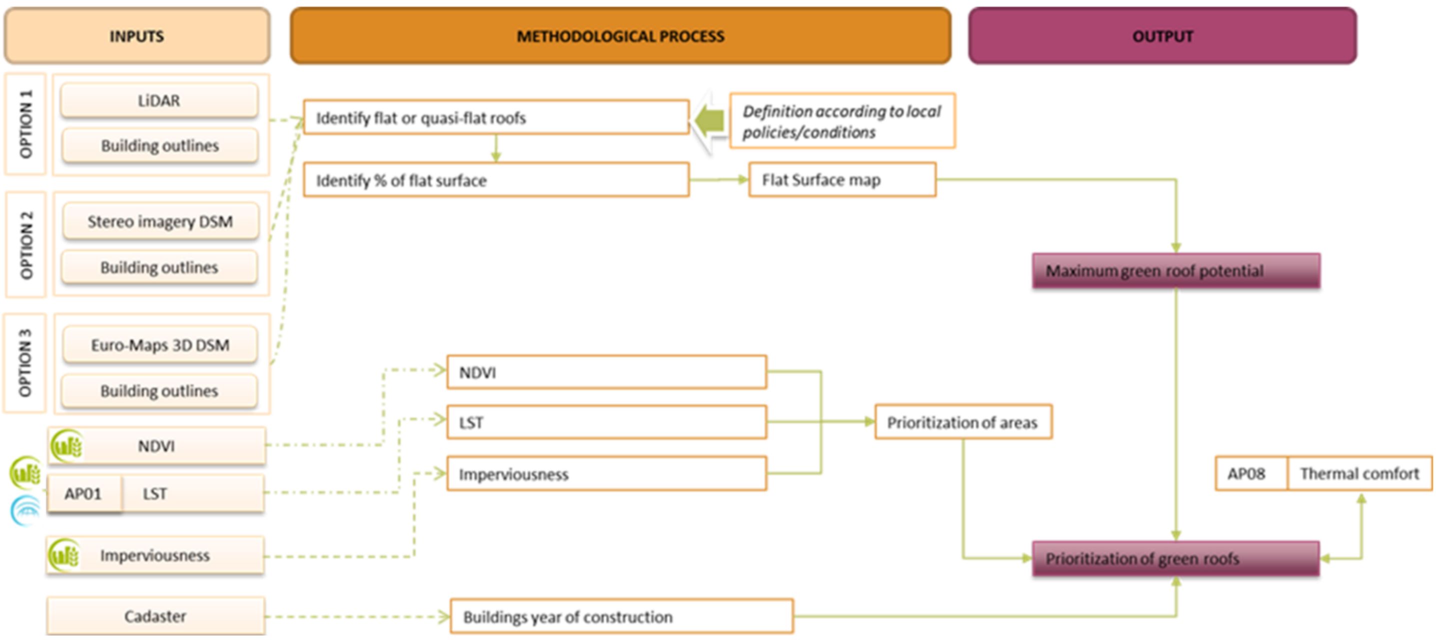
Methodology

The proposed methodology aims to estimate the potential for green coverage at rooftop level by identifying suitable locations for green roof deployment and supporting decision-making towards broader sustainable urban development.

The CURE AP10 enables identifying areas with high roof retrofitting potential by quantifying potential green roof deployment according to specific installation conditions. To accurately quantify the urban assets capabilities and identify the maximum green roof potential, it is crucial to identify firstly the buildings' types of roofs. As flat or quasi-flat roofs are the most suitable to host a green cover, slope computation is performed. The roof slope of each building is analysed using a statistical algorithm that provides the estimation of the real slope and the available flat area, calculating the maximum area that is suitable to host a green roof.

The benefits of green roofs are more essential, if these solutions are installed in areas characterized by impervious surfaces, low Normalized Difference Vegetation Index (NDVI) and high LST, contributing also to reducing the UHI effect. All these characteristics determine the priority of the urban area for installing green roofs.

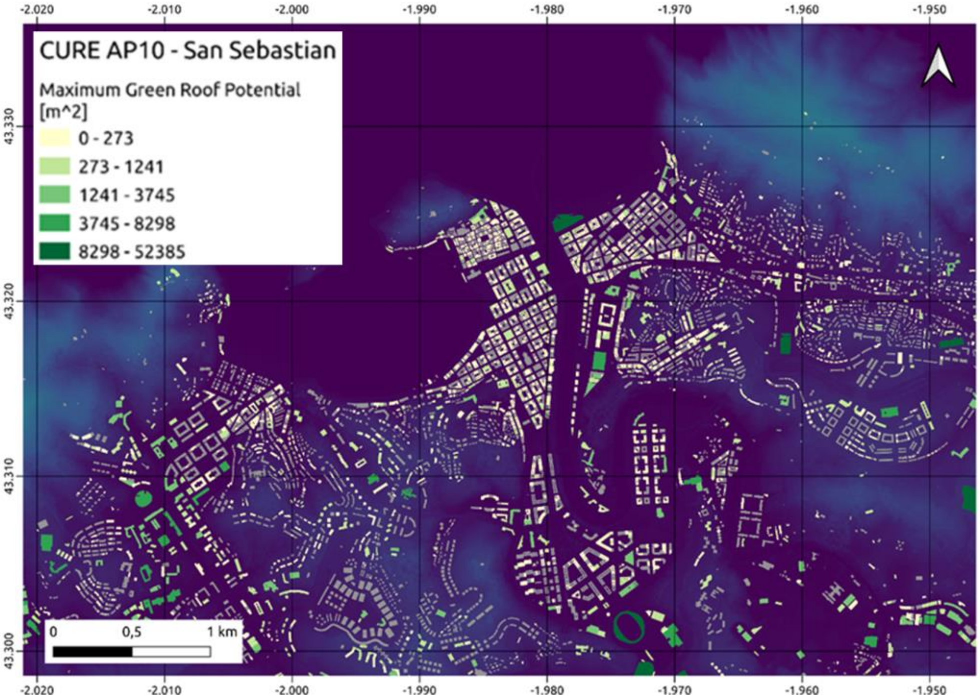
Furthermore, specific characteristics of the buildings can be used to determine a prioritization ranking, considering general parameters, which are usually available in most European cities. In general, it is possible to estimate the loading capacity of a building considering its year of construction, thus buildings with sufficient loading capacity to install a green roof will be prioritized, while buildings requiring structural rehabilitation would be less prioritized. To prioritize the buildings for implementing green roofs, both the area priority and the building priority are combined. The prioritization of areas is based on data from the CURE AP01 (i.e. LST) and the Copernicus Land Monitoring Service (CLMS) (i.e. NDVI and Imperviousness), while the prioritization of buildings is based on the year of construction and maximum green roof potential. These prioritizations are



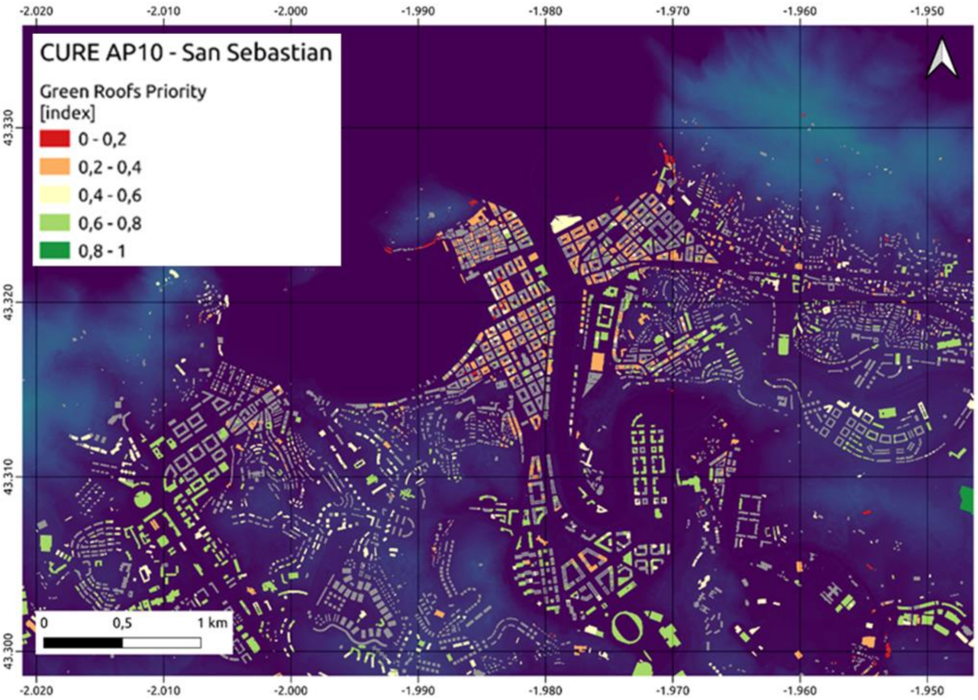
The steps of the methodological sequence required for the CURE AP10.

calculated with a weighted combination that might be specified by the user depending on the city characteristics. The result of this process allows stakeholders and decision-makers to focus on rehabilitation policies in optimized areas of intervention, where the green roofs may have a greater impact.

After applying these thresholds, prioritizations and suitability criteria, the outputs of the estimated green roof potential are coupled with the outputs of the [CURE Urban Thermal Comfort Application (CURE AP08)](). This allows to spatially assess the potential improvement in the thermal performance of urban public spaces, in case of massively installing green roofs. Furthermore, alternative scenarios for green roof installation could be benchmarked via assessing the thermal comfort benefits in each of the cases.



The CURE AP10 maximum green roof potential in Donosti-San Sebastian, Spain.



The CURE AP10 green roof priority in Donosti-San Sebastian, Spain.

Products

The CURE AP10 currently operates for the cities of Donosti-San Sebastian, Spain and Sofia, Bulgaria and provides green roof potential at building scale in a given time period, depending on the availability of Very High Resolution images.

The results obtained for the city of Donosti-San Sebastian are shown in the adjacent figures. The first figure shows the maximum green roof potential, which expresses for each building the extent that can accommodate a green roof, as a result of previously calculating the Digital Surface Model (DSM) cells that do not exceed a certain slope and subsequently establishing the flat roof percentage. On the other hand, pre-1900 buildings have been discarded, because it has been assumed that they do not meet the structural conditions necessary to support the loads associated with the implementation of a green roof. It can be seen that the buildings with the highest green roof potential are located in the more peripheral areas of the city, as they are newer constructions with larger roof areas. Furthermore, out of the total number of roofs on buildings in Donosti-San Sebastian, around 20% are suitable for green roofs, compared to the 80% that are not due to their building's age, roof slope or small area.

Finally, the highest priority roofs have been identified taking into account the maximum green roof potential of the building, as well as the LST, Imperviousness and NDVI. This CURE Application allows establishing, by means of a series of parameters, weights in the criteria used to obtain the prioritisation index according to the most critical issues for the city (e.g. thermal stress, flooding, etc.). The second figure shows the green roof prioritisation map, where it can be seen that in the city of Donosti-San Sebastian the areas that obtain a higher priority level are located in the west, central and south areas of the city.

These products can facilitate decision-makers to implement NBS through green roofs on buildings addressing various challenges faced by cities, such as risks from high temperatures and flooding.

Health Impacts Application

by Louise Kjær-Hansen and Birgitte Holt Andersen

Urban air pollution

The World Health Organization (WHO) estimates that 4.2 million people die prematurely every year as the result of exposure to outdoor (or ambient) air pollution and reckons that 99% of the world's population is living in places, where the WHO air quality guideline levels are not met.

The air pollution in the urban atmosphere derives from emission and transmission sources that are influenced by different factors. In order to understand the magnitude of the negative impacts to human health and subsequently the economy, the CURE AP11 is able to provide cities with a detailed survey of air pollution and its sources to indicate how many people die prematurely due to air pollution and the associated costs for society.

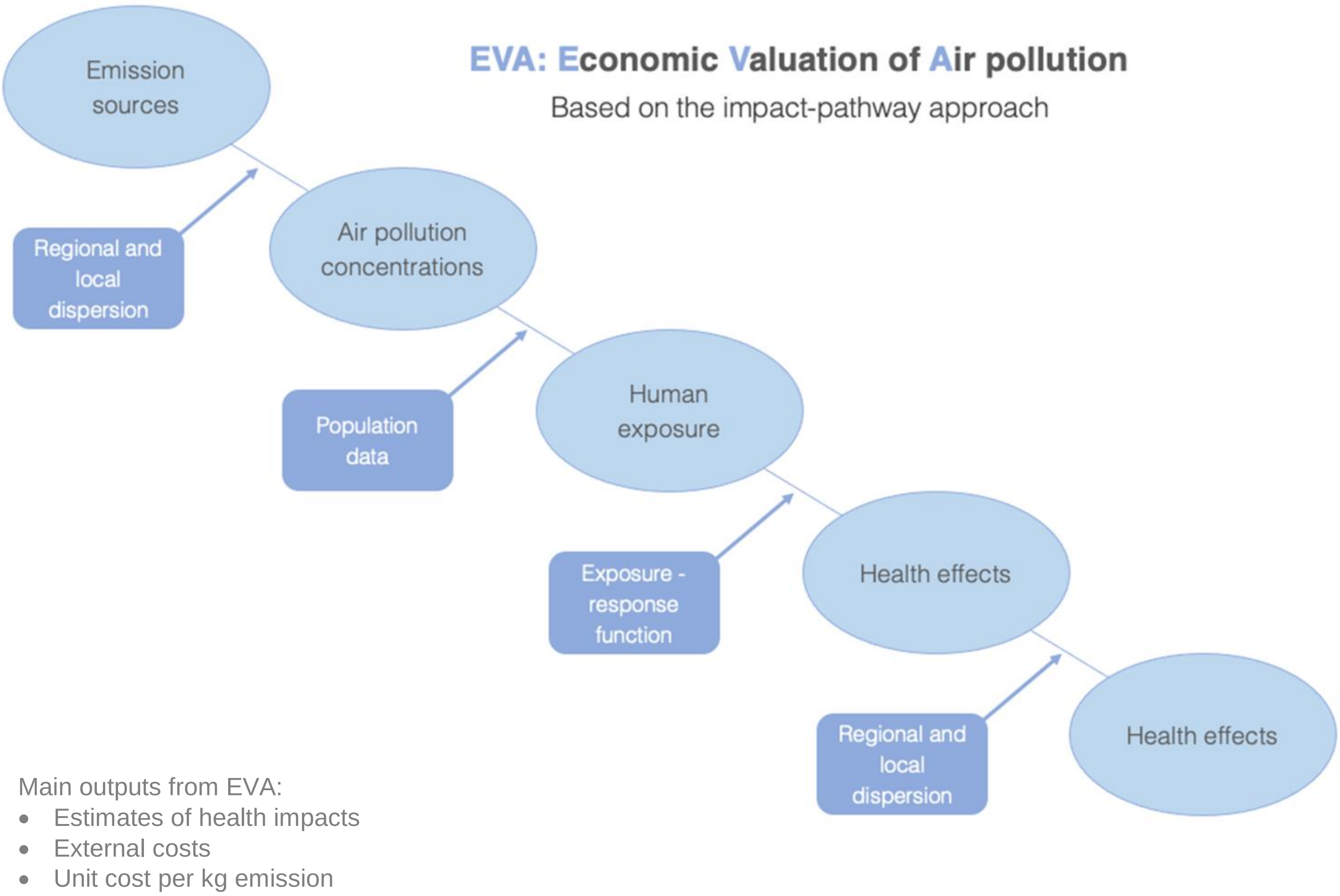
Methodology

The model in this CURE Application uses the products from the CURE Urban Air Quality Application (AP07), which utilises raw input data that stems from Copernicus datasets and integrates as much as possible into the ATMO-Streets model chain. The main outputs of the CURE AP11 are estimations of health effects related to air pollution and the emission sources as well as economic costs attributed to air pollution exposure.

The CURE AP11 uses the Economic Valuation of Air pollution (EVA) model, which adopts an impact-pathway approach to assess health impacts. This model considers acute deaths (from short and long term exposure), asthma and bronchitis in adults and children, sick days, hospital admissions for respiratory and cardiovascular diseases, lung cancer, years of lost life, total count of deaths, as well as related health costs of exposure to air pollution. The EVA model also includes chemical components important for human health such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3) and fine particulate matters ($PM_{2.5}$).

Emission sources and costs

The health effects and related health costs are calculated for the total air pollution of each city. The total air pollution includes all sources from a city, and all other sources from the corresponding country and abroad. The EVA model can estimate how much of



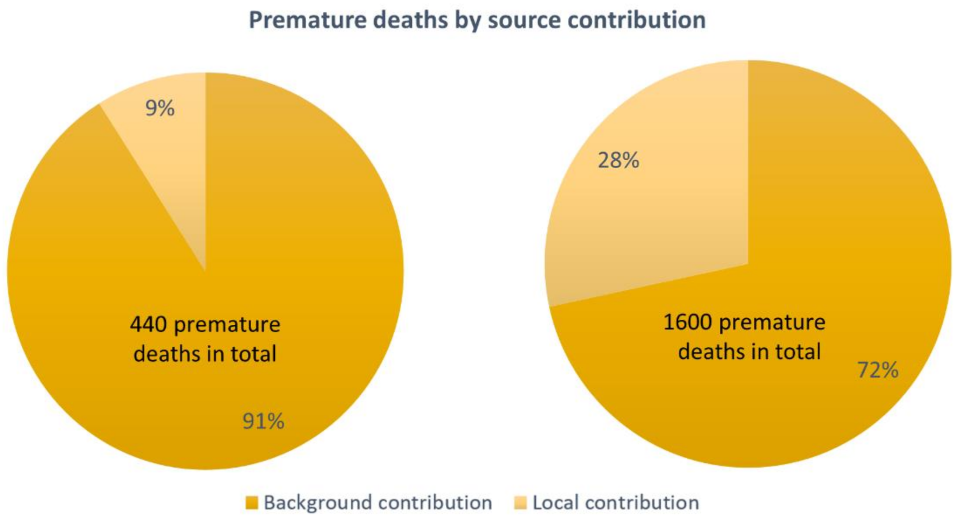
The methodological steps for implementing the EVA model.

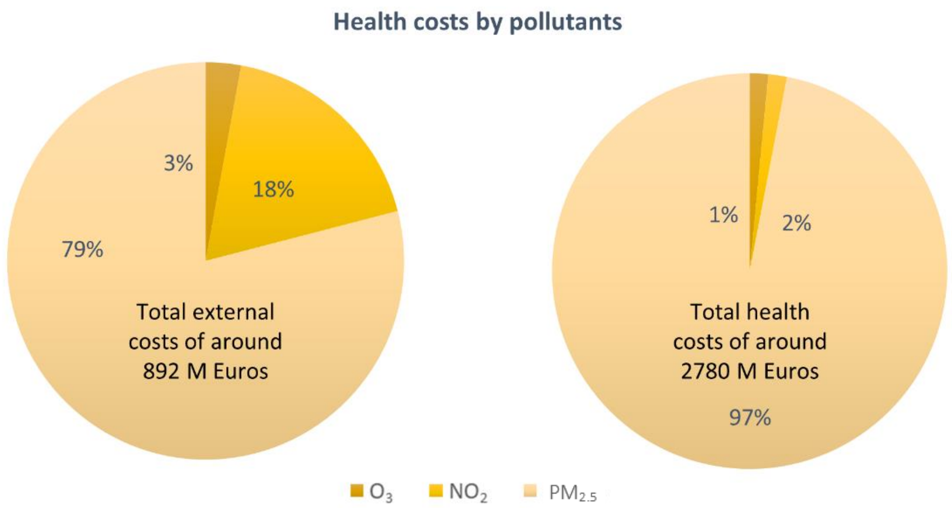
the total air pollution originates from local sources and how much comes from sources outside the city, and thereby the related health costs. Moreover, calculations are performed for each type of emission source in the city to quantify the contribution of different sources. These include sources such as road traffic, industry, power plants and residential heating.

Main findings

The city of Copenhagen, Denmark experienced in 2019 around 440 acute premature deaths from short term exposure to O_3 and $PM_{2.5}$ and chronic premature deaths from long-term exposure to $PM_{2.5}$, mostly due to background contributions from outside the city (~90%). The local contributions stemmed from the road traffic (~45%), the residential combustion (~33%), the industry (~13%), as well as the power and waste management (~8%). The total health costs in the city of Copenhagen due to the overall air pollution from both Danish and foreign emission sources amounted to around 892 million EUR.

The city of Sofia, Bulgaria experienced in 2018 around 1600 acute premature deaths from short term exposure to O_3 and $PM_{2.5}$ and chronic premature deaths from long-term exposure to $PM_{2.5}$. In this case, the contributions were a bit more divided between background (~70%) and local (~30%) contributions. The local contributions stemmed mainly from the residential combustion (~87%) and the road traffic (~12%), while only minor local contribution from the industry as well as the public power and waste management (>1%). The total health costs in the city of Sofia due to the overall air pollution from both Bulgarian and foreign emission sources was around 2780 millio n EUR.





Premature deaths by source contribution and health costs by pollutants for Copenhagen, Denmark (left) and Sofia, Bulgaria (right).

Severity of air pollution

There is generally great uncertainty associated with estimating mortality and illness due to air pollution, which is why there are also uncertainties with the model calculations and the cases of premature death might be greater or lesser. However, air pollution has significant negative health consequences for human health even at very low levels, e.g. even below the current limit values from the European Union (EU).

The full disease picture associated with exposure to air pollution is still unknown. Recent research indicates that there may be a connection between the air pollution and diseases such as dementia, mental illness, autism, and breast cancer. Also, the air pollution may affect the neurological development of children and accelerated aging. Therefore, the air pollution can result in far more significant health and societal consequences than these known and thus, in greater health costs.

Larger perspective

The results from the CURE AP11 can support local and regional decision-makers in their policy-making with sound economic estimations of costs due to poor air quality. The results from the EVA model show that the air pollution constitutes a serious problem to human health and that the related health costs are considerable. The model can find the primary responsible activities and the emission sources for cities in Europe, and overseas. The results emphasize the importance of defining the right questions and actions in the decision-making process, since the most of the atmospheric chemical compounds are linked via non-linear chemical reactions. The model can answer relevant health-related socio-economic questions and can be used for ranking environmental stressors. For example, major visible and already highly regulated emission sources, such as the power plants and the road traffic do not always constitute the most significant problems for human health. Less obvious sources can have significant impacts on human health, and thus, it is important to make an overall screening of all emission sectors and sources in order to create a scientific basis for sound political decisions.

Project news

Selection of CURE cities in EU Missions

Selections for the EU Missions of "100 Climate-neutral and Smart Cities by 2030" and "Adaptation to Climate Change" were announced in April and June 2022 by the European Commission. Bristol, Copenhagen, Munich, Sofia, Vitoria-Gasteiz and San Sebastian (the Basque Country), participating in the CURE project as front-runner or follower cities for developing/validating the CURE Applications, are among the selected cities, regions and local authorities of these two Missions.

4th Progress Meeting

The 4th Progress Meeting of the CURE project was successfully completed on 28 January 2022 with the participation of the CURE Consortium partners. The Meeting was held virtually due to the COVID-19 pandemic. During the Meeting, the CURE progress during the second 2021 semester and the CURE planning for the next six months were outlined.

2nd Review Meeting

The 2nd Review Meeting of the CURE project was successfully completed with the participation of the Project Officer, Reviewer, Advisory Board members, and CURE Consortium partners. The Meeting was held on 19 April 2022 both in person (Brussels, Belgium) and virtually due to the COVID-19 pandemic.

CURE presentation in international scientific meetings

The CURE project was presented in the following meetings:

- FIRE Focus Group II – Urban Workshop, 21 February 2022
- EGU General Assembly 2022, 23-27 May 2022
- Living Planet Symposium 2022, 23-27 May 2022
- 5th Changing Cities Conference, 20-25 June 2022

All news of the CURE project are available through the project's web-site: http://cure-copernicus.eu/news.html.

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