HEAT ISLAND EFFECT IN URBAN AREAS

Izabella MARIN LAZĂR, Lecturer D. Architect, „1 Decembrie 1918” University of Alba Iulia, Romania, marin.izabella@uab.ro

***Abstract**: In densely built urban environments, microclimate characteristics are critically important in terms of comfort and health conditions for residents (thermal comfort/thermal stress)[1], but also in relation to environmental performance and, implicitly, the energy performance of urban areas. Given the context of climate change, the increasing frequency of heat waves, awareness of the need to ensure conditions for resilience and analysis of variations and developments in the urban microclimate have grown.*

It is important to note that the evolution of the urban microclimate not only influences the feeling of thermal discomfort experienced by the population in public spaces due to rising outdoor temperatures, but also amplifies the thermal stress resulting from the overheating of indoor spaces [1], including in residential units, resulting in an increase in the energy required for air conditioning. Thus, the simulation of the energy behavior of buildings in urban areas is conditioned by a prior assessment of the UHI intensity in the analyzed area.

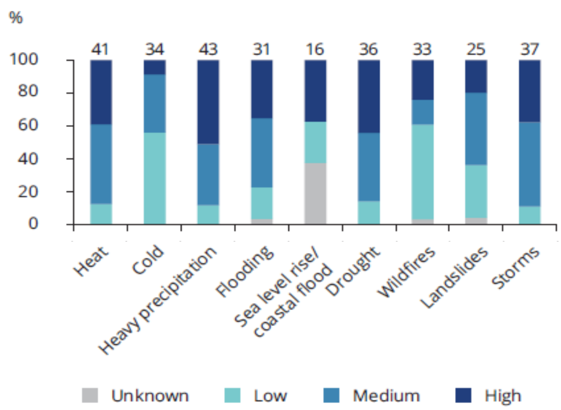
"*Together with climate change, this phenomenon may be crucial to how we view urban areas as living environments*."*[1]*

***Keywords:** Urban Heat Island (UHI) effect Mitigation; urban resilience; nZEB-nearly Zero Energy Buildings; renewable energy sources; green adapation actions; urban retrofitting; integrated solutions*

1. Introduction

The Urban Heat Island (UHI) phenomenon, defined by the increase in temperatures in urban areas compared to neighboring rural areas, is caused on the one hand by the high proportion of impermeable concrete surfaces, which leads to a reduction in evapotranspiration compared to areas surrounding the city, and on the other hand by the urban structure itself (morphology, built/open space configuration, density) that influences air currents, as well as concentrations of anthropogenic heat emissions (resulting from the use of buildings, transport, industrial activities, etc.). These aspects influence the energy balance of the urban environment and lead to the overheating of urban areas through the absorption of solar radiation, which amplifies the feeling of thermal discomfort during periods subject to the climatic hazard of heat waves and can reach a level that poses a risk to the health of the population, especially vulnerable people.

The European Environment Agency Report [2] illustrates an increase in Romania for the forecast period 2051-2100 in the percentage of summer days that can be classified as heat waves of 10-20% in the low-impact climate analysis scenario and 30-40% in the high-impact scenario compared to the 1951-2000 reference period.



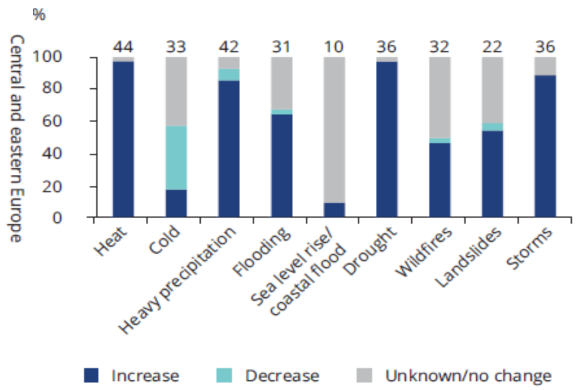


Figure1a- Current climate risk situation for cities in Central and Eastern Europe

Figure1b-Forecast climate risks for cities in Central and Eastern Europe

*) Source Urban Adaptation in Europe: how cities and towns respond to climate change _ EEA Report 12/2020

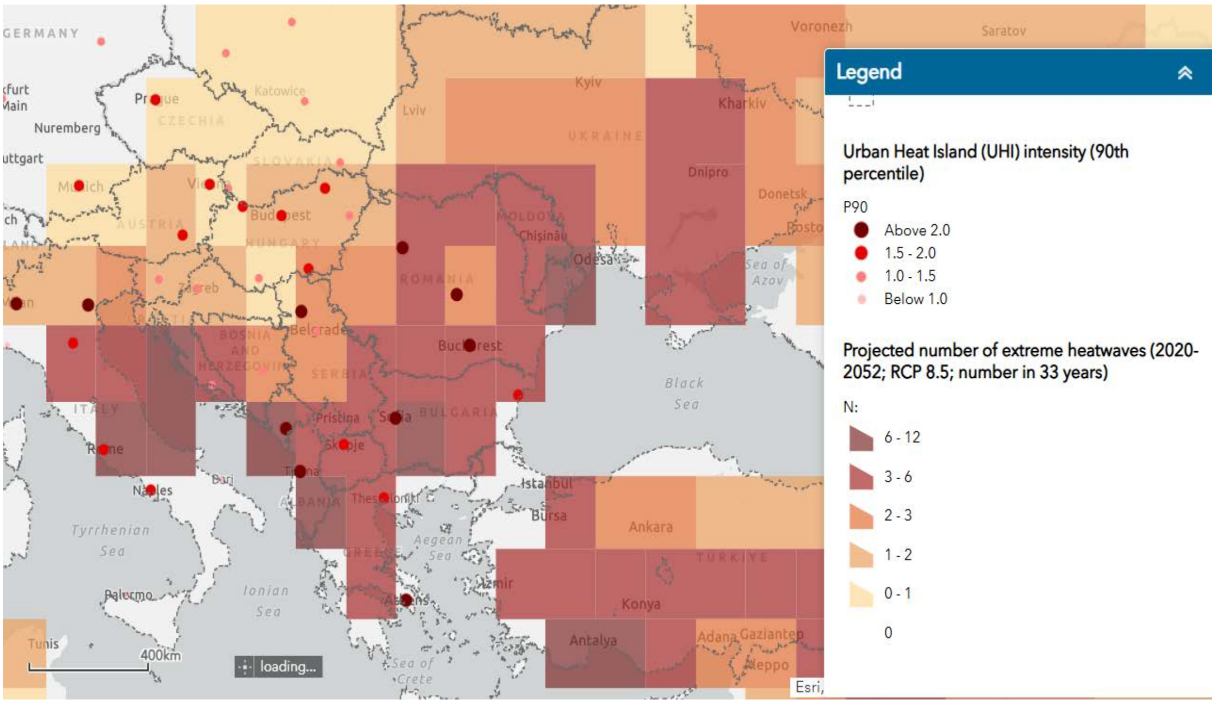


Figure 2 - vector data set UHI intensity 2.22°C- specific exposure indicator for Bucharest
*) Source https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-adaptation

Recent studies highlight the intensity of the UHI phenomenon, providing detailed data on the urban climate for a hundred European cities over a ten-year period's. Urbclim application generates thermal maps by downscaling global climate model results for the cities analysed based on field data, resulting in air temperature and thermal comfort indicators at a spatial resolution of 100m. [3] The data was processed as part of the Destination Earth (DestinE) project [4], which aims to develop a highly accurate digital virtual model of the Earth for modeling, monitoring, and simulating natural phenomena, climate hazards, and related human activities in order to develop adaptation and mitigation strategies. The maps show UHI data for three cities in Romania, namely Cluj Napoca, Brașov, and Bucharest.

At the level of Bucharest Municipality, relevant data were published in the study "*Bucharest under heatwave- the impact of the climate crisis on the urban population, especially on vulnerable groups*"[5] by determining the LSP (Land Surface Temperature) parameter and by modeling the average annual temperatures and the average maximum daily temperature in July for the period 1971-2100, for the climate scenarios RCP 4.5, RCP 8.5 with medium and high impact, based on the analysis of the values measured at the Filaret and Băneasa stations in the reference period 1901-2023. Given that average surface temperatures exceed 40°C in July in the central areas of the city, the level of "*high and very high risk of extreme temperatures and heat waves*" is indicated for more than 50% of the capital's surface area.

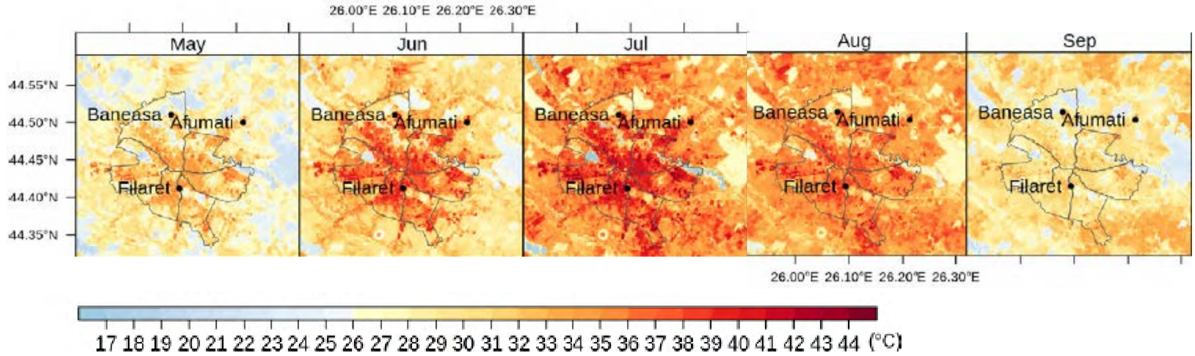


Figure 3 - Urban surface temperature extracted from Landsat 8 satellite images (2013-2018) (Cheval et al. 2025)

The estimated increase in the average maximum temperature in July for the 2050 time horizon could frequently exceed 32°C in the absence of mitigation measures to limit greenhouse gas emissions (RCP 8.5 scenario).

2. Materials and Methods

The issues raised highlight the need for a multi-criteria approach to major urban renovation projects. Systemic solutions applicable both at the buildings level and those targeting urban technical systems, e-mobility, the expansion of green infrastructure, can help reduce greenhouse gas emissions with a tangible environmental impact at the level of the city.

The analysis for the major energy renovation of an Urban Test Area located in Bucharest in order to achieve the nZEB (nearly zero-energy buildings) performance classification shows the need to relate solutions to increasing the energy and environmental performance of the existing buildings with solutions aimed at urban resilience [6]. Such an approach can lead to an improvement in the UHI effect, avoiding risk situations for the population and, at the same time, slowing down the phenomenon of rising temperatures described in the models presented above.

To identify the vulnerable areas to the UHI effect, a classification framework for *local climate zones (LCZ)* was developed (by analyzing the interaction of different land surfaces with the atmosphere, temperature, heat exchange, humidity, and air currents). The classification is based on the structure of the surfaces (density, height regime, etc.) or on the permeability/impermeability of the surfaces, resulting in a tool for urban planning aimed at increasing resilience. [7]

Figure 4 - LCZ structure – Copernicus datasets regarding surface classification for the Test Urban Area – Bucharest Municipality
*) https://land.copernicus.eu/en/map-viewer?dataset=106e3af635d3425fbca5c931dcf7e9d3

Factors amplifying UHI effect [8]

- reduced vegetation in urban areas _ reduction of the natural cooling effect through evapotranspiration and shading
- urban surface properties _ absorption of solar energy _ overheating of surfaces and air
- urban geometry _ the height and distance between buildings affect the amount of radiation received and emitted by urban infrastructure
- anthropogenic heat emissions _ contribute to additional heat accumulation in the air – high-performance technologies in buildings and mobility

Figure 5 - Analysis of urban form with reference to the layout of collective residential buildings within the Test Urban Area

The analysis of urban form highlights the relationship between the intensity of the UHI phenomenon and land use categories. Thus, LST (land surface temperature) measurements in various urban areas show that the values of this parameter decrease for areas characterized by the distribution of massive collective residential buildings surrounded by large green spaces and increase for areas with smaller collective residential buildings separated by smaller green areas, resulting in the second situation where urban areas are more affected [9].

3. Results and Discussion

The main measures to reduce the UHI effect can be grouped into solutions based on increasing the share of green infrastructure –*green/blue adaptation actions*, on the use of materials characterized by high albedo, thus reducing solar energy absorption (cool roofs, cool pavements, etc.) and, last but not least, on actions to reduce anthropogenic heat emissions, including factors such as buildings and mobility. The first category relies on increasing the planted areas and the number of trees, both by creating green roofs/facades and by planting underutilized areas or densifying alignments, creating green corridors. Vegetation provides shade and, through evapotranspiration, helps to lower temperatures and thus improve the microclimate [10], [11].

The *Smart Surfaces* [12] concept brings together highly reflective and permeable materials used for sustainable urban regeneration and development, both in terms of reducing the UHI effect and from the perspective of rainwater retention as components of sustainable drainage systems. The phenomenon of de-paving involves removing impermeable surfaces and replacing them with permeable surfaces or green spaces.

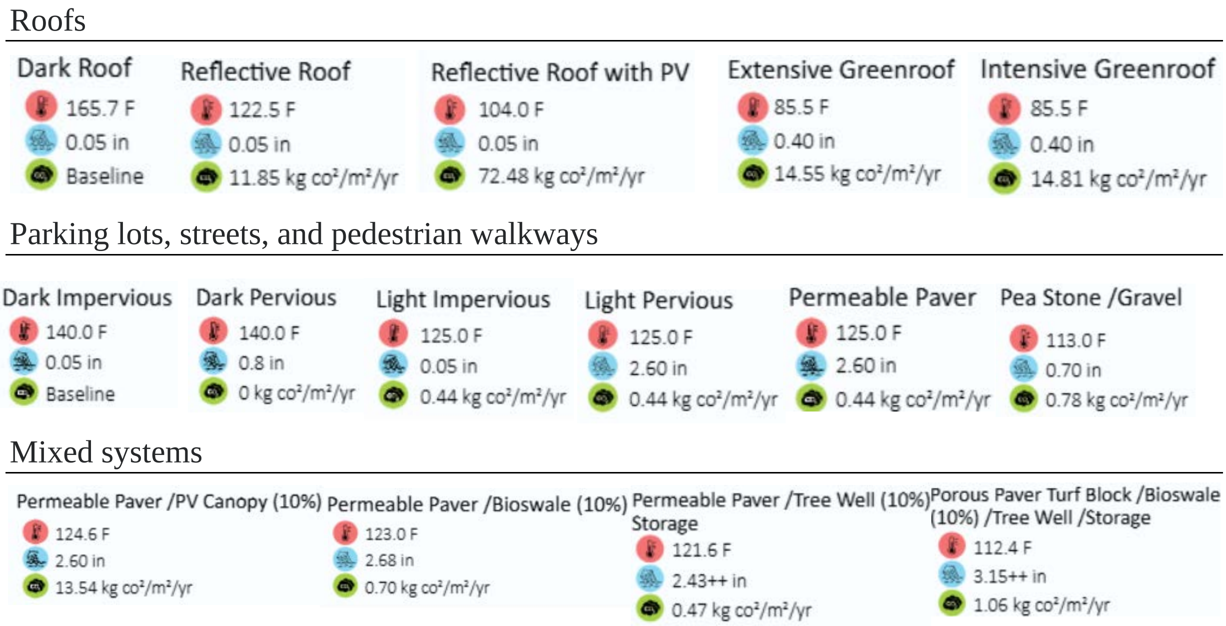


Figure 6 - Smart surfaces

The zonal analysis proposes establishing intervention possibilities in order to reduce the UHI effect by identifying measures applicable at the urban zone level, both in terms of the built environment and the interstitial space.

1. Expansion of green areas

- green roofs—this solution will be applied with caution for the Test Urban Area, given the current and forecast low level of rainfall in the summer season specific to southern Romania. The large-scale creation of intensive and extensive green roofs using the building envelope as a support requires significant amounts of water for maintenance. It is proposed that this solution be applied to low-rise buildings such as local heating stations/the roofs of school and kindergarten buildings, thus also achieving the advantage of improving the aesthetic quality of the area.
- *depaving* – it is proposed to partially remove concrete surfaces from areas such as school grounds.

2. Categories of anthropogenic surfaces on which interventions are proposed

A first step is to identify surfaces with high solar radiation absorption as well as impermeable concrete surfaces that can be replaced. The use of materials such as permeable paving, porous concrete, or gravel can reduce the amount of heat absorbed by the surface and allow rainwater to infiltrate the soil, providing natural cooling and reducing the urban heat island effect.

- for parking lots, the use of permeable materials with high reflectivity is proposed.
- terrace roofs of collective residential buildings – use of cool roof materials in combination with the installation of photovoltaic panels.
- cold facades – use of high albedo finishes for opaque vertical envelope elements – as part of building renovation to meet nZEB requirements.

By comparing the areas available for the proposed intervention categories with the total urban area analyzed, it can be seen that the solutions in the second category can have a **significant impact** on the area.

3. Achieving the nZEB standard through major renovation of existing buildings

The proposed solution packages are aimed to increase energy and environmental performance of buildings through adequate thermal insulation measures, efficient windows, the use of shading systems, but also through to high-performance technical systems and the implementation of active energy production technologies from renewable sources like photovoltaic panels [6].

The existence of a cause-effect relationship between the built environment and the urban microclimate can be highlighted, practically the building itself becomes an Anthropogenic Factor increasing the UHI effect through the residual hot fluids removed into the atmosphere due to the use of air conditioning devices. This fact causes an increase in the outside temperature and at the same time a higher consumption of energy for cooling.

In the area analyzed, it has been estimated that apartments equipped with split-type air conditioners represent approximately 40-50% of the total and the amount of residual heat emitted into the atmosphere from unrenovated housing units is around 802 MWh/ year [6], [13], [14]. Given the projected trends of rising temperatures and increased frequency of heat waves, it is expected that, if the weak energetic conformation remains unchanged, all residential units will be equipped with split air conditioning systems. This, combined with the high energy requirements for cooling, will lead to twice the amount of residual heat being emitted into the atmosphere, which would increase the UHI effect.

4. Conclusions

These aspects lead to the need to expand nZEB buildings as a strategy for *the city's adaptability to climate change* through integrated energy reconfiguration solutions that allow for increased environmental performance.

Integrated desing of new buildings that allows optimization of energy performance minimises the impact of urban settlements, as Anthropogenic Factor, on the natural environment.

The cumulative solutions applicable at the urban level offer, through the complementarity of energy renovation and resilience renovation measures, the premises for climate adaptability and increased safety and quality of urban life.

5. References

1. *Ardeshir Mahdavi, Kristina Kiesel & Milena Vuckovic - " Methodology for UHI Analysis " – Capitol - Urban Heat Island Phenomenon and Related Mitigation Measures in Central Europe p.71-91 https://link.springer.com/chapter/10.1007/978-3-319-10425-6_3*
2. *"Urban Adaptation in Europe: how cities and towns respond to climate change" _ EEA Report 12/2020*
3. *ECMWF- European Centre for Medium-Range Weather Forecasts – Destination Earth project https://destine.ecmwf.int/use-case/urban-heat-island-effect/*
4. *https://destination-earth.eu/*
5. *Irina Zamfirescu, Sorin Cheval și Alexandru Dumitrescu "Bucureștiul sub caniculă-impactul crizei climatice asupra populației urbane, în special asupra grupurilor vulnerabile", Friedrich-Ebert-Stiftung Romania -București, iulie 2025.*
6. *Marin Lazăr I.,"Atlas Verde al României aplicații în arhitectura clădirilor cu consum de energie aproape de zero (Nearly Zero Energy Buildings – nZEB),"Ion Mincu" University Publishing House, Bucharest, 2021*
7. *A method to combat the Urban Heat Island effect" -- https://land.copernicus.eu/en/use-cases/a-method-to-combat-the-urban-heat-island-effect/a-method-to-combat-the-urban-heat-island-effect*
8. *"Reducing Urban Heat Islands: Compendium of Strategies Urban Heat Island Basics" _EPA United State https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_1.pdf*
9. *Lucian Sfîcă, Claudiu-Ștefănel Crețu, Pavel Ichim, Robert Hrițac, Iuliana Gabriela Breabăn -"Surface urban heat island of Iași city (Romania) and its differences from in situ screen-level air temperature measurements", Sustainable Cities and Society, volum 94, 2023*
10. ****Victoria Ochinciuc, (Director de proiect), &echipa de cercetare Consorțiu, Proiect de cercetare: "Reducerea Efectelor Insulei Termice Urbane Pentru Îmbunătăţirea Confortului Urban Şi Echilibrarea Consumului Energetic În Bucureşti", 2014- 2017, Contract UEFISCDI nr. 102 / 1.07.2014, UAUIM nr.2/2014*
11. *Helmuth Erich Landsberg, The urban climate (International geophysics series v. 28), Academic Press, New York, 1981*
12. *"Smart surfaces guide – The path to a cooler future with smarter design for urban surfaces" – Carnegio Mellon University, School of Architecture, Center for building performance and diagnostic, 2024*
13. *https://smartsurfacescoalition.org/analysis/2022/8/9/smart-surfaces-guidebook*

14. *Constantinescu D., Reziliența climatică și performanța energetică și de mediu a clădirilor de locuit,"Ion Mincu" University Publishing House, Bucharest, 2020*
15. *Constantinescu D. –"Tratat de inginerie termică. Termotehnica în construcții", volume 2 "AGIR" Publishing House, Bucharest, 2020*