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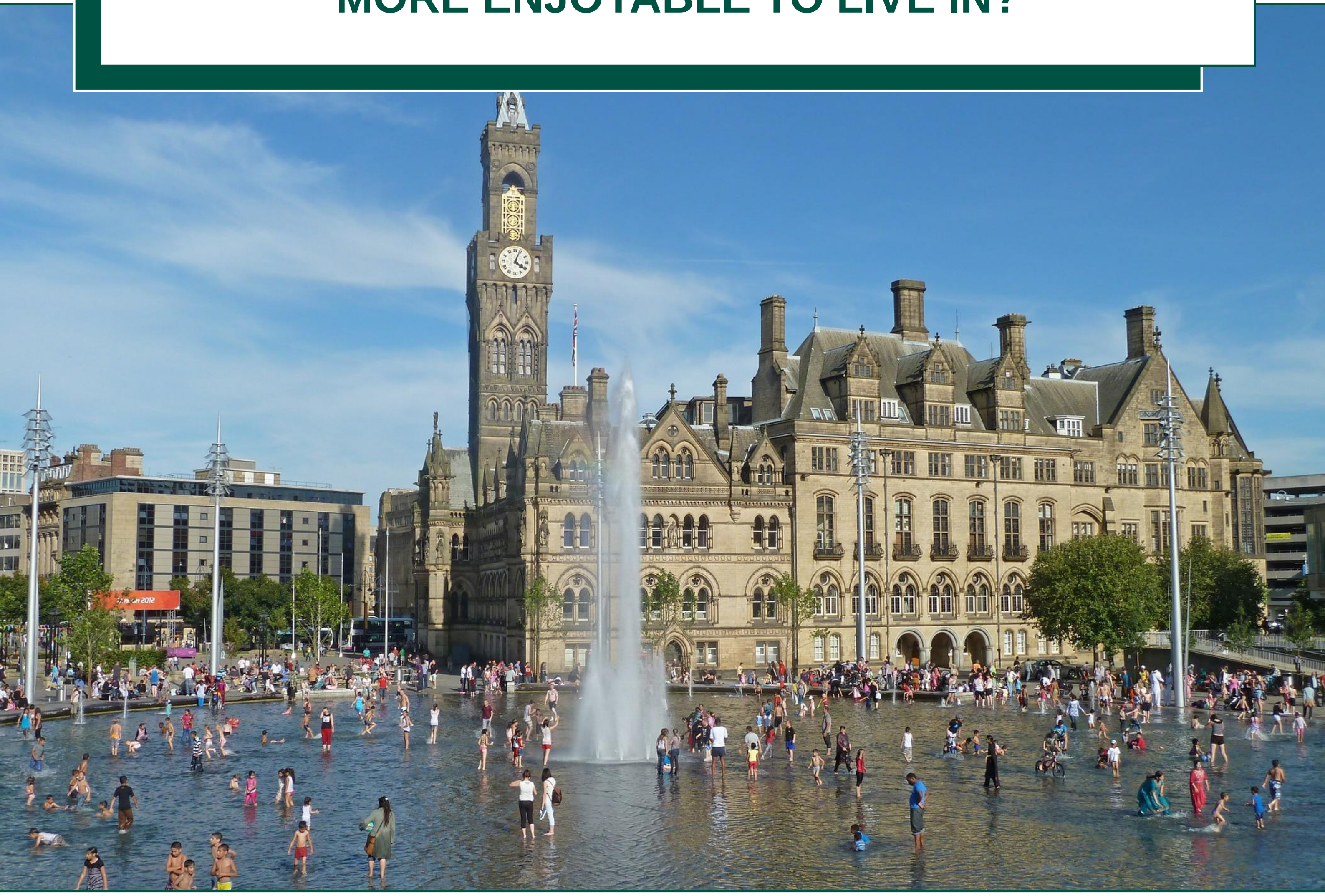
urbanistik

by JCDecaux

URBAN HEAT ISLANDS: HOW TO MAKE PUBLIC SPACES MORE ENJOYABLE TO LIVE IN?



Bradford, Angleterre © Tim Green

REMINDER OF THE CONTEXT

Today, **56%** of the global population **lives in cities**, and this rate is projected to **rise to 70%** by 2050.

This increase in urban population is likely to exacerbate certain existing climatic phenomena and impact the health of residents.

One of the climatic effects observed in these densely populated and urbanized areas is the significant average temperature difference compared to the surrounding countryside.

This temperature difference has been regularly observed since the 19th century, notably by the British meteorologist Luke Howard, who was the first to document, in 1833, a 3.7°C difference between central London and its countryside.

This phenomenon is known as the urban heat island (UHI).

> **An urban heat island is characterized by an elevation in air and surface temperatures within a city, neighborhood, or even a single street, compared to the surrounding rural areas.**

This strategic note addresses the issue of urban heat islands and provides an overview of the solutions, sometimes innovative, that are already available to city planners and developers. These solutions help combat, mitigate, and consider the impact of urban heat islands on public spaces.

Urban heat in key figures

Thirty days of extreme heat:
That's what **3.8 billion people, nearly half of the world's population**, experienced from **June to August 2023.**
Source – ONG Climate Central, 2023

Heatwaves will double in France by 2050.
These heatwaves will have a greater impact in densely populated and urbanized cities.
Source – Météo France, 2019

+1.5°C globally by 2050.
Source – GIEC, 2023

A 24°C difference between the temperature in **New Delhi** (India) and that of the **surrounding rural fields** was recorded on May 5, 2022, at midnight — the highest temperature difference ever observed within an urban heat island.
Source – NASA, 2022

© Ryoji Iwata

THE CHALLENGES OF URBAN HEAT ISLANDS FOR CITIES

THE CAUSES OF URBAN HEAT ISLANDS

Besides the context of global climate warming, several factors related to the **urban environment** contribute to **the emergence and intensification of urban heat islands.**

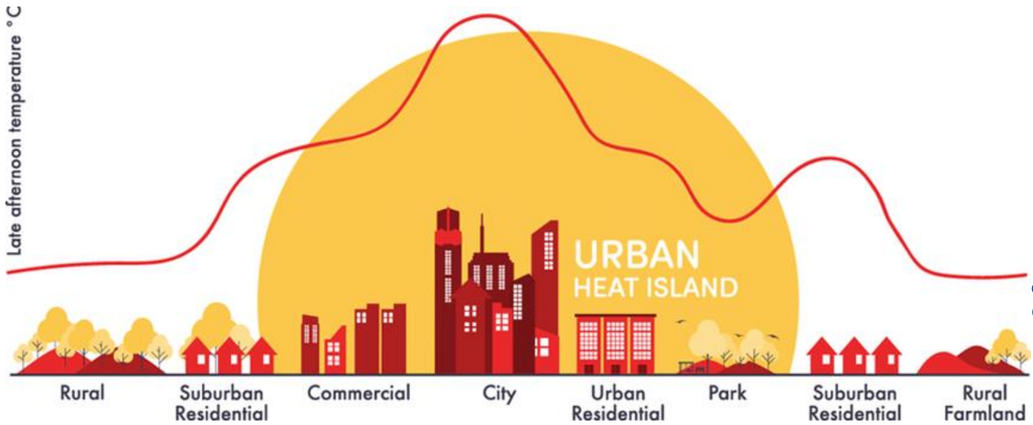
Urbanization: Urbanization alters the spatial organization of the geographic area and thus the climatic parameters. The densification of tall buildings and the narrowness of streets create canyons where heat accumulates due to solar radiation (through reflection and absorption) or human activities. This urban morphology disrupts existing wind patterns, which fail to dissipate the stagnant heat sufficiently. Additionally, the materials used to construct cities strongly retain heat during the day, releasing it at night, limiting nocturnal temperature decreases.

Loss of nature in cities: Urban densification has reduced the space available for natural areas, favoring highly mineral public spaces. However, vegetation and water play a crucial role in cooling the ambient air. Through the absorption of sunlight, evapotranspiration (water release in vapor form by plants), creation of shade, and evaporation of rainwater, **natural areas act as natural air conditioners.**

Anthropogenic activities: The concentration of human activities contributes to local warming of urban air. Greenhouse gas emissions from urban traffic, industrial activities, and building heating increase the atmosphere's capacity to absorb heat. Moreover, human activities (transportation, air conditioning, appliances, etc.) also generate heat that adds to the growing urban heat.

Thus, within the city, we observe an additional heat creation phenomenon that cannot dissipate or be absorbed. A **hotter microclimate** appears within these urbanized areas, especially at night. **The more these areas densify and urbanize, the more the urban heat island phenomenon increases.**

Illustration of an Urban Heat Island:
the more urbanized the space, the higher the heat



© World Meteorological Organization

THE IMPACTS OF URBAN HEAT ISLANDS ON THE CITY AND ITS INHABITANTS

Heat is the deadliest meteorological hazard during an average year. Rising temperatures directly increase the risk of a wide range of health problems for citizens (respiratory diseases, dehydration, heart diseases, exhaustion, etc.). Additionally, urban heat has a significant impact on air pollution.

Beyond 30°C, conditions become favorable for ground-level ozone formation, which contributes to the concentration of atmospheric pollutants. According to a study published in July 2023 in Nature Medicine, **60,000 deaths in Europe during the summer of 2022 were attributable to heat.**

URBAN HEAT AND INEQUALITIES

Urban heat islands **exacerbate** social inequalities within territories.

Several studies have demonstrated that the poorest neighborhoods in large North American cities are also the neighborhoods with the highest urban heat. The temperature difference is explained by the higher building density combined with lower-than-average vegetation cover. According to Dr. Pierre Gosselin, coordinator of the health program at Ouranos (the Quebec research consortium on regional climatology and climate change adaptation), "income influences housing quality, insulation, air conditioning, access to parks, pools, air-conditioned libraries, etc." The most vulnerable populations are therefore the most affected by this urban heat phenomenon and have fewer means to protect themselves.

Urban heat also unevenly impacts different demographics. Vulnerable populations (seniors, children, homeless individuals, undocumented immigrants, etc.) are more susceptible to prolonged exposure to extreme heat. For example, a 27% increase in mortality among seniors over 75 was observed in the Parisian region following the heatwaves of summer 2022.
Poverty and isolation exacerbate existing inequalities in the face of urban heat.

EXISTING SOLUTIONS

Cities, particularly city centers, are increasingly confronted with a challenge regarding the thermal comfort of their citizens. Successive heatwaves, coupled with the urban heat island effect, even pose health risks. Without effective adaptation measures, cities, especially their public spaces, may become increasingly unusable and unlivable.

> **How to limit the impact of Urban Heat Islands on public spaces?**

To address the challenges of urban heat islands, it is important for all city stakeholders to work towards adapting or even transforming the territory to make it more resilient. Today, there are numerous solutions available to reduce the temperature of public spaces.

The CEREMA (the French Center for Studies and Expertise on Risks, Mobility, and Urban Planning) proposes to classify these solutions into **three categories:**

1	2	3
Green solutions	**Grey solutions**	**Soft solutions**

GREEN SOLUTIONS: PROMOTING NATURE IN CITIES

Green solutions correspond to all nature-based solutions (NBS): they involve using all natural elements to cool the ambient air.

GREENING PUBLIC SPACE

Vegetation, especially trees, serves as natural air conditioners. Through a natural process called evapotranspiration, all plants release water drawn from the soil in gaseous form. According to an ADEME (the French Agency for Ecological Transition) study, **an adult tree can evaporate up to 450 liters of water per day**, equivalent to the operation of **5 air conditioners** running for 20 hours.

Another advantage of vegetation is that it does not emit light energy, which is used for photosynthesis. For example, in summer, with similar sunlight exposure, a patch of grass records less than a 6°C difference between shaded and sunny areas, compared to a difference of over 20°C for mineral surfaces.

Lush vegetation also creates shade in public spaces to mitigate the impact of solar radiation on the ground and contributes to creating cooler spaces.

This demonstrates the importance of maximizing urban greening to have sufficient vegetation cover to reduce temperatures in public spaces.

Many cities are implementing strategies to green their public spaces. For instance, Santiago launched the “Brodar program”, which involves planting over 30,000 trees in the city to provide cooling effects for half a million residents.

Singapore, through its Green Plan strategy, aims to plant 1 million new trees by 2030, ensuring that every household is located within a 10-minute walk from a park.

Greening efforts involve all stakeholders in city planning, including citizens. The more vegetation there is, the greater the cooling effect. Cities like Paris engage citizens in this process by granting them the opportunity to green public spaces. Since 2015, a greening permit has been in place, allowing residents to reclaim public space by participating in its greening.

La ville de Santiago, Chili © David Berkowitz

REINTRODUCING WATER IN CITIES

Water plays a significant role in cooling the ambient air. It is also essential for the proper development of vegetation. The more plants can draw water from the soil, the faster their growth will be, and the higher their evapotranspiration capacity will be. Cities require large quantities of water to cool their public spaces.

> **Reintroducing rivers in city centers allows for the creation of an entire self-sustaining vegetal ecosystem nearby, which nourishes itself by capillarity in the soil.**

Cities are therefore seeking to revive rivers within their neighborhoods to take advantage of their effect on vegetation. The "daylighting" trend aims to uncover rivers buried by urbanization. Inspired by this trend, Montreal has implemented the "Bleue Montréal" project since 2017, which aims to bring part of the 330 kilometers of streams existing under the city to the surface.

Thanks to its high thermal conductivity, water also has the ability to absorb heat. This cooling effect of air by water has been demonstrated in urban areas by the study "Interaction of Rivers and Urban Development in Mitigating the Urban Heat Island Effect: A Case Study in the UK“ by E.A. Hathway, S. Sharples.

This study shows a significant cooling of 1°C in ambient air when the average temperature exceeds 20°C. This cooling effect can also be optimized by integrating vegetation around these watercourses.

In Lyon, for example, on the banks of the Rhône, a difference of 3 to 5°C has been measured due to the combination of the presence of the Rhône River and vegetated areas, compared to a mineral zone.

The Cheonggyecheon River, formerly buried under a road, Seoul, South Korea
© Doug Sun Beams

REVERSING SOIL SEALING

© CEREMA

« Débitumeur », a character created by artist Jean Jullien, Nantes
© Garance Wester

Reversing soil sealing contributes to combating urban heat islands. By reducing the surface covered by ground coverings and leaving the soil exposed, it creates more space for greening and reintroducing water into the city.

Furthermore, by reversing soil sealing, rainwater infiltrates directly into the ground. This water can subsequently nourish vegetation or evaporate during heatwaves, thereby contributing to cooling the ambient air.

Artificial soils store heat throughout the day. This heat is released throughout the night and significantly contributes to reducing temperature differentials between day and night.

Areas of bare soil store less heat during the day and thus promote nighttime cooling of public spaces.

> **In France, the "Climat et Résilience" law imposes a "net zero artificialization" of soils by 2050, and many cities are already seeking to reduce the proportion of sealed soil in their territories.**

In 2022, the city of Nantes launched its "Pleine Terre" plan, which aims to convert 7 hectares of mineral surfaces into natural and living soil.

PROMOTING WIND IN CITIES

Wind is crucial for air renewal and dissipating stagnant heat. By harnessing the flow of wind, cities can establish a "natural air conditioning system" for their public spaces. Additionally, the faster the wind, the cooler it feels for users.

Cities are therefore seeking to optimize their spatial organization to preserve natural ventilation corridors or to construct new ones. Major avenues, green corridors, rivers, and streams are the main ventilation corridors in cities.

The city of Stuttgart, Germany, has mapped its territory to avoid construction around its natural ventilation corridors and thus not disturb the flow of winds. More than 60 hectares of buildings have been avoided, allowing the city's air to be better renewed.

In partnership with the World Bank, the city of Guangzhou in China has experimented with numerous nature-based solutions to mitigate the urban heat island effect. The city has notably restored six major ventilation corridors, which crisscross the city, to take advantage of the coolness brought by the wind.

Guangzhou, China

TO CONCLUDE, ARE GREEN SOLUTIONS THE MOST EFFECTIVE?

Nature-based solutions appear to be **the most effective and virtuous solutions** for mitigating the impact of urban heat islands.
All these solutions offer numerous co-benefits (reduction of air and noise pollution, improvement of mental health, etc.) for citizens and urban well-being.

GREY SOLUTIONS: EFFECTIVE ALTERNATIVES

Nature-based solutions can be challenging to implement in highly constrained public spaces (limited access to the ground, load-bearing capacity, loss of visibility, etc.).

Many urban heat islands have specific characteristics (such as a mineral square above a parking lot or subway) and cannot accommodate natural solutions.

Thus, ADEME defines a second category of solutions, aimed at addressing urban heat challenges: grey solutions.

© CEREMA

> **Grey solutions encompass all urban infrastructures (pavements, urban furniture, buildings, etc.) that improve thermal comfort.**

TRANSFORMING GROUND COVERINGS

Artificial ground coverings play a significant role in capturing and retaining heat. A study by the Parisian Urban Planning Workshop (APUR) classifies current ground coverings into three categories on a hot (35°C) and sunny day:

- "**Very hot**" materials such as asphalt roadways and asphalt sidewalks, which exceed 60°C by the end of the day.
- "**Moderately hot**" materials such as granite sidewalks and stabilized surfaces (compacted mixture of sand, gravel, and other minerals). Their temperature ranges between 50 and 55°C by the end of the day.
- "**Cool**" materials, such as grass (the climatic reference), which reach 40°C by the end of the day.

To reduce their impact on the creation of urban heat islands, new forms of ground coverings and materials are being developed to decrease the absorptive properties of surfaces and increase their capacity for water infiltration.

Permeable pavements are made up of perforated tiles that leave part of the ground exposed to the air. This solution provides direct access to the soil for water and allows for the addition of vegetation, while still allowing users to walk on it. Many solutions for permeable pavements exist and vary based on the materials used, tile sizes, and the filling of the empty space. The startup Purple Alternative Surface has developed a solution of perforated tiles made from 100% recycled and reusable plastic.

However, all permeable pavement solutions still have constraints due to significant maintenance requirements and lower load-bearing capacity. Their primary use remains in lightly trafficked roads, road shoulders, and parking spaces.

Purple Pav® © Purple Alternative Surface

Other ground covering solutions have characteristics that allow rainwater to easily infiltrate. By directly irrigating the soil, these coverings improve thermal comfort on the surface through evaporation.

The American startup AquiPor has developed permeable concrete made from industrial by-products and without cement.

In France, a solution has been developed by the laboratory of the ESITC Caen school, called Fresh Ecopavers. It consists of concrete pavers mixed with scallop shells, providing significant porosity and therefore strong drainage capabilities.

Fresh Ecopavers © ESITC Caen

> **The more the materials constituting the ground of urban spaces reflect sunlight, the less heat they absorb, and therefore, the less they contribute to the warming of the city.**

This reflection is calculated using albedo (the amount of solar radiation reflected by a surface). It ranges from 0 to 1, with 0 corresponding to a surface absorbing all radiation and 1 to a surface reflecting all radiation.

In Athens, replacing a dark asphalt covering (albedo of 0.04) with a white covering (albedo of 0.55) reduced surface temperatures by 4°C during the day.

The city of Los Angeles experimented with an innovative ground covering to better reflect solar radiation. The solution used, CoolSeal, from the company GuardTop, was deployed in over 15 different neighborhoods of the city.
A difference of 5.5°C was measured between the CoolSeal solution and nearby black asphalt.

CoolSeal © GuardTop

Ground coverings have a direct positive impact on users of public spaces, especially pedestrians.

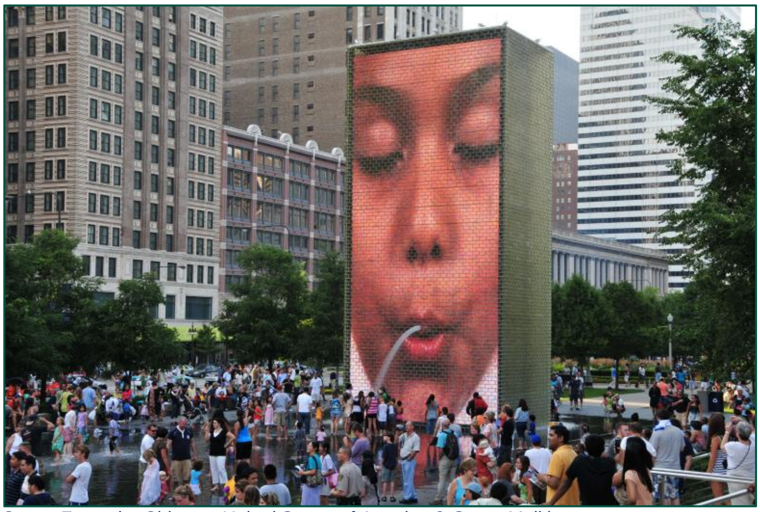
By absorbing less heat from solar radiation and allowing water to pass through, they help limit the temperature of the ground. However, they require a lot of maintenance and are less durable than asphalt or concrete, which are commonly used in cities. Their use should therefore be prioritized in areas with low traffic, such as pedestrian zones.

DEPLOYING DEVICES USING WATER IN ALL ITS FORMS

Cooling devices that use water are **highly favored** by users of public spaces. These solutions increase the number of water points, promoting evaporation for a strong impact on local cooling.

Historically present in cities, fountains are the primary location for refreshing oneself and accessing water in public spaces. Among them, water mirrors are horizontal fountains installed in cities, allowing a very thin layer of water to flow over a large surface. The thinness of the water layer facilitates its evaporation, thus cooling the user.

According to a study by Matheos Santamouris titled "*Passive and active cooling for the outdoor built environment*," these devices cool the local ambient air by an average of 1°C. Additionally, the ability to come into direct contact with water offers a much greater sensation of coolness.



Crown Fountain, Chicago, United States of America © Serge Melki

Misting Wallace fountain in Paris © Christophe Charnay

Water misting is the physical device that has the greatest impact on users' sensation of coolness. A study by G. Ulpiani titled "*Water mist spray for outdoor cooling: A systematic review of technologies, methods, and impacts*" demonstrates an average perceived temperature reduction of 7.9°C in the heart of a water mist.

"*Eau de Paris*" has developed an adaptable misting system for Wallace fountains. Since July 2023, 50 fountains have been equipped with this device.

However, misting cools very locally. As soon as users move away a few meters from the devices, the cooling effect fades. Moreover, misting raises questions about the amount of water considered excessive and requires to be connected to the drinking water network, to ensure a diffusion of safe water.

To cool urban spaces, it is possible to water the streets to recreate the natural effect of rain. By wetting the hot surfaces, the water will evaporate and create coolness.

This watering is even more effective when applied to porous materials.

The city of Kobe in Japan waters its streets during the hottest periods of the summer. A study conducted on the watering of Kobe's roads in 2022 demonstrated an average reduction of 6°C in surface temperature.

However, this temperature decrease was short-lived (less than 30 minutes on the hottest days).

Watering the streets in Kobe, Japan © Takebayashi, H., Mori, H. & Tozawa, U. (2023). Study on An Effective Roadway Watering Scheme for Mitigating Pedestrian Thermal Comfort According to the Street

The implementation of these public space cooling solutions using water plays an essential role in cities' strategies to combat urban heat islands. They allow local authorities to create thermal buffers, tempering temperature fluctuations and thus creating microclimates in public spaces.

However, these solutions entail significant water consumption. Periods of high heat are often associated with high tension on water resources. The widespread adoption of these solutions therefore often raises questions regarding restricted or even imposed usage during these periods.

DEPLOYMENT OF SHADE IN PUBLIC SPACES (1/3)

Particularly effective during periods of intense sunlight and heat, shade limit the impact of direct solar radiation on pedestrians. They reduce temperatures in a very localized area, providing a refuge during the day. Additionally, the re-emission of heat in the form of infrared radiation from the urban environment during the night is also reduced, as it has been shaded during the day.

> **Shading solutions act directly at the pedestrian level to enhance their thermal comfort and perception: they are localized solutions that can also offer services to users.**
>
> **They create refuge areas, promoting walking, and thus preserving the ability to use outdoor urban space, even during periods of high heat.**

Shading solutions are often the lightest solutions that do not require extensive reworking of the environment where they are installed. They have the significant advantage of being modular, and their installation is often straightforward, allowing for quick adaptation to periods of high heat. However, for all shading devices, further improvements can still be made. In the current state of development, these solutions can be optimized, particularly in terms of managing the cast shadow to ensure maximum shaded space for users throughout the day.

It is important to distinguish between:

- **Urban islands**, which are urban furniture themselves, often permanent fixtures
- **Shade sails**, which are the simplest installation solutions and can cover large areas
- **Innovative structures**.

Below, we present an overview of existing shading solutions.

Green Shades © SingularGreen

Green Shades, from the Spanish company specialized in greening public spaces Singular Green.

True hanging gardens, vegetal canopies bring vegetation and all its benefits to areas where it is not possible to install trees. The large canvases use rainwater for their autonomous watering and include a system for recovering excess water. In addition to providing broad protection against the sun, the vegetation present on the system absorbs CO_2 and NO_x (atmospheric pollutants that contribute significantly to the greenhouse effect) and promotes biodiversity in the city.

Particularly suitable for narrow streets where greening is not possible, the solution is also capable of taking shape on anchoring supports, suitable for any space.

The Portuguese creative agency **ImpactPlan** implemented shade installations in Toulouse and Rennes during the summer of 2023, covering the sky over shopping streets.

Initially simple decorations, this agency has been increasingly called on to provide its solutions as part of efforts to combat urban heat islands.

Combining shade and design, the agency's installations have been highly successful worldwide, from Miami to Japan. In Toulouse, the company also installed its "ceiling" over 600m² of Place du Capitole, showing that it is not just for narrow streets.

Projection of the ephemeral and artistic shading structure © Impact.Plan.

DEPLOYMENT OF SHADE IN PUBLIC SPACES (2/3)

CityMur oasis © CitéFlor

The **CityMur** range by the Gironde-based company CitéFlor is a range of urban furniture that creates a natural shaded area, thanks to a self-contained, mobile structure.

The climbing vegetation creates a "parasol tree", a real vegetal roof that can reach up to 9m² for a single module. Shade sails can connect multiple Oasis modules to increase the shaded area and transform a mineral urban area. In addition to providing shade, pedestrians who rest there also benefit from the coolness produced by the plants through evapotranspiration.

This furniture provides a cooling effect up to 13°C under its shade.

Sombrero H2O, the giant inflatable shade structure from Michelin Innovation Lab, was tested during the summer of 2023 in the André Abbal square in Toulouse.

This mineral square does not allow for vegetation due to its subsoil. Offering up to 260m² of shaded area with its 20m wingspan, this massive shade structure can be deployed in less than an hour.
According to initial measurements, at 30°C, the temperature is reduced by 3°C under the structure, with a much higher perceived temperature drop thanks to the misters included in the base.

Sombrero H2O © Michelin

Shades Plaza is a modular urban island furniture, offering great freedom of arrangement.

The 3m square modules, made of robust and durable materials, can be filled with photovoltaic panels, or different types of shading devices, which can also serve as supports for climbing plants.

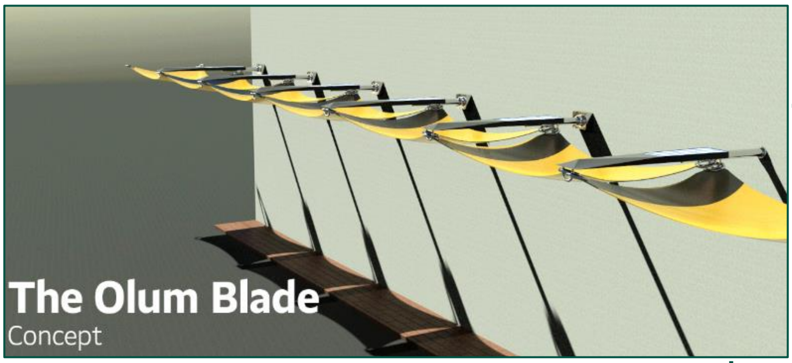
The structure is designed to be accompanied by urban furniture, transforming it into an outdoor space, conducive to meetings and relaxation in the shade.

Shades Plaza © Streetlife

Lumiweave provides shade during the day and light at night through an innovative fabric, equipped with photovoltaic energy sensors on one side, and LED lighting on the other.

Crowned with a Women4Climate Tech award in 2020, this solution requires no connection as it is designed with high-capacity batteries in its base. It is therefore easy to install and move, allowing cities to illuminate the night. Equipped with sensors, Lumiweave installations can also autonomously manage the movement of the sail according to the sun's movements.

© Lumiweave

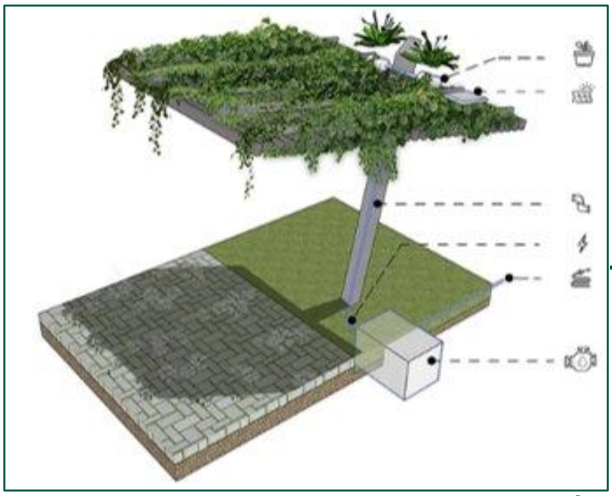


© Olum Blade

The **Olum Blade** concept was conceived by students during a design challenge aimed at encouraging foot traffic on an avenue in Dubai.

The Olum concept reimagines ancient shading techniques by envisioning "blades" with autonomous movement, attached to the walls of the avenue and connected by canvas. The blades adjust their orientation according to the sun. Their design enhances air circulation under the canvas and thus creates natural ventilation.

For all these shading devices, further progress can still be made. In their current state of development, these solutions can be optimized, particularly in terms of managing the shadow cast, to ensure maximum shaded space for users throughout the day.



© BioShade

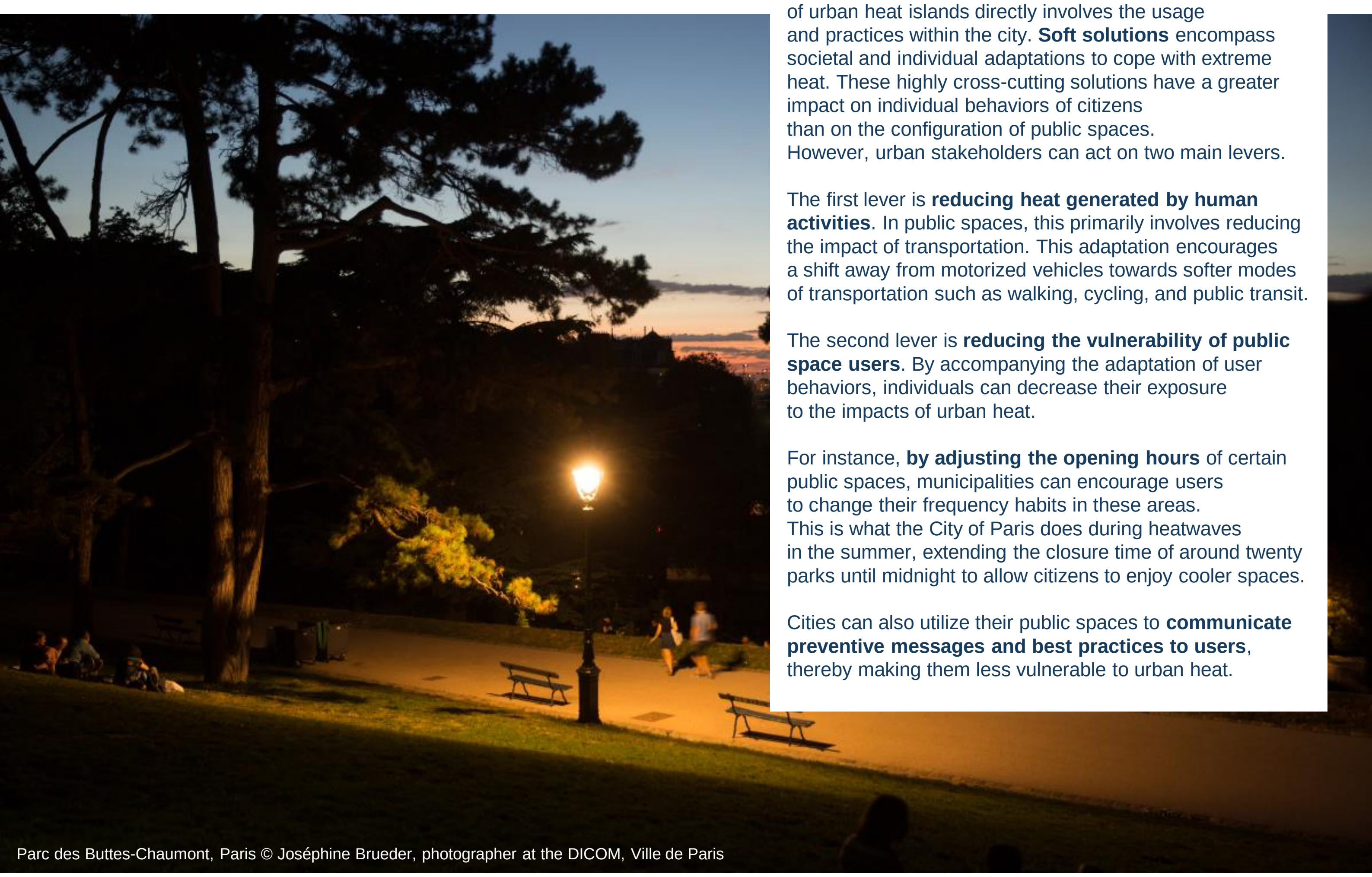
BioShade offers a shade solution through plants that is particularly effective, as it incorporates innovative hydroponic technology. With this system specially adapted to the growth of climbing and covering plants, the shade consumes 80% less water than traditional soil-based growth and provides vegetative coverage that grows twice as fast.

The reduction in heat by 10°C under the shelter is thus coupled with improved air quality and CO_2 sequestration by the plants.

TO CONCLUDE, ARE GREY SOLUTIONS RELEVANT ALTERNATIVES?

Grey solutions appear as **relevant alternatives to green solutions**.
Easier to adapt to the constraints of urban environments, they can be used to complement cool island systems.
These solutions require special attention in terms of communication with users : it is important to incorporate pedagogy throughout the project to explain the choice of this type of solution, compared to a green solution, and the expected impacts.

SOFT SOLUTIONS: BEHAVIORAL ADAPTATION



Parc des Buttes-Chaumont, Paris © Joséphine Brueder, photographer at the DICOM, Ville de Paris

The final category of solutions to mitigate the impact of urban heat islands directly involves the usage and practices within the city. **Soft solutions** encompass societal and individual adaptations to cope with extreme heat. These highly cross-cutting solutions have a greater impact on individual behaviors of citizens than on the configuration of public spaces. However, urban stakeholders can act on two main levers.

The first lever is **reducing heat generated by human activities**. In public spaces, this primarily involves reducing the impact of transportation. This adaptation encourages a shift away from motorized vehicles towards softer modes of transportation such as walking, cycling, and public transit.

The second lever is **reducing the vulnerability of public space users**. By accompanying the adaptation of user behaviors, individuals can decrease their exposure to the impacts of urban heat.

For instance, **by adjusting the opening hours** of certain public spaces, municipalities can encourage users to change their frequency habits in these areas. This is what the City of Paris does during heatwaves in the summer, extending the closure time of around twenty parks until midnight to allow citizens to enjoy cooler spaces.

Cities can also utilize their public spaces to **communicate preventive messages and best practices to users**, thereby making them less vulnerable to urban heat.

USING NEW TECHNOLOGIES TO MORE EFFECTIVELY COMBAT URBAN HEAT ISLANDS

To combat urban heat islands, numerous technological tools have been developed alongside technical advancements (spatial imaging, artificial intelligence analysis software, digital twins, etc.). Today, these tools offer a range of applications, from mapping heat islands to recommending personalized solutions, to simulating the impact of future urban developments.

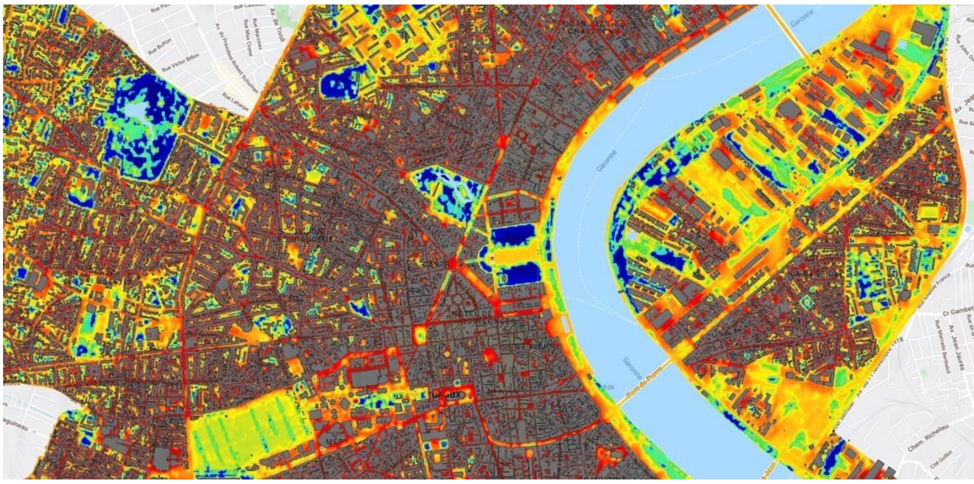
To further advance the struggle against urban heat islands, it is essential to integrate measures enabled by these tools with in-situ data collected by environmental sensors installed in public spaces. This allows for real-time representation of various indicators (temperature, humidity levels, etc.).

Thus, through the combined use of technologies, it becomes easier to identify priority areas for development and monitor their impact on ambient air cooling. In recent years, there has been a proliferation of actors developing these tools to support territories in their battle against urban heat islands (Netcarbon, Kermap, Ecoten, Sirade, etc.).

The city of Bordeaux, leveraging a dataset collected within its territory, has developed a toolkit concerning urban thermal comfort. This toolkit aids decision-making in implementing new developments to mitigate urban heat, by simulating their impact on ambient temperature.

The uniqueness of this approach lies in gathering data from citizens who provide feedback on their perceived temperature, thus enabling the objectification of all collected data.

An innovative solution that earned the city international recognition in the Energy and Environment category at the World Smart City Awards.



Mapping of Bordeaux, France, based on the urban thermal comfort index (ICTU) © VERDI INGENIERIE, 2022

KEY TAKEAWAYS

Urban heat islands are phenomena already known to city stakeholders. Their intensity are expected to continue growing, making urban spaces uncomfortable or even hazardous to users' health.

Green solutions are **the most effective** in **mitigating urban heat islands** and **cooling urban spaces**. They bring numerous co-benefits for users of public spaces (improved air quality, reduced noise pollution, better mental health, etc.). Therefore, they appear as **the priority solutions to implement**.

However, **grey solutions** provide **effective alternatives**, either as complements or when conditions don't allow for the deployment of green solutions.

The expected effects of each solution on cooling public spaces differ according to each urban context. Therefore, it is essential **to identify the specific characteristics of each area** to choose the most suitable solutions that complement each other effectively.

Indeed, to maximize the cooling effect on public spaces, it is necessary to implement a combination of the entire spectrum of solutions presented in this document (green, grey, and soft), considering their combined effects. As demonstrated throughout this document, **addressing the challenges of urban heat islands requires a comprehensive approach that combines complementary solutions**.

APPENDIX

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