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Urban Heat Islands (UHI)

Definition of the Challenge & Background Information

Multicriteria

Mcrit Multicriteria Planning

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1. What is an Urban Heat Island (UHI)?

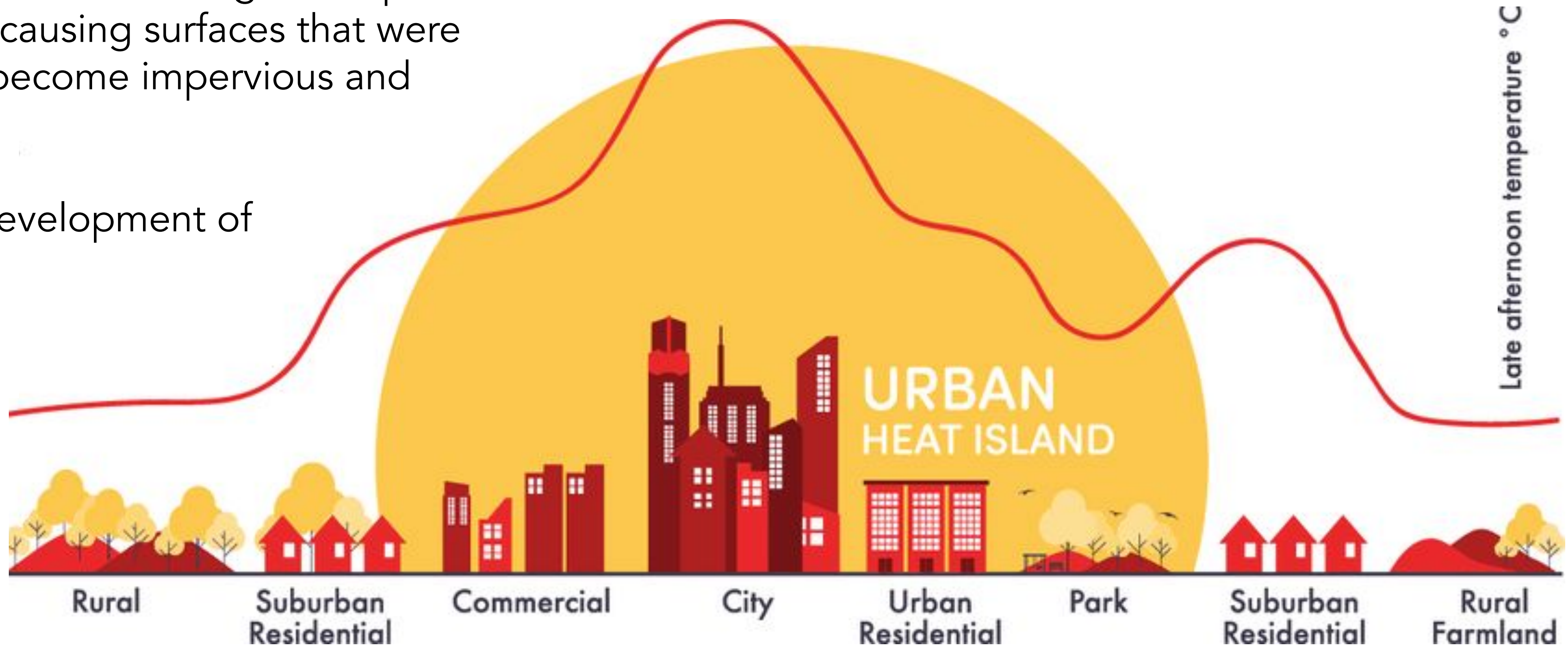
1.1 Definition

1.1 What is an Urban Heat Island?

In our world today, urban populations are increasing rapidly in size as more and more people continue to leave rural areas to migrate to cities. Because of this rapid urbanization, cities require large amounts of energy in order to function properly.

As an urban area develops, changes occur in the natural landscape. Buildings and roads begin to replace open space and vegetation, causing surfaces that were once pervious and moist to become impervious and dry.

These changes lead to the development of urban heat island (UHI).



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1.1 What is an Urban Heat Island?

- Therefore, UHIs occur when…

“a densely populated urban area experiences significantly higher temperatures than the surrounding rural or less populated area”.

When naturally vegetated surfaces such as grass and trees are replaced with **non-reflective, impervious surfaces**, those surfaces absorb a high percentage of incoming solar radiation, causing a **warming effect.**

- Urban heat islands **can pose both health and environmental risks** due to increased heat exposure and enhanced levels of **air pollutants**, specifically ozone.
- It is imperative that **city planners take the heat island effect into account** when planning for a city to ensure the best actions are being taken

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2. Background

2.1 How are Urban Heat Islands and Climate Change related?
2.2 The need for an urban focus on UHI and climate change adaptation in Europe

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2.2 How are UHIs and Climate Change related?

≠	Local Climate Change	Its effects are confined to the local scale and decrease with distance from their source.
	Global Climate Change	Its effects are not locally or regionally confined.

The warming effect that results from urban heat islands is an example of local climate change.

However, the impacts from UHI and global climate change are often similar, which emphasize the importance of urbanization to environmental and climate change:

- Both increase energy demand
- Both can cause an increase in air pollution and greenhouse emissions

Magnitude and rate of urban warming are comparable to that considered possible at the global scale, and any global warming will raise the base temperature on top of which the UHI effect is imposed.

2.3 The need for an urban focus on UHI and climate change adaptation in Europe

- Climate change is happening, projected to continue and posing serious challenges for cities.
- Urban areas are the places in Europe where most people are, and will be, vulnerable to the effects of climate change. UHI will be a growing phenomenon as urbanization is expected to increase.
- The sense of urgency in addressing climate change is felt by European citizens, too: he number of Europeans who consider climate change to be a very serious problem — currently 8 out of 10 — has grown over the past few years, and over two thirds of Europeans believe that adapting to the adverse impacts of climate change can have positive outcomes for EU citizens (EC, 2019).

Europe's future depends on strong and resilient cities - towards a joint, multi-level approach to cope with climate change.

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3. Causes: How do Urban Heat Islands form?

3.1 Reduced vegetation in urban areas
3.2 Materials
3.3 Heating and cooling energy needs
3.4 Additional factors

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3. Causes: How do UHIs form?

1 Reduced Vegetation in Urban Areas

- Urban areas characterised by dry & impervious surfaces
- Less shade & moisture to keep areas cool

2 Low Albedo & High Heat Capacity Materials

- Reflect less and absorb more of the sun's energy
- Low emittance values

3 Heating & Cooling Energy Needs

- Anthropogenic heat contributing to UHI

4 Weather Conditions

- Absence of winds and clouds can maximize the amount of solar energy reaching urban surfaces (and, therefore, UHI)

5 Geographic Location

- Climate & topography influence UHI formation (i.e. large bodies of water moderate temperatures and can generate winds that take heat away from cities)

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3.1 Reduced vegetation in urban areas

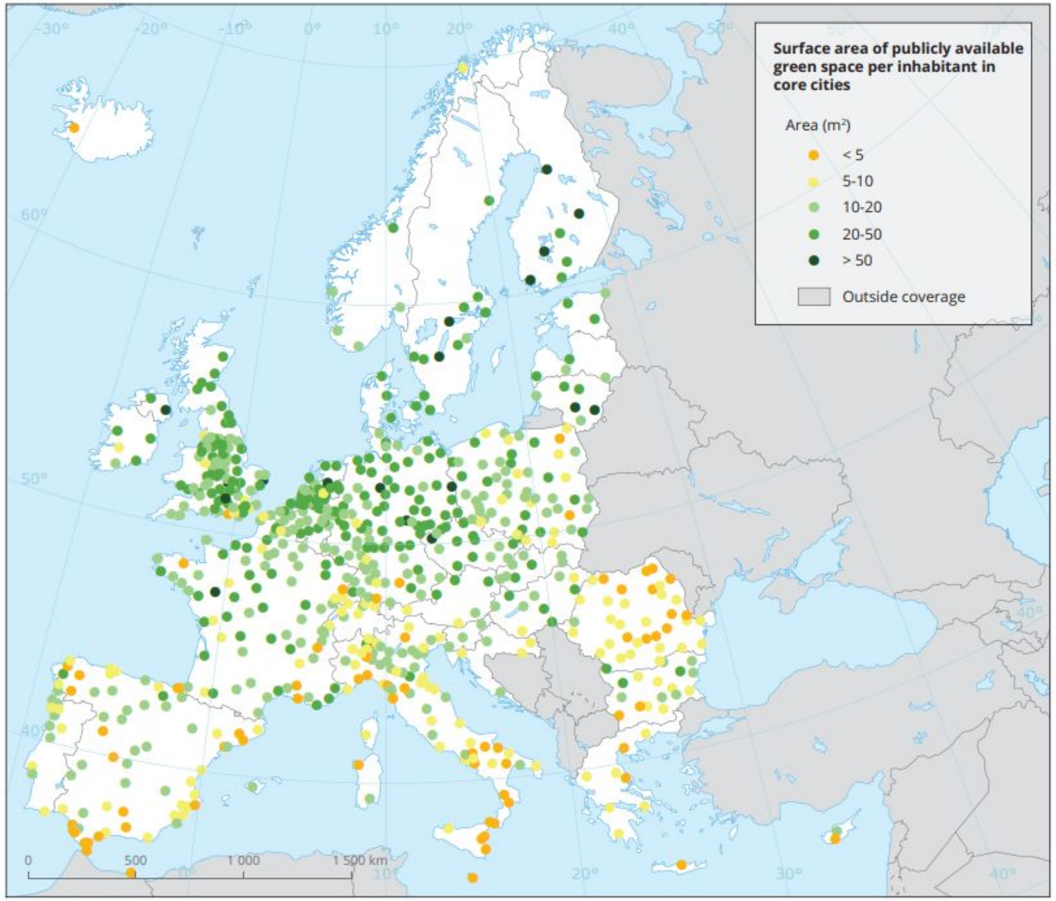
- Urban areas are characterised by dry, impervious surfaces. As cities develop, more vegetation is lost.

40% of the surface area of European cities consists of green space

44% of Europe's urban population lives within a walkable distance (300 m) of a public park

Presence and accessibility of green areas varies greatly between countries and cities. The highest numbers of people with difficult access to recreational or green areas were in Albania, Turkey, Romania, and the lowest numbers were in Denmark, Sweden and Finland (Eurofound, 2016)

Surface area of publicly available green space per inhabitant in core cities



Reference data: ©ESRI

Source: EEA (2020)

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3.2 Materials

Properties of urban materials that influence UHI development:

A. **Solar reflectance**

% of solar energy reflected by a surface

- Dark surfaces tend to have lower solar reflectance values than lighter surfaces
- Built up communities reflect less and absorb more of the sun's energy
- This absorbed heat increases surface temperatures

B. **Thermal emissivity**

A measure of a surface's ability to shed light or emit long-wave (infrared) radiation

- Surfaces with high emittance values will stay cooler, because they release heat more rapidly
- A lot of construction materials have low thermal emittance values

C. **Heat capacity**

The ability of a material to store heat

- Many building materials have higher heat capacities than rural materials, such as dry soil and sand.

3.3 Heating and cooling energy needs

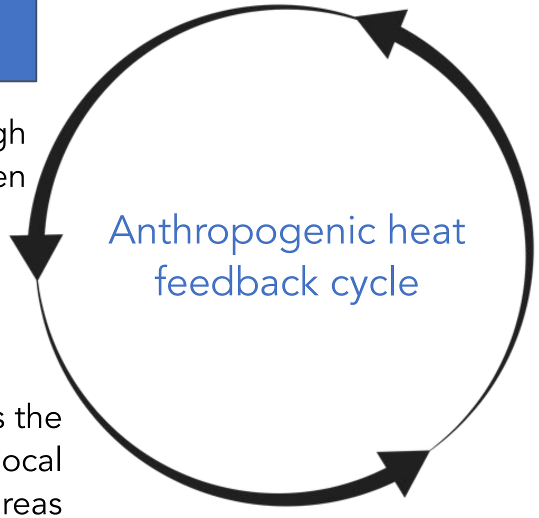
- Heat emitted by human activities - cooling/heating of buildings, industrial processes and transportation - plays a key role. One of the main sources of anthropogenic heat emissions is air conditioning systems.

Air conditioning usage in cities increases

Due to rising temperatures and heatwave events, high demand for cooling of indoor spaces has arisen

Increase of climate change and UHI effect

Air conditioning systems further add to he UHI effect as the waste heat generated by these systems increases local temperatures in built-up areas



Energy demand increases

Growing use of air conditioners is expected to be one of the top drivers of global electricity demand

During prolonged heat periods, air conditioning usage can increase urban air temperatures up to 3°C locally (de Munck et al., 2013)

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3.4 Additional factors

Weather	Geographic location
Two primary weather characteristics affect UHI: Wind & Cloud Cover ● In general, urban heat islands form during periods of calm winds and clear skies (amount of solar energy is maximized). ● Conversely, strong winds and cloud cover suppress UHI.	Two primary weather characteristics affect UHI: Climate & Topography ● Large bodies of water moderate temperatures and can generate winds that convect heat away from cities. ● Nearby mountain ranges can either block wind from reaching a city, or create wind patterns that pass through a city. ● Local terrain has a greater significance for heat island formation when larger-scale effects, such as prevailing wind patterns, are relatively weak.

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4. Urban Heat Islands in Europe

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4.1 Overview of climate-related risks to European cities

- The key climate change hazards and impacts in Europe, both present and projected, vary among regions.
- Cities with high levels of vulnerability to all hazards are more numerous in central Europe, Estonia, parts of Germany, Latvia and Romania but also scattered throughout Europe.

Arctic region
Temperature rise much larger than global average
Decrease in Arctic sea ice coverage
Decrease in Greenland ice sheet
Decrease in permafrost areas
Increasing risk of biodiversity loss
Some new opportunities for the exploitation of natural resources and for sea transportation
Risks to the livelihoods of indigenous peoples

Atlantic region
Increase in heavy precipitation events
Increase in river flow
Increasing risk of river and coastal flooding
Increasing damage risk from winter storms
Decrease in energy demand for heating
Increase in multiple climatic hazards

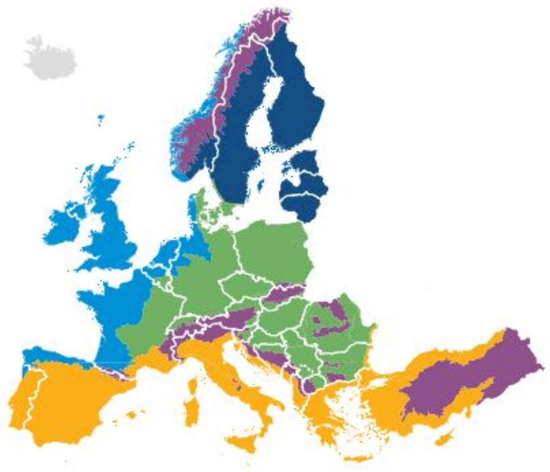
Mountain regions
Temperature rise larger than European average
Decrease in glacier extent and volume
Upward shift of plant and animal species
High risk of species extinctions
Increasing risk of forest pests
Increasing risk from rock falls and landslides
Changes in hydropower potential
Decrease in ski tourism

Coastal zones and regional seas
Sea level rise
Increase in sea surface temperatures
Increase in ocean acidity
Northward migration of marine species
Risks and some opportunities for fisheries
Changes in phytoplankton communities
Increasing number of marine dead zones
Increasing risk of water-borne diseases

Boreal region
Increase in heavy precipitation events
Decrease in snow, lake and river ice cover
Increase in precipitation and river flows
Increasing potential for forest growth and increasing risk of forest pests
Increasing damage risk from winter storms
Increase in crop yields
Decrease in energy demand for heating
Increase in hydropower potential
Increase in summer tourism

Continental region
Increase in heat extremes
Decrease in summer precipitation
Increasing risk of river floods
Increasing risk of forest fires
Decrease in economic value of forests
Increase in energy demand for cooling

Mediterranean region
Large increase in heat extremes
Decrease in precipitation and river flow
Increasing risk of droughts
Increasing risk of biodiversity loss
Increasing risk of forest fires
Increased competition between different water users
Increasing water demand for agriculture
Decrease in crop yields
Increasing risks for livestock production
Increase in mortality from heat waves
Expansion of habitats for southern disease vectors
Decreasing potential for energy production
Increase in energy demand for cooling
Decrease in summer tourism and potential increase in other seasons
Increase in multiple climatic hazards
Most economic sectors negatively affected
High vulnerability to spillover effects of climate change from outside Europe



Key observed and projected climate change and impacts for the main biogeographical regions in Europe

Source: EEA (2020)

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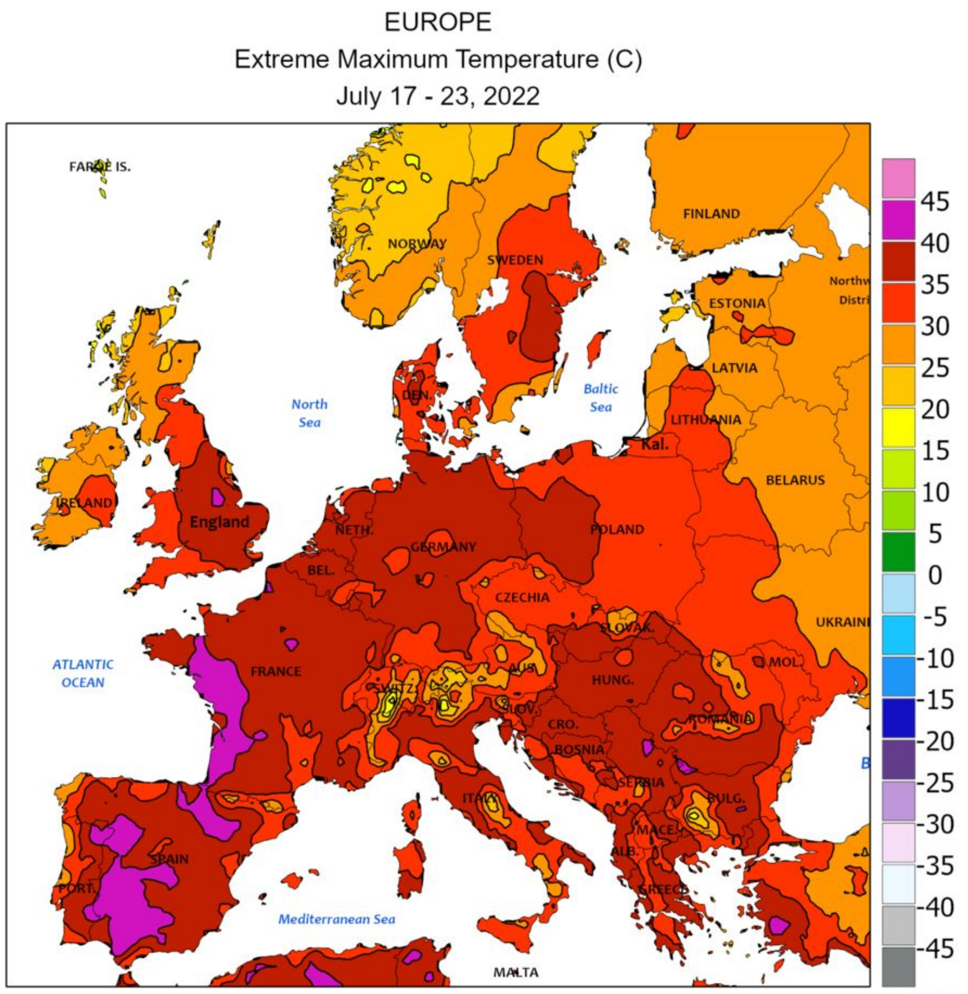
4.2 High temperatures

- Climate projections for Europe show a **temperature increase across the continent**, the strongest seasonal warming occurring during summer in southern Europe and during winter in northern Europe (IPCC).
- The highest temperature recorded until now in the continent was 47.0 °C (116.6 °F) in Pinhão, Portugal, on 14 July.
- In September 2022 it was reported that the European Union saw 53,000 excess deaths in July.



Extreme Maximum Temperature of the Heat Wave in July 17 to 23, 2022

CLIMATE PREDICTION CENTER, NOAA
Computer generated contours
Based on preliminary data

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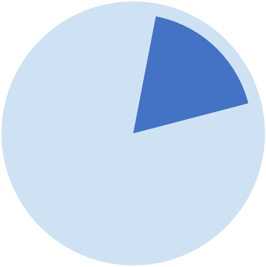
4.3 Heatwaves

- Europe is strongly affected by heat waves, and the UHI effect enhances the excessive heat in cities during heat waves.
- Climate projections for Europe show a temperature increase across the continent, the strongest seasonal warming occurring during summer in southern Europe and during winter in northern Europe (IPCC). Projections also show a marked increase in temperature extremes, leading to an increase in the number, frequency, and intensity of heatwaves.
- Increases in maximum temperature during heatwaves are expected to be larger in cities located in central Europe (Guerreiro et al., 2018).
- Mortality during warm events is more pronounced than during cold events.

Heatwaves, the natural hazard that causes more deaths in Europe

77.637

Fatalities caused by heat wave events



13.818

Fatalities caused by storms, floods, mass movements, cold waves, droughts, forest fires, earthquakes, volcanoes, tsunamis

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4.4 The UHI effect (I)

UHI Facts

Fact 1 – UHI affects all cities in an uneven way

- The scope and impacts of UHI are not uniform, i.e., depending on peculiarities of urban morphologies.

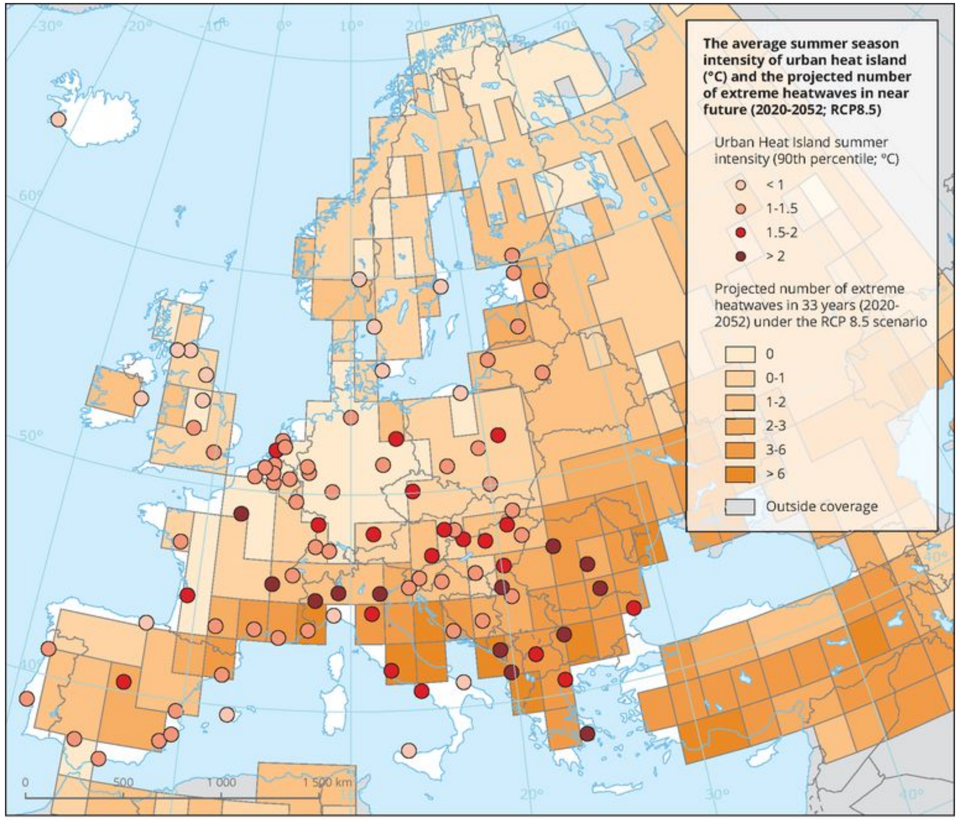
Fact 2 – No city can be regarded as not being influenced by UHI

Fact 3 – Maximum UHI values can develop during night

Fact 4 – UHI decreases with wind speed increasing

Fact 5 – UHI is more intense in anticyclonic regime

Projected number of extreme heat waves in the near future across Europe and the summer intensity of the UHI effect in 100 cities.



Source: ESRI based on EEA (2019) and VITO (2019)

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4.4 The UHI effect (II)

UHI Trends

Trend 1 – Urban development is projected to increase all over Europe, but especially rapidly in Eastern Europe

Trend 2 – Urban Heat Islands will increase in intensity in the future, with stronger warming projected in Southern Europe in summer, and in Northern Europe in winter

- Except under the most aggressive mitigation scenario studied, global average temperature is expected to warm at least twice as much in the next 100 years as it has during the last 100 years
- Predicted future heat waves will strongly hit on the coast of the Mediterranean

Trend 3 – Warming and changes in rainfall patterns may have significant and wide ranging impacts on health

Trend 4 – Heat islands will especially affect vulnerable population and cities with fewer resources to adapt

Source: IPCC (2018), EEA (2019)

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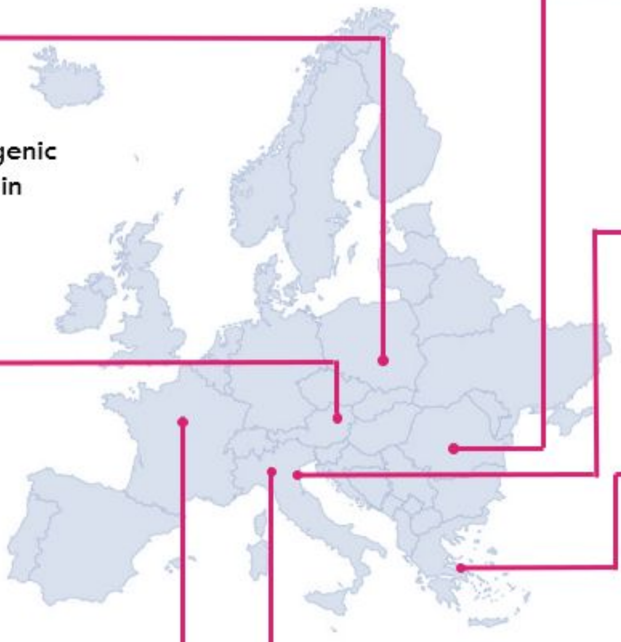
4.5 UHI case-by-case: some European examples

UHI affecting all Europe, in an uneven way



Kraków (Poland)

- Hot locations in the city centre (along **transport arteries & industrial zones**)
- UHI main causes: emission of anthropogenic heat, insolation, and seasonal changes in vegetation and weather conditions

Vienna (Austria)

- Modifications and changes in land use and land cover playing an important role in determining UHI
- UHI main causes: **urbanization**

Paris (France)

- Parisian climate is, on average, **2.5°C warmer** compared to peripheral rural areas
- Special role of Seine river in the climate

Bucharest (Rumania)

- Areas with high **density of urban fabric** contribute to 20% formation of UHI
- **Large urban parks** and **water bodies** cool the environment

Venice (Italy)

- High UHI and **pollution rate** due to local topography, meteorological conditions and regional transport processes

Athens (Greece)

- UHI highly determined by **wind speed** and **direction**
- Sea moderates cooling rates after sunset
- UHI intensity found to increase during **heat weaves** compared to summer conditions (synergies between heat wave and UHI)

Milan (Italy)

- **Rapid urban expansion** increasing the effects of UHI and extreme heat
- Reduced presence of **green areas** (13.4m2 of green areas per citizen)

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5. Effects: Why do we care about Urban Heat Islands?

5.1 Human Health
5.2 Air Quality and Greenhouse Gases
5.3 Water Quality
5.4 Biodiversity
5.5 Energy Use
5.6 Economy

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5. Effects: Why do we care about UHI?

Physical aspects

Health Problems

- Decrease in human comfort
- Lack of night-time relief
- Respiratory problems
- Sunstroke, dehydration, tiredness
- Even increase in mortality rates

Air Quality & Greenhouse Gases

- Hot weather exacerbates air pollution
- Increased formation of ground-level ozone
- Greenhouse effect

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Increased Energy Use for Cooling

- Increase in the demand for energy to power air-conditioning units

High Impact on Economy

- Less productive workers, raise cooling costs for buildings, and deteriorated water and air quality
- Effects caused by UHI could double foreseen economic losses due to Climate Change (Huang, Li, Liu and C. Seto 2019)

Unequal effect on territories and society, depending on their degree of vulnerability

Socio-economic aspects

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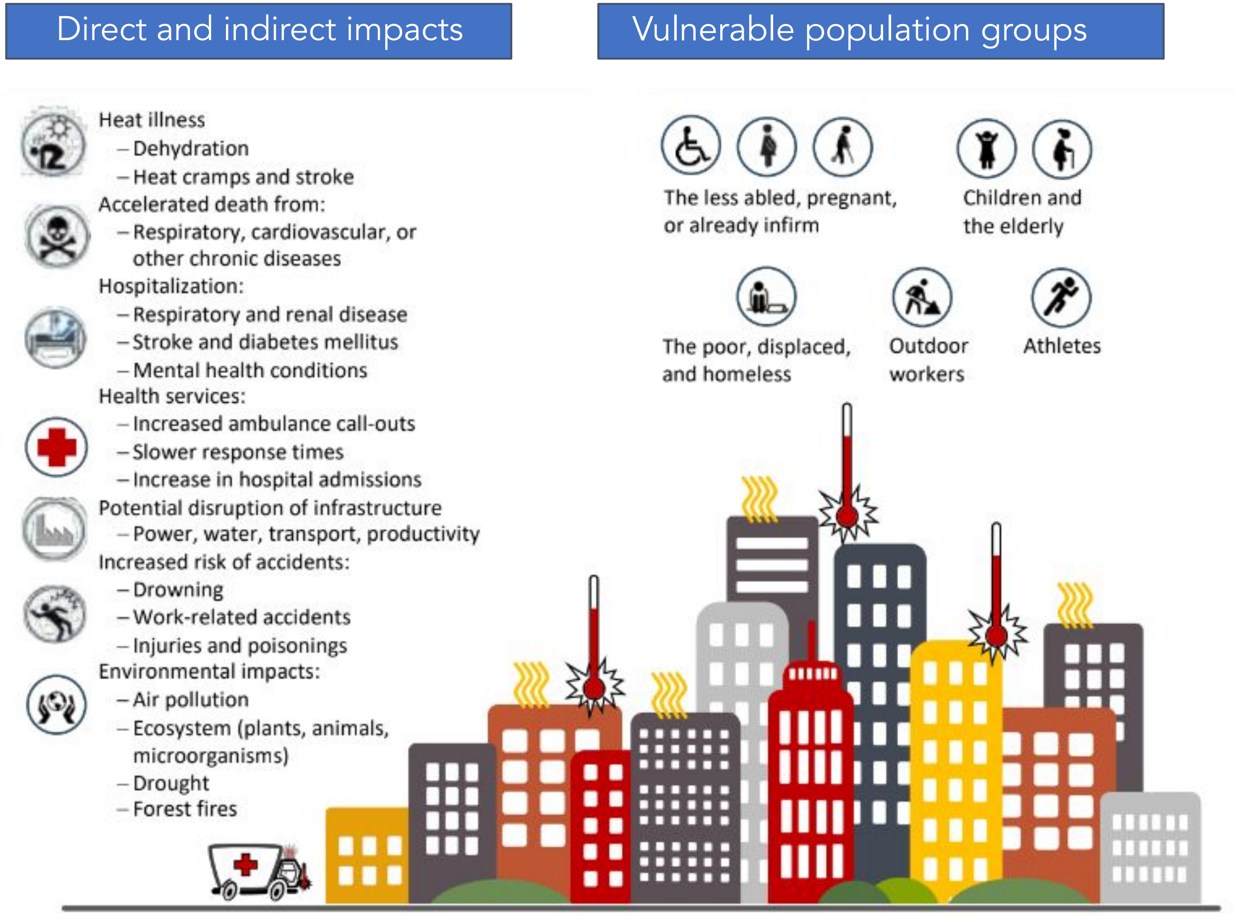
5.1 Human Health

- Increasing temperatures **decrease human comfort** in hot climates and **raise mortality rates** at temperatures outside an optimum range.
- These heat situations have an impact on both the physical and mental health of people.
- Also, there are **indirect impacts**: increase in accidents, loss in labour productivity, increased risk of forest fires, impacts on water resources, transport restrictions, agricultural losses…
- It affects particularly **vulnerable groups**.

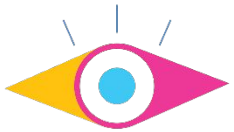


5.2 Air Quality and Greenhouse Gases

- Air pollution in urban areas places additional stress on humans, and some pollutants have synergies with heat.

- The majority of Europeans are exposed to levels of air pollutants known to damage health:

- In the member states of the European Union, **97%** of the urban population is exposed to levels of fine particulate matter above the WHO guideline (driven by emissions from energy use, road transport, industry and agriculture).
- **94%** of the urban population is exposed to levels of nitrogen oxygen above the WHO guideline (due predominantly to emissions from road transport).
- **99%** of the urban population is exposed to levels of ozone above the WHO guideline.



- Increasing temperatures and heatwaves in the future are expected to exacerbate the existing ozone problem.
- Forsberg et al., (2011) projects an increase of ozone-related deaths over the next 60 years in Europe, with 10 to 14 % increase being marked for Belgium, France, Portugal, and Spain.

5.3 Water Quality

- High temperatures of pavement and rooftop surfaces **can heat up stormwater runoff**, which drains into storm sewers and **raises water temperatures** as it is released into streams, rivers, ponds, and lakes.

- Rapid temperature changes in aquatic ecosystems resulting from warm stormwater runoff can be particularly **stressful, and even fatal, to aquatic life**.

- Water temperature affects all aspects of aquatic life, especially the metabolism and reproduction of many aquatic species.

Bilbao's river Nervión

One study found that **urban streams are hotter on average than streams in forested areas**, and that temperatures in urban streams rose over 7°F during small storms due to heated runoff from urban materials (Somers, K. et al, 2020).

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5.4 Biodiversity

Urban areas as hotspots for bees and pollination

- The urban heat island effect has been linked to species distributions and abundances in cities.

- However, effects of urban heat on biotic communities are nearly impossible to disentangle from effects of land cover in most cases because hotter urban sites also have less vegetation and more impervious surfaces than cooler sites within cities.

Despite the short history of research on the biotic effects of urban heat, researchers have found important patterns across diverse taxa. For example, remnant native plant communities in urban environments may be altered under warming conditions, favouring more xerophilic species.

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5.5 Energy Use

Air conditioning in Singapore

- Heat islands increase **demand for air conditioning** to cool buildings.

- Heat islands increase both overall electricity demand, as well as **peak energy demand**. Peak demand generally occurs on hot summer weekday afternoons, when offices and homes are running air-conditioning systems, lights, and appliances.

In an assessment of case studies spanning locations in several countries, electricity demand for air conditioning increased approximately 1–9% for each 2°F increase in temperature (Santamouris, M., 2020).

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5.6 Economy

- A recent study published by IOP Publishing indicates that the effects associated with the warming caused by urban heat islands could double foreseen economic losses due to climate change.

  Why? Health diseases, workers being less productive, raise in the cooling costs, deteriorated water and air quality, etc.

- Transforming 20 percent of a city's pavement and rooftops to cooling surfaces could save a city up to 12 times what the structures cost to maintain and install, providing a bump to the local GDP.

City-level adaptation strategies to limit local warming have important economic net benefits for almost all cities around the world.

▼ **5.6-10.9%** in GDP

by 2100 due to Climate Change

Overheated cities face climate change costs at least twice as big as the rest of world because of UHI

Source: University of Sussex, 2017

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6. Mitigation Measures: Strategies to reduce Urban Heat Islands

6.1 Strategic Planning
6.2 Strategies and Processes to reduce UHI

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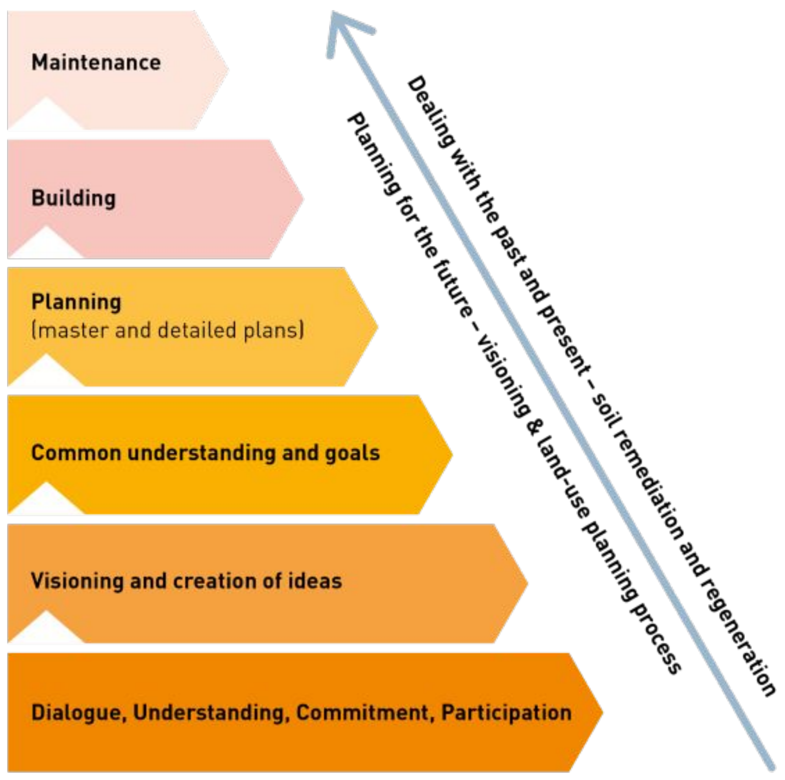
6.1 Strategic Planning

- Cities need to gain a better understanding of what drives the heat waves and UHI effects they are subject to.
- Strategic planning for increased resilience to UHI effects should identify specific public investments and actions to promote green, blue, or white adaptation measures (the first ones related to increasing vegetation, the second to water bodies, and the third to cool materials).

Tools: monitoring networks, with the establishment of an appropriate operational monitoring system (cost-intensive); alternative networks like citizen weather stations (supplemental information); measurement campaigns (evaluate specific aspects of urban climate); or remote sensing data.

Urban planning pyramid



Source: Baltic Urban Lab

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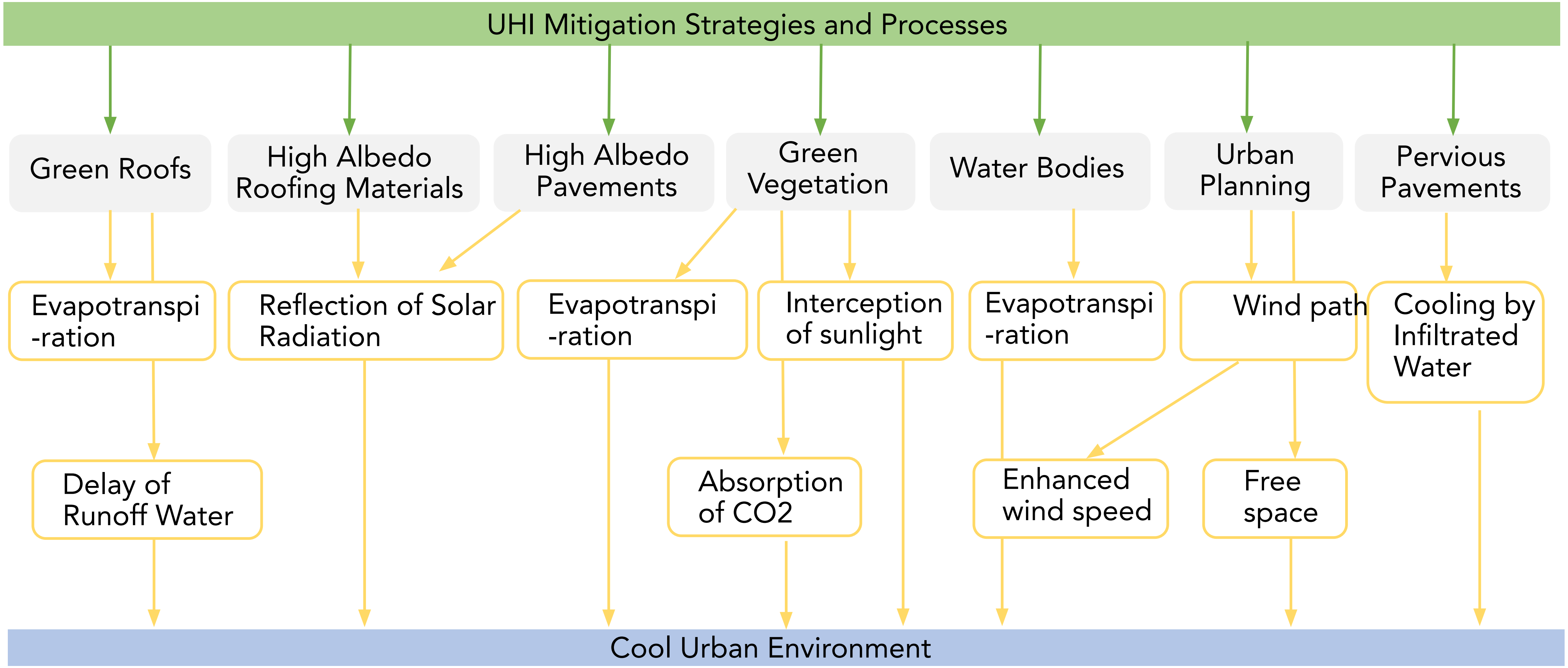
6.2 Strategies and Processes to reduce UHI



A. Vegetation

Integrating nature into cities

Properties of vegetation include:

- High albedo and low heat emittance, which reduces accumulation of incoming solar energy in the urban area
- Providing shade, minimising the heat gain from solar radiation
- Fostering the resilience building of urban dwellers by improving comfort
- Filtration of pollution and noise reduction
- The cooling effect of urban green resources may indirectly translate into lower CO_2 emissions by decreasing the power demand for indoor cooling and heating
- Increasing carbon storage and sequestration rates
- Providing recreation, biodiversity, cultural identity, etc.

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B. Urban Geometry

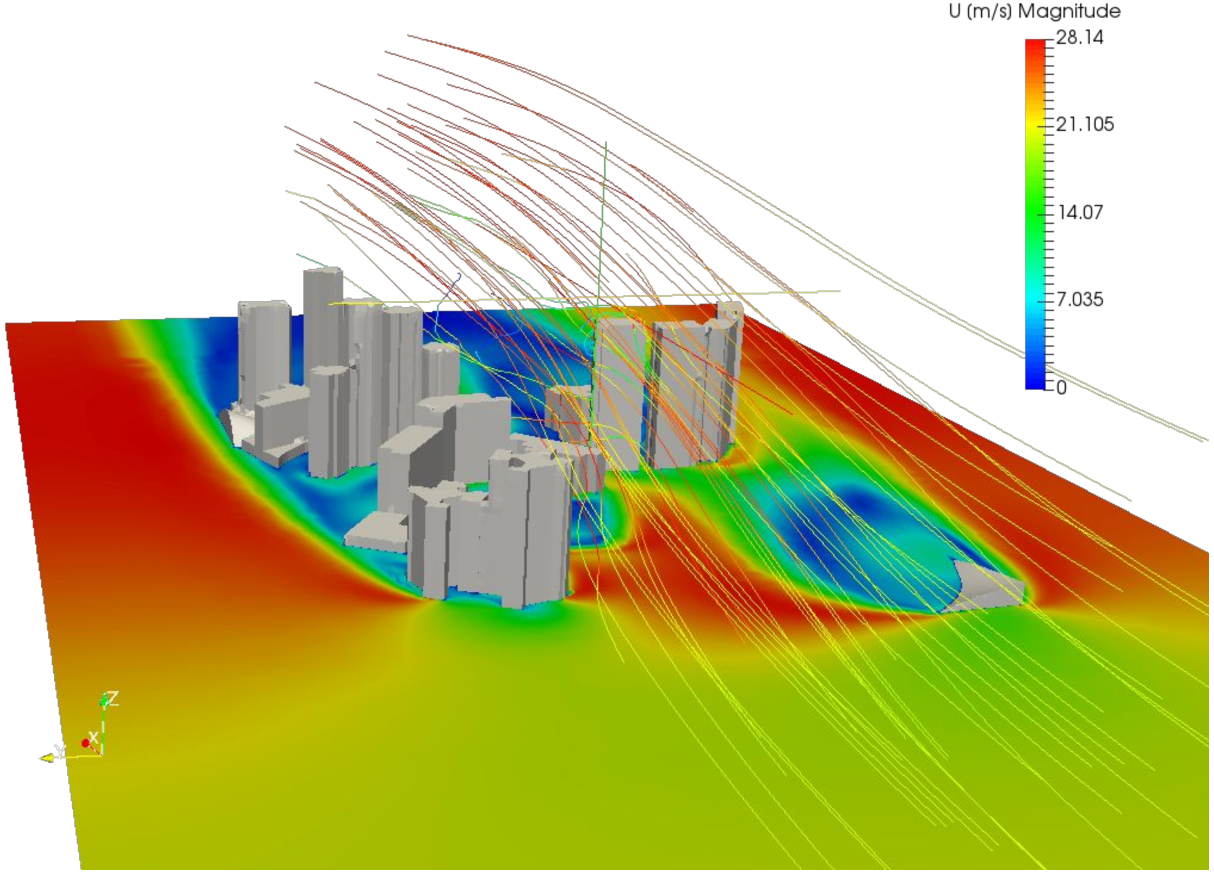
Variables that condition the thermal performance of the urban area include:

- Building layout
- Location of urban elements
- Building height
- Geometry

Measures that can be applied:

- Effective shading
- Enhancing air movement in between buildings
- Passive cooling strategies & design measures (orientation, glazing, thermal mass)
- Night-time ventilation

Urban ventilation and airflow



Source: Climate Resilient Cities

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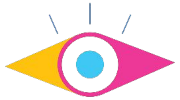
C. Materials and Surfaces

A stretch of Coronado St. in Los Angeles, one of 15 blocks that is piloting a cool pavement

- Traditional pavements such as concrete and asphalt can reach temperatures of up to 48-67°C in the summertime (EPA, 2008).
- The **use of reflective pavements** is one of the most well studied and most cost effective mitigation measure by reducing the surface temperature of the pavement.
- Making a pavement surface a **lighter colour** decreases the amount of solar radiation that it absorbs.



The global implementation of reflective roofing, pavements and other structures would reduce the air and pavement temperature, offset billions of tons of carbon dioxide emissions, reduce smog and aid the ailing environment (Yang, Wang and Kaloush 2015).

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D. Water Bodies & Features

Granary Square Fountain in London

Properties of water bodies and features include:

- Cooling effect (specially in the afternoon)
- Evaporation and increase of the air humidity
- Wind circulation patterns, depending on the size of the water body
- Drinking fountains as an important public resource

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E. Shading

The "Metropol Parasol" in Seville, the world's largest wooden structure

Properties of shading include:

- Reduction of air and surface temperature
- Mitigation of heat stress of pedestrians, as is affects the thermal sensation and adaptation of pedestrians

Measures that can be applied:

- Adequate urban geometry and building/street orientation
- Horizontal and vertical shading structures or devices
- Urban trees and vegetation

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7. Barriers to Urban Heat Islands mitigation

7. Barriers to Urban Heat Islands mitigation

There are several barriers to deploying pilots and strategies to mitigate Urban Heat Islands. These include:

Legal barriers

These regulations can limit the use of land for certain activities, such as composting or anaerobic digestion, and may make it difficult to process food waste on-site. Zoning regulations vary by country and region, therefore it is worth to consider:

- Privacy and data protection laws.
- Regulatory barriers.
- Liability and safety concerns.
- Procurement laws.
- Interoperability.

Institutional barriers

There are several legal barriers to deploying tech pilots in European cities and rural communities. These include:

- Lack of consumer acceptance.
- Lack of regulatory incentives.
- Institutional fragmentation.

Organizational culture

EU directives that aim to reduce the amount of waste generated and promote recycling and recovery of waste materials.

- Difficulty in reconciling resources and the actors involved.
- Lack of scaling up sustainable startups.

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8. Case Studies: What will be needed in the future?

8.1 Urban Projects
8.2 Start-ups and Initiatives

7.1 Urban Projects

Climate Shelters (Barcelona, Spain)

- The City of Barcelona identified schoolyards as an underutilized resource since they were only used by the school population, during school time.
- Through a project funded by the Urban Innovation Actions of the European Commission, the City of Barcelona turned through carefully selected interventions, **11 school yards to "cool islands"**, termed as Climate Shelters.
- This was accomplished by means of blue and green interventions at the selected school buildings and their yards. These measures included:
  - **Blue interventions:** inclusion of points providing water, such as drinking fountains or unique places for children to play with water.
  - **Green interventions:** more green space, improvements in vegetation, creation of shade with green walls, more garden space, trees, green pergolas and fencing.

7.2 Start-ups and Initiatives (I)

ECOTEN Urban Comfort (Czech Republic): Helping urban developers build more resilient cities

ecoten urban comfort

- Data-driven approach to help cities adjust by designing greener and cooler cities.
- Conducts **urban heat vulnerability assessments** (and identifies critical hotspots) and conducts urban microclimate simulations to assess the impacts of potential urban projects.

Urban Canopee (France): Greening the cities

URBAN CANOPEE

- Deploys **plant canopies** at key locations in urban areas.
- These canopies combat heat, restore urban biodiversity, fight air pollution, and improve the quality of life for citizens.

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7.2 Start-ups and Initiatives (II)

*Cbalance (India): **Recycling plastic into insulation***

CBALANCE

- Works with communities to pioneer passive design solutions.
- Some of these turn waste into materials that prevent heat absorption. i.e. Discarded plastic packaging can be recycled into sheets and insulation boards.

Sustainable Business Model Categories

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Technological

Maximalise material and energy efficiency

Low carbon manufacturing / solutions
Lean manufacturing
Additive manufacturing
De-materialisation of products / packaging
Increased funcionality to reduce total number of products required

Create value from waste

Circular economy, closed loop
Craddle 2 Craddle
Industrial Symbiosis
Reuse, recycle, re-manufacture
Take back management
Use excess capacity
Sharing assets, ownership and collaborative consumption
Extended producer responsibility

S

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Sola
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Blue
Bior
The
Slo
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Social

Deliver funcionality rather than ownership

Product oriented PSS - manteinance, extended warranty.
Use oriented PSS - rental, lease, shared
Result-oriented PSS - Pay per use
Private Finance Initiative (PFI)
Design, Build, Finance, Operate (DBFO)
Chemical Management Services (CMS)

Adopt a stewardship role

Biodiversity protection
Consumer care: promote consumer health and well-being
Ethical (fair) trade
Choice editing by retailers
Radical transparency about environmental / societal impacts
Resource stewardship

###

Cor
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Slo
Pro
Pre
Fru
Res

Organisational

Repurpose for society / environment

Not for profit
Hybrid businesses, social enterprise for profit
Alternative ownership: cooperative, mutual, farmers collectives
Social and biodiversity regeneration initiatives: Net positive
Base of pyramid solutions
Localisation
Home based, flexible working

Develop

Collaborative approaches:
Incubators and entrepene
Licensing, franchising
Open innovation platform
Crowd sourcing / funding
Patient / slow capital colla

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Additional information

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History

1800-1830 Luke Howard, British chemist and meteorologist.

- The first to recognize the effect that urban areas have on local climate.
- His studies showed that temperatures in London were 3.7°F warmer at night than those in the surrounding countryside.

1830-1940 Since Howards first contributions toward studying urban heat islands, many researchers have been following his path.

1940s However, sustained study of the urban climate effect did not begin until the late 1940's when researchers began to explore local variations in atmospheric properties, most notably air temperature.

1940s-2000s

Period	Approach
1940-	Observation and description of urban effects using conventional meteor-ological equipment (e.g. thermometers).
1960-	Employment of statistical methods to test hypotheses; Move toward energy budget approach and explanation.
1970-	Application of computer modeling techniques; Observations of energy fluxes; More rigorous definition of urban 'surface', urban scales and observing urban effects.
1980-	Adoption of common urban forms for modeling and measurement; Use of scaled-physical models; Measurement of fluxes in different cities.
1990-	Establishing relationships between urban forms and their climate effect; Urban field projects examined by research teams.
2000-	Improved models of urban geometry; Increased links between modeling and measurement programs.

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Urban Projects (I)

eCitySevilla (Spain)

- **Public-private partnership** initiative led by the Andalusian Regional Government, the Seville City Council, the Cartuja Science and Technology Park (PCT Cartuja) and Endesa

- Proposes the development of an **open, digital, decarbonised and sustainable** ecosystem city model on the island of La Cartuja by 2025.

100% renewable, electric & self-sufficient energy

ecity Sevilla

Urban Projects (II)

Vauban Sustainable Urban District (Freiburg, Germany)

- Based on the city government's aim of restoring an old military barracks based on ecological and social cohesion criteria.
- Creation of more than **40 cooperative housing groups** and creation of participation initiatives related to climate, consumption and gender.
- **Bioclimatic architecture criteria:** green facades, greening, construction using local wood, building with high energy efficiency, renewable energies, rainwater collecting mechanisms, etc.

Bioclimatic architecture & greening

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Contact Us: info@urbanshift.eu

http://urbanshift.eu

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