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Be Ready Local Action Plan to Prevent and Mitigate Urban Heat Island Risks and Vulnerabilities April 2026 – March 2029

City of VARAŽDIN

Activity 3.2	Development of a UHI Management Plan
Result	Local Action Plan to Prevent and Mitigate Urban Heat Island Risks and Vilnerabilities April 2026 – March 2029 - City of Varaždin
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Place and date	Varaždin – Zagreb, 11 March 2026

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Contents

1. EXECUTIVE SUMMARY

This **Action Plan (AP) for the Prevention and Mitigation of Risks and Vulnerabilities Related to Urban Heat Islands (UHI)** represents a systematic effort by the City of Varaždin to address the growing impacts of extreme heat and climate change through a planned, integrated, and participatory approach. Developed within the Be Ready project (Activity 3.2), it builds on research, vulnerability assessments, capacity-building activities, and pilot interventions, translating these outputs into concrete, actionable measures.

The AP identifies areas of high heat exposure, particularly densely built-up zones with limited green infrastructure, and highlights vulnerable groups such as older adults, children, and people with chronic health conditions. It addresses spatial, institutional, and communication measures to reduce heat stress, improve urban thermal comfort, strengthen municipal capacities, and raise public awareness. Key interventions include expanding green and blue infrastructure, increasing shading, using reflective materials, and integrating UHI considerations into planning and projects.

Planned for **April 2026 – March 2029**, the AP establishes clear priorities, responsible actors, indicative budgets, timelines, and monitoring indicators. Its flexible framework ensures transparency, evidence-based decision-making, and the ability to adapt as conditions evolve.

Through this integrated approach, the AP aims to embed UHI mitigation into municipal planning, enhance public health, reduce energy demand for cooling, and create greener, more thermally comfortable, and inclusive urban spaces, strengthening the long-term climate resilience of the City of Varaždin.

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2. INTRODUCTION

2.1 City Context and Approach to UHI

The City of Varaždin, located in northwestern Croatia along the Drava River, covers 59.45 km² and has approximately 43,782 inhabitants according to the 2011 census. Varaždin's strategic location provides excellent connectivity, being 80 km from Zagreb, 140 km from Graz, 180 km from Ljubljana, 250 km from Rijeka, 280 km from Budapest and Trieste, and 330 km from Vienna. Administratively, the city encompasses 10 settlements, while the area analyzed for urban heat island studies covers 24.45 km², or 35% of the total city territory.

Climate Characteristics

Varaždin has a **temperate** humid climate with warm summers. Over the period 2013–2023, mean annual temperatures ranged from 11.1 °C (2013) to 12.4 °C (2023), with an overall ten year average of 11.8 °C. Monthly averages show that the coldest month (January) reached -4.8 °C in 2017, while the warmest month (July) reached 23.0 °C in 2015 and 2021. Extreme monthly temperatures have ranged from an absolute maximum of 39.4 °C (August 2013) to a minimum of -28 °C (February 1956), highlighting the wide thermal variability in the region. Days with maximum temperatures ≥ 25 °C have been increasingly frequent, with peaks during summer months, while days above 30 °C have also become more common, signaling an intensification of heatwave events.

Annual **precipitation** over the last decade varied between 827.1 mm and 1,312.2 mm. Monthly extremes include a low of 1.2 mm in December 2015 and intense rainfall in September 2014. Seasonal distribution shows that precipitation is generally higher in late spring and summer, with variability posing risks for urban drainage systems. Snow cover is occasional, with maximum monthly snow depths ranging from 2 cm to 76 cm depending on the winter season.

Relative **humidity** averages 75.7% annually, with the highest recorded mean of 92% (December 2020) and the lowest at 62% (June 2021). **Wind** patterns show variable speeds and directions, influencing local microclimates and urban ventilation. Sunshine duration varies seasonally, with the highest insolation observed in July (up to 285 hours) and the lowest in December (around 63.7 hours), affecting urban heat absorption and cooling potential.

Climate Adaptation Challenges

Varaždin faces increasing urban climate pressures from rising temperatures and more frequent heatwaves. Summer peaks above 35°C, combined with dense infrastructure and limited green spaces, heighten heat stress risks and exacerbate urban heat islands. Extreme rainfall events also pose flooding and drainage challenges. Effective adaptation requires integrated urban planning, expanded green and blue infrastructure, and resilient building design to reduce heat impacts and maintain livability.

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2.2 UHI Vulnerability and Risk Assessment

The analysis of UHI in Varaždin focuses on the urban area defined by the General Urban Plan (GUP). **The research area covers 24.45 km²** (2,444.63 hectares), representing approximately 35% of the total administrative area of the City of Varaždin. **This area serves as the basis for identifying UHI hotspots and planning targeted adaptation measures.**

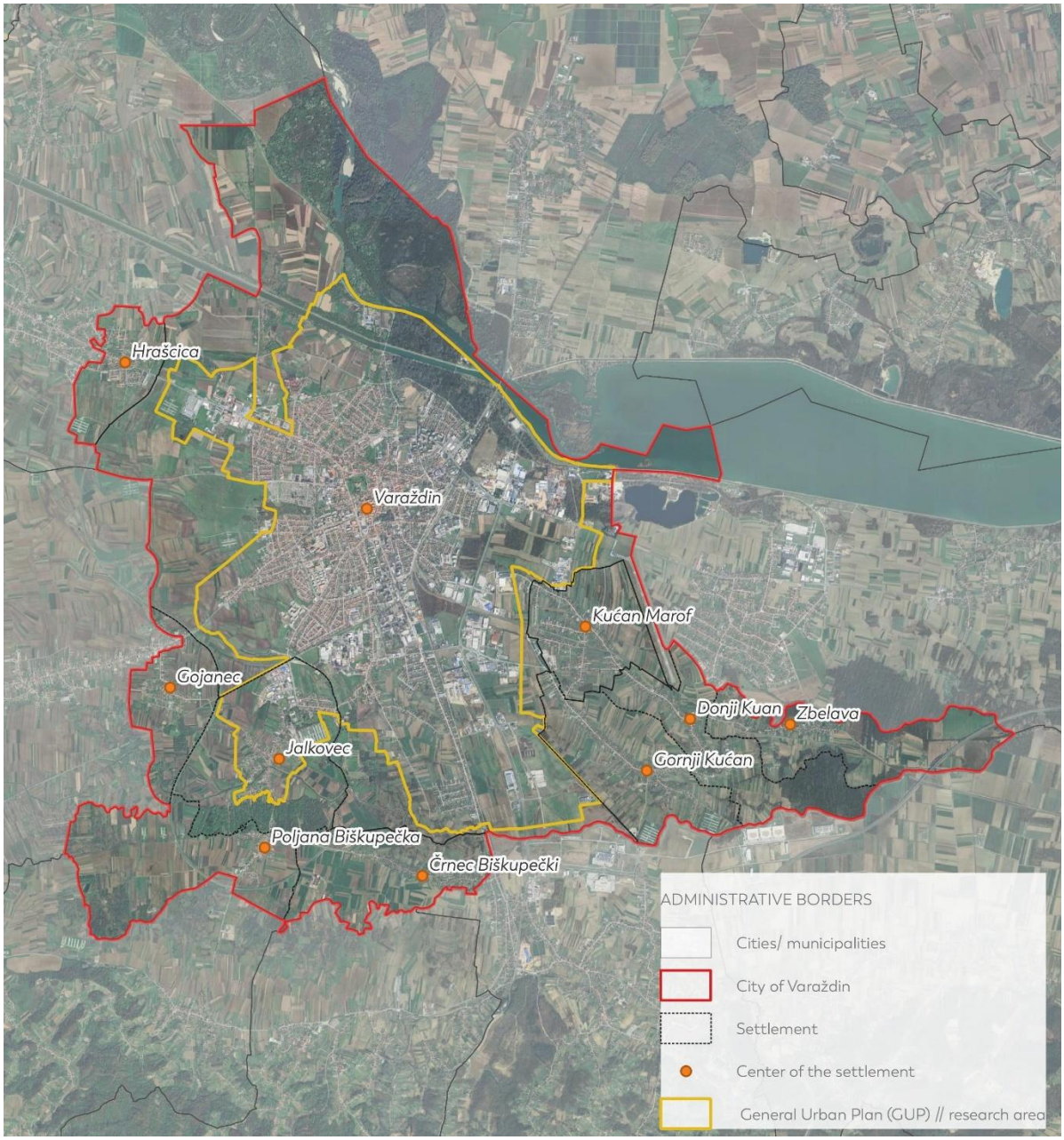

*Figure 1 - **Administrative division of City of Varaždin** (Map base: Google XYZ Satellite Imagery (Google, Maxar Technologies, 2024.), Map content: PPUG, GUP and OSM, author: 3 E PROJEKTI d.o.o.)*

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- **Priority areas exposed to UHI**

The City of Varaždin's Urban Heat Island (UHI) vulnerability and risk assessment covers four key dimensions: exposure to heat effects, population sensitivity, preparedness of the local system to respond to risks, and adaptive capacity.

The following section presents and describes the composite map of urban heat islands (UHI), developed as part of the UHI risk analysis. The map highlights areas most affected by UHI, with contributing factors including the highest values of surface albedo (above 0.2), traffic intensity (most congested points), building energy consumption (public buildings with the highest electricity use), surface temperature (above 30 °C), building coverage ratio (>0.7), floor area ratio (>2), street canyon ratio (>1.25), and soil impermeability (impervious surfaces). On the map, these factors are visualized in shades of red, categorized into low, medium, and high intensity zones, while green and blue areas indicate locations that provide natural relief from urban heat, such as parks, forests, water bodies, and shaded spaces.

Within the research area, the zones most exposed to UHI include the densely built city center with narrow streets, paved public areas such as squares, small plazas, and fairgrounds, as well as parking zones and spaces around multi-residential buildings. Peripheral industrial and commercial areas at the edges of the city are also vulnerable, along with open areas lacking vegetation or with very low plant cover, including large consolidated agricultural fields and meadows without hedgerows or tree lines. The analysis identifies specific hotspots of high heat accumulation, indicating priority areas for targeted adaptation measures for this AP.

A composite map based on the UHI vulnerability assessment for the Varaždin research area is presented on the next page (*Figure 2*).

- **Sensitive populations**

The research area has 43,782 residents, with women accounting for 52.88% and a population density of 1,466 residents per km². Vulnerable groups include the young population (13.82% aged 0–15) and the elderly population (10.47% aged 74+).

Economically, 4.79% of residents of the City of Varaždin are inactive, and about 27.6% are retired. About 72.18% of residents have low-skilled education, including 0.34% with no schooling, 12.29% with primary education, and 58.08% with secondary education.

The city has 6,296 registered persons with disabilities (1.1%) and foreign nationals represent 0.78% of the population.

Mortality and birth data for the City of Varaždin in 2023 indicate 252 deaths (0.57% of the population) and 328 births (0.74% of the population), resulting in a natural population increase of 1.32%.

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- **Public spaces and infrastructure at risk**

In areas of the City of Varaždin where Urban Heat Island (UHI) intensity is high, public spaces and critical urban infrastructure (including roads, squares, and streets in densely populated neighborhoods) are increasingly vulnerable to prolonged exposure to high temperatures. Impermeable surfaces (covering 27.5% of the city) that retain heat and areas with limited tree canopy further elevate temperatures, potentially affecting the operation of transport systems, energy networks, and public health infrastructure, while also reducing outdoor comfort and overall livability for residents.

Tree canopy coverage in public spaces varies significantly: 78.19% of the area has only 0–20% vegetation cover, while areas with more than 53% canopy account for just 6.52% of the study area.

The city's healthcare and social infrastructure plays a key role in responding to these risks. Varaždin has 935 hospital beds (0.94 per 1,000 residents), with the capacity to increase by 15% in emergencies, and is served by 14 public and private healthcare facilities, including hospitals, clinics, and medical offices. The city is also home to seven retirement homes. Varaždin (City departments) owns five buildings dedicated to social housing, with 164 apartments in Hrašćica and A. Harambašić Street, along with additional units across the city, totaling approximately 300 apartments.

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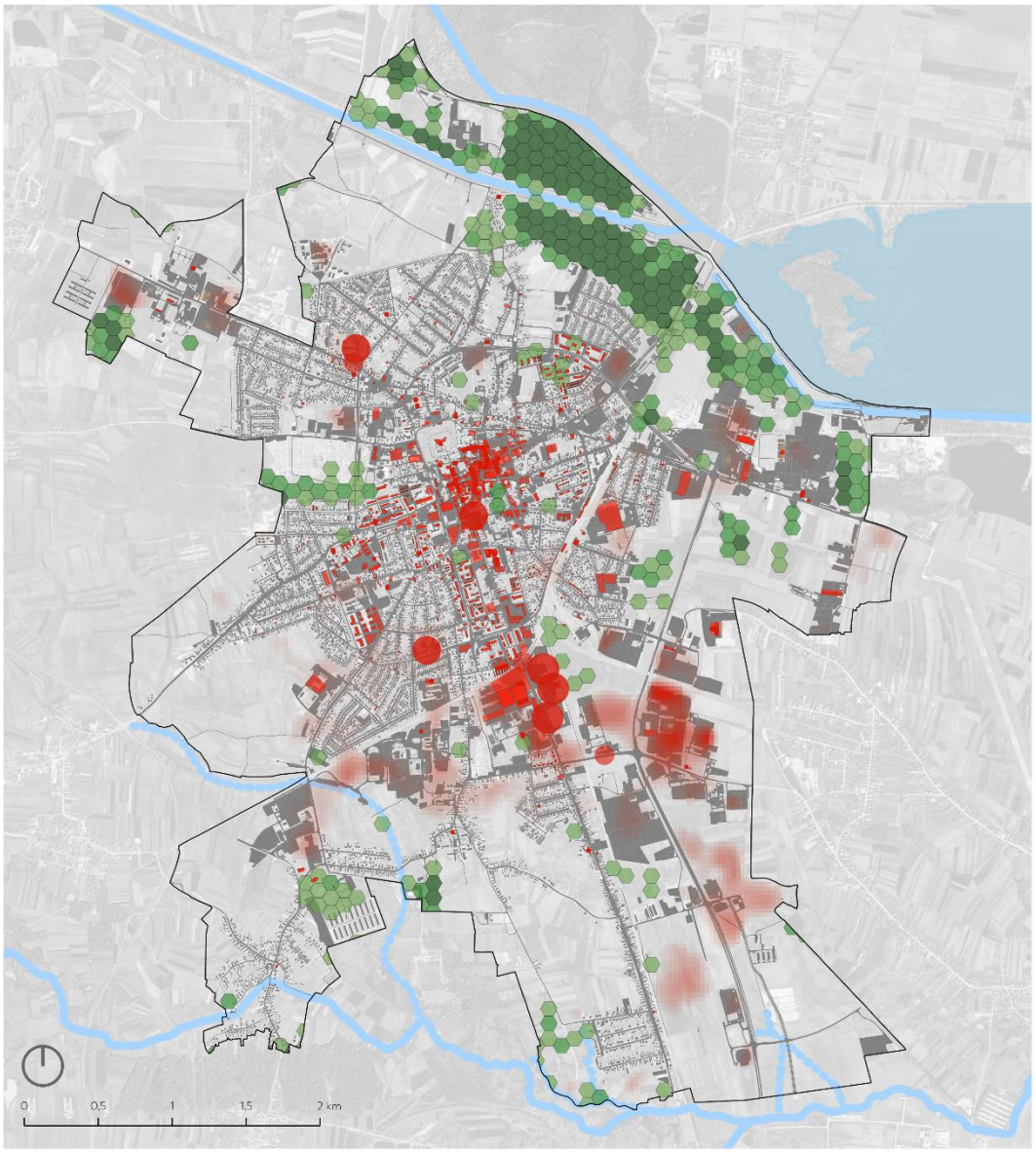

Figure 2 – ***Composite map based on UHI vulnerability assessment for the Varaždin*** *(Map base: Google XYZ Satellite Imagery (Google, Maxar Technologies, 2024.), Map content: UHI vulnerability assessment within GUP (proprietary data), author: 3 E PROJEKTI d.o.o.)*

2.3 Integration with Local Strategic Framework

The AP for managing urban heat islands in Varaždin has been developed in alignment with existing local, national, and sectoral strategies, ensuring coherence with climate adaptation, spatial planning, energy efficiency, and environmental development objectives.

At the national level, the AP aligns with the Law on **Climate Change and Protection of the Ozone Layer**, which regulates climate change adaptation. Following Article 14, paragraph 3, the Croatian Parliament adopted the **Climate Change Adaptation Strategy in the Republic of Croatia (2020–2040, with a view to 2070**). Its main objectives are to reduce vulnerability of natural and social systems, increase resilience to climate impacts, and exploit potential positive effects of climate change. The strategy identifies key sectors at risk, including water resources, agriculture, forestry, biodiversity, energy, tourism, and health, while also emphasizing cross-sectoral topics such as spatial planning, urban development, and disaster risk management.

At the local level, Varaždin has signed the **"Charter of Mayors on Climate and Energy",** committing to implement energy efficiency measures and reduce CO_2 emissions in line with the European 20-20-20 targets. This commitment led to the development of the city's **Sustainable Energy and Climate Action Plan (SECAP)**, which integrates climate adaptation, energy efficiency, and urban planning measures. In this way, the AP not only responds to the city's current exposure to heat but also strengthens its adaptive capacity, integrates with existing policy frameworks, and ensures alignment with national, regional, and European climate adaptation and sustainability objectives.

Civil protection and disaster risk management are also integrated into the AP. **Assessment of the risk of major accidents for the area of the City of Varaždin (2022)** identifies extreme temperatures among moderate risks for the area, alongside floods, earthquakes, industrial accidents, and epidemics. Operational measures are coordinated by the city's civil protection headquarters, fire brigades, Croatian Red Cross, Mountain Rescue Service, associations, and civil protection commissioners. The AP complements these structures by addressing heat-related vulnerabilities in urban areas, particularly in densely built-up neighborhoods prone to urban heat islands.

The **Spatial Development Plan of the City of Varaždin (PPUG)** and **the General Urban Plan (GUP)** establish the basic organization of urban space, the protection of natural, cultural, and historical values, and the designated use of areas, including specific conditions and measures for their development. The plans aim to maintain a balanced relationship between built-up and undeveloped areas, ensuring the existence of a complete and connected network of natural and green open spaces. Sustainable urban metabolism requires a sufficient share of open green areas, which have been identified in the plans for the preservation of existing green spaces and the development of new ones. Many of these green areas are incorporated into the AP, supporting heat mitigation and climate adaptation efforts in the city.

3. GUIDING PRINCIPLES FOR AP DEVELOPMENT

The AP for mitigating UHI effects in the City of Varaždin is grounded in a set of interrelated principles that ensure its effectiveness, institutional applicability, and long-term sustainability. These principles guide the design, implementation, and monitoring of interventions, while ensuring their integration into broader local development, climate adaptation, and risk management frameworks.

- **Sustainability and Climate Resilience** – The AP focus on long-term reduction of UHI impacts, enhancing urban resilience to climate change and improving environmental quality and livability. The key action emphasizes recurring interventions, such as tree planting, green and blue infrastructure maintenance, and public space improvements, to ensure sustained cooling benefits.
- **Evidence-Based Planning -** Interventions are grounded in the results of the UHI vulnerability and risk assessment, pilot actions, participatory processes, and relevant data analyses. This ensures that actions are targeted to the areas and populations most vulnerable to heat stress and other climate-related risks.
- **Nature-Based Solutions (NbS) -** – The AP prioritizes green and blue infrastructure, such as urban greening, tree-lined streets, parks, and rain gardens, providing natural shading, evapotranspiration cooling, improved air quality, enhanced biodiversity, and reduced UHI effects.
- **Cross-Departmental Cooperation -** Effective implementation relies on collaboration among city administration departments, public utility companies, academic institutions, civil society organizations, and other stakeholders. Responsibilities are shared to ensure coordinated action across health, emergency response, and urban infrastructure sectors.
- **Stakeholder and Citizen Participation -** The AP actively involves local stakeholders and residents in planning, implementation, and monitoring. This participatory approach enhances social acceptance of interventions and fosters collective responsibility for managing climate risks.
- **Transparency and Inclusiveness -** All processes are based on clear procedures and open access to information. Special attention is given to vulnerable population groups, including the elderly, children, and low-income residents, ensuring equitable access to benefits and climate risk information.
- **Alignment with EU and National Climate Policies -** The AP is fully aligned with EU climate priorities and national legislation, particularly the Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) procedures, embedding environmental objectives into planning, consultations, and implementation.
- **Integration of New European Bauhaus Principles** – The AP combines sustainability, climate resilience, aesthetic urban design, and social inclusiveness, creating public spaces that reduce heat, improve well-being, and foster community engagement.

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4. VISION & KEY PERFORMANCE INDICATORS

Vision

The City of Varaždin aspires to become a leading example of a climate-resilient city in which urban spaces are designed to mitigate the impacts of UHI. The city aims to expand and enhance green and blue infrastructure, create cooler and more comfortable public spaces, and protect vulnerable populations from extreme heat. By integrating sustainable urban design, innovative nature-based solutions, and active community engagement, Varaždin seeks to improve public health, increase thermal comfort, and strengthen overall adaptive capacity, ensuring a safer, healthier, and more livable urban environment for all residents now and in the future.

Goal 1 — Reduce heat exposure in critical UHI zones

Implementation strategies include green, blue, and white cooling interventions, expansion of shaded areas and tree canopy, and improving thermal comfort in public spaces. Key actions include the landscape development of St. Anne Promenade, Drava Park Forest, Green Space projects in M. Krleža Street, and tree planting under the city's operational maintenance plan for public green areas.

KPIs for Goal 1:

- Number of trees and shrubs planted (increase in tree coverage by 20% per location)
- Area of public spaces enhanced through nature-based solutions (NBS), including rain gardens, permeable pathways, lawns, and flower meadows
- Completion of project documentation and initiation of implementation

Goal 2 — Strengthen institutional capacities for climate adaptation

The city will enhance its ability to respond to UHI risks through municipal staff training, integration of UHI assessment results into spatial planning, adoption of the Green and Blue Infrastructure Strategy, and development of a Geographic Information System (GIS) for green infrastructure.

KPIs for Goal 2:

- Number of municipal staff trained (minimum 3 staff members via Be Ready Virtual Training Program)
- Updated spatial and planning documents reflecting UHI assessments
- Adoption and implementation of the Green and Blue Infrastructure Strategy
- Operational GIS covering all green areas and canopy coverage in the city

Goal 3 — Increase public awareness and behavioural adaptation

The city will implement awareness campaigns, public presentations, and citizen engagement activities, including events on Earth Day, professional and public UHI presentations, and interactive initiatives such as “Trees that Tell Stories – selection and valorization of the Tree of the Year.”

KPIs for Goal 3:

- Number of public awareness events and presentations conducted
- Citizens reached through campaigns and interactive projects
- Distribution of educational materials and engagement metrics from online and in-person activities

5. IMPLEMENTATION PLAN

Goal 1 — Reduce heat exposure in critical UHI zones							
No	*Key Action*	*Responsible Department*	*Supporting Actors*	*Budget*	*Timeline*	*KPIs*	*Sources of verification*
1	**Landscape Development of St. Anne Promenade in Varaždin**	Department of Construction and Communal Affairs (City Department)	Environmental Protection and Energy Efficiency Fund	€ 300,000.00	2026.-2028.	Establishment of 136 trees, 911 shrubs and other vegetation, a rain garden, permeable pathways, lawn, flower meadows, and other nature-based solutions (NBS) on an area of 0.93 ha	Project documentation completed and project implementation started
2	**Tree planting under the operational maintenance plan for public green areas – City of Varaždin**	Utility company - Parkovi Ltd. (City-owned company)	Department of Construction and Communal Affairs (City Department)	€100,000.00–€120,000.00	2026. - 2028.	Planting of 180 deciduous trees and 120 coniferous trees in the City of Varaždin and updating tree data in the registry	Report on the implementation of the maintenance plan for public green areas
3	**Landscape Development of Drava Park Forest *("Green infrastructure InterACTive management and regeneration tested through River Drava Forest Park in Varaždin")***	City departments	City of Ludbreg, Faculty of Organization and Informatics, Varaždin, Croatian Forest Research Institute, Public Institution “Nature of Varaždin County”, Tourist Board of the City of Varaždin, and Croatian Forests Ltd. European Urban Initiative	€ 5,166,425.60	2027.	Planting of approximately 20 000 young seedlings of native tree species (oak, maple, cherry, white poplar, and black alder), development of trails, forest clearings, and the Drava riverbank, as well as other recreational facilities	Project Implementation and Submission of the Final Report

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4	**Green Space Development Project in M. Krleža Street**	Department of Construction and Communal Affairs (City Department)	/	€25,000 for project documentation and €100,000 for implementation per location.	2026. - 2028.	Establishment of trees, shrubs, and other vegetation, a rain garden, permeable pathways, lawns, flower meadows, and other nature-based solutions (NBS) across the designated area	Project documentation completed and project implementation started
Goal 2 — Strengthen institutional capacities for climate adaptation							
No	*Key Action*	*Responsible Department*	*Supporting Actors*	*Budget*	*Timeline*	*KPIs*	*Sources of verification*
5	**Training of relevant municipal staff on UHI mitigation and adaptation (online training program)**	Department of Construction and Communal Affairs (City Department)	Development Agency North (DAN)	/	2026.	At least 3 staff members successfully complete the Be Ready Virtual Training	Be Ready Virtual Training Program statistics
6	**Integration of Urban Heat Islands Vulnerability and Risk Assessment results for the City of Varaždin into spatial plans**	Department of Construction and Communal Affairs (City Department)	Private limited companies (Ltd.); licensed architect – urban planner	€ 20,000.00	2026.-2028.	Updated spatial planning documents incorporating the results of the UHI assessment	Adopted and approved spatial plans
7	**Adoption of the Green and Blue Infrastructure Strategy of the City of Varaždin**	Department of Construction and Communal Affairs (City Department)	City Council	€ 13,000.00	2026.-2028.	Adopted and implemented Strategy	Report on the adoption and implementation of the Strategy
8	**Geographic Information System (GIS) of Green Infrastructure of the City of Varaždin**	Department of Construction and Communal Affairs (City Department)	Ministry of Spatial Planning, Construction and State Assets	€ 10,000.00	2026	Established digital system of all green areas in the City	Layer within the Green Infrastructure Registry in the Spatial Planning Information System

Goal 3 — Increase public awareness and behavioural adaptation							
No	*Key Action*	*Responsible Department*	*Supporting Actors*	*Budget*	*Timeline*	*KPIs*	*Sources of verification*
9	**Promotion and presentation for professionals and the interested public on Urban Heat Islands in the City of Varaždin**	Development Agency North (DAN)	Department of Construction and Communal Affairs (City Department); Private limited companies (Ltd.)	/	2026	1 Public presentation and event	Report on delivered UHI presentation and promotion
10	**UHI awareness promotion at City of Varaždin events (e.g., Earth Day)**	Department of Construction and Communal Affairs (City Department)	Faculty of Geotechnics and Development Agency North (DAN)	/	2026	1 Public event	Number of flyers distributed
11	**Project "Trees that Tell Stories – selection and valorization of the Tree of the Year**	Utility company - Parkovi Ltd. (City-owned company)	Public Institution "Nature of Varaždin County"	/	2026.-2028.	10 000 Citizens Reached	Online voting statistics

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6. MONITORING, EVALUATION & REVIEW

Effective implementation of the Action Plan (AP) for Urban Heat Island (UHI) mitigation in The City of Varaždin requires a structured system for monitoring, evaluation, and periodic review. This ensures continuous assessment of progress, identification of challenges, and adaptation of measures to achieve the city's climate resilience objectives.

Monitoring focuses on the regular collection of data related to implemented measures, their completion, and achieved indicators. Instruments include:

- Progress reports on implemented projects, including tree planting, forest park regeneration, green and blue infrastructure, and public space improvements.
- GIS and digital monitoring systems documenting canopy coverage, green area conditions, and spatial integration of UHI interventions.
- Citizen engagement metrics, such as participation in awareness campaigns, workshops, and UHI-related events.

Implementation AP is coordinated by the **Department of Construction and Communal Affairs**, in collaboration with development asgency, public utilities, academic institutions, and relevant stakeholders.

Evaluation assesses the effectiveness, relevance, and sustainability of implemented measures. It specifically examines:

- Reduction of heat exposure in identified UHI hotspot areas
- Improvements in public thermal comfort and behavioral adaptation
- Institutional efficiency and coordination in delivering climate adaptation measures
- Achievement of Key Performance Indicators (KPIs) established for Goals 1–3, including tree planting, shaded areas created, staff trained, updated planning documents, and citizens reached through awareness campaigns

Review and Revision ensures the Action Plan remains responsive to changing conditions and new data. Based on monitoring and evaluation results, priorities, measures, and indicators may be updated to optimize outcomes and further strengthen the city's adaptive capacity.

Table 1 - Mechanisms for Monitoring, Evaluation, and Revision of the Action Plan

Mechanism	Description	Timeline
Progress Reports	Tracking implementation of measures and KPIs	Semi-annual / Annual
Mid-term Evaluation	Assessment of progress, review, and adjustment of measures	2027
Final Evaluation	Assessment of outcomes and achievement of objectives	202

7. CONCLUSION

The Action Plan to Prevent and Mitigate Urban Heat Island Risks and Vulnerabilities in the City of Varaždin provides a structured approach to reducing heat exposure, enhancing green infrastructure, and improving thermal comfort in public spaces. It strengthens institutional capacities, promotes citizen engagement, and integrates climate adaptation into city planning and management.

Implemented during April 2026 – March 2029, the AP establishes a adaptable framework for long-term urban heat management, emphasizing evidence-based decision-making, cross-departmental coordination, and nature-based solutions. The interventions will contribute to healthier, more resilient, and inclusive urban spaces, while providing a foundation for future policies, investments, and citywide replication.

Through collaboration with municipal departments, public enterprises, academic institutions, and civil society, the AP ensures coordinated implementation, transparent monitoring, and sustained impact, positioning the City of Varaždin as a climate-resilient city prepared to face rising temperatures.

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