MONUPED

2025 STATUS REPORT

Deliverable 7.1 *- Popular science summaries of the project contents and updates following major deliverables*

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Work Package 7: DUT
Knowledge Hub

www.monuped.eu

Mainstreaming governance, co-investment and technology solutions for Positive Energy Districts in monument protected areas (MONUPED)

Start date of project: 01/01/2025 **Duration 36 months**

D7.1 Popular science summaries of the project contents and updates following major deliverables

Work Package 7: DUT Knowledge Hub

MONUPED

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DUT Driving Urban Transitions

Co-funded by the European Union

Consortium partners

CTU Czech Technical University in Prague

Stadt Leipzig

Primăria Municipiului Alba Iulia

CENERO

Zavod za varstvo kulturne dediščine Slovenije
Institute for the Protection of Cultural Heritage of Slovenia

ZAG Zavod za gradbeništvo Slovenije — Slovenian National Building and Civil Engineering Institute

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List of acronyms

No.	Acronym	Description
8	GIS	**Geographic Information System** - A system for capturing, storing, analysing, and managing spatial or geographical data.
9	LPZ	**Leipzig** - Refers to the German city of Leipzig, often used as an abbreviation in project documents.
10	MP	**Monument Protected** - A designation for structures or areas legally protected due to cultural or historical significance.
11	MPA	**Monument Protected Area** - A zone containing multiple protected monuments or historic features.
12	MPB	**Monument Protected Building** - A single building that is protected due to its historical or architectural value.
16	PED	**Positive Energy District** - Energy-efficient and energy-flexible urban areas or building clusters that achieve net-zero GHG emissions and generate a renewable energy surplus.
17	PV	**Photovoltaics** - Technology that converts sunlight directly into electricity using solar cells.
18	RES	**Renewable Energy Sources** - Naturally replenished energy sources like solar, wind, hydro, geothermal, and bioenergy.
20	SPARCS	**Sustainable energy Positive & zero cARbon CommunitieS** - An EU Horizon 2020 project supporting the development of sustainable and energy-positive cities.
21	TRL	**Technology Readiness Levels** - A scale (1-9) used to assess the maturity level of a particular technology.
22	WP	**Work Package** - A key component or sub-project within a larger research or innovation project.

OVERVIEW / EXECUTIVE SUMMARY

Monument-Protected Areas (MPAs) across Europe pose a unique challenge in the transition to climate-neutral cities: how to enhance energy performance without compromising cultural heritage. The **MONUPED** project—launched in January 2025—addresses this challenge by developing a **toolkit of digital tools, technical solutions, and regulatory frameworks** that enable the implementation of **Positive Energy Districts (PEDs)** within protected urban settings. With pilot Living Labs in **Leipzig, Prague 6, and Alba Iulia**, and additional case studies in **Koper** and **Pinkafeld**, the project engages municipalities, heritage bodies, researchers, and investors to co-develop innovative, heritage-compliant energy solutions.

The MONUPED approach tackles regulatory and architectural constraints through **digital innovation**, such as **GIS-based solar mapping**, **digital twins**, **thermal profiling**, and a **matchmaking app** that connects building owners with renewable energy investors. These tools collectively support energy planning, stakeholder engagement, renovation feasibility, and regulatory alignment. Technical solutions like **geothermal heat storage** and **low-temperature heating assessment** are tailored to heritage contexts. A highlight is the introduction of the **virtual PED** concept—linking energy generation and consumption across dispersed sites, a strategy already validated in EU projects like POCITYF.

By mid-2025, the project has delivered two major public reports and launched real-world testing of its solutions. Expected impacts by 2027 include greater investor and stakeholder collaboration, streamlined approval processes, enriched planning through digital tools, and increased deployment of small-scale renewable energy interventions in protected areas. MONUPED not only bridges the gap between sustainability and heritage but also sets a replicable pathway for climate-positive transformation of Europe's most treasured urban spaces.

1 INTRODUCTION

Monument protected areas (MPAs) in some cities represent between 10% and 20%, or more. In the case of Prague, the Czech Republic, it is over 16%. In Koper, Slovenia, the historical centre represents about 10% of the built area. In Leipzig, Germany, there are about 14.000 cultural heritage sites. In Alba Iulia, Romania, the core of the city with its Vauban fortress is heritage protected. The relatively small Pinkafeld, Austria, also has several dozen distributed monument-protected sites, including soon-to-be-renovated City Hall.

In this first popular summary for the wider public (published as Deliverable 7.1), we introduce the project, describing the **challenges** we face, the **solutions** the project brings, the **expected results**, and we present the **work done so far**, focusing on two main publications in 2025.

In light of the overall societal **transition towards sustainability**, this huge cultural value for cities around Europe also represents a technological challenge. Shall we keep the monument-protected areas intact, or shall we try to transform them as well? And if so, how?

The MONUPED project aspires to sensitively explore the possibilities, show directions towards both cities and investors in monument-protected buildings, and deliver concrete tools to support efforts for the continuous improvement of the energy performance of the historical buildings. The project kicked off in January 2025. In the first six months, it has delivered **two major results describing its Urban Living Labs (Leipzig, Alba Iulia, and Prague 6, as well as two case studies in Koper and Pinkafeld, and the MONUPED toolbox**. Let us explore where the state-of-the-art is and what we can expect in the upcoming months.

The MONUPED project develops a toolkit of digital tools, technical solutions, and conceptual frameworks to support the implementation of **Positive Energy Districts** (PEDs) in MPAs. The central objective is to bridge the gap between climate-neutral urban transformation and the constraints of heritage preservation.

2 CHALLENGES WE FACE

The MONUPED project addresses a central challenge in European urban transformation: how to reconcile the objectives of climate-neutral Positive Energy Districts (PEDs) with the preservation of cultural heritage in Monument-Protected Areas (MPAs) and Buildings (MPBs). Across Europe, historic city centers and protected buildings form a core part of urban identity and structure, but they often remain excluded from energy transition pathways due to strict regulatory environments, architectural constraints, and fragmented approval processes.

A few years ago, in 2017, an idea came up to introduce a new concept where a city can contain islands of decentralized energy production, and a Positive Energy District (PED) was born. It is an urban area, or a cluster of interconnected buildings, designed to produce more renewable energy annually than it consumes, thereby achieving a net-positive energy balance. This concept is central to Europe's sustainable urban development strategies and plays a pivotal role in the transition toward climate-neutral cities. **Core Characteristics of PEDs** include:

1. **Energy Efficiency**: PEDs prioritize minimizing energy consumption through advanced building designs, high-performance insulation, and the integration of smart technologies to reduce overall energy demand.
2. **Local Renewable Energy (RES) Generation**: They harness renewable energy sources such as solar, wind, or geothermal to meet and exceed their energy needs, ensuring that the surplus can be shared with the broader energy grid.
3. **Energy Flexibility**: PEDs incorporate systems that allow for dynamic energy management, including storage solutions and demand-response mechanisms, to adapt to varying energy supply and demand conditions.
4. **Integrated Systems Approach**: These districts require the seamless integration of various infrastructures—energy, mobility, information and communication technologies (ICT), and water systems—to function cohesively and sustainably.
5. **Social and Environmental Sustainability**: Beyond technical aspects, PEDs aim to enhance the quality of life for residents by promoting social inclusion, economic viability, and environmental stewardship.

So, how is monument protection compatible with the PED vision? Can we actually achieve local RES generation, or are there other ways? Shall we protect the traditional red tile roofs of beautiful European cities, or do we aim to convert them into virtual power plants? And how about changing the facades and adapting the buildings indoors? Should our vision look like the one in the picture (See Figure 1)?

Luckily, MONUPED is not the first to cope with this challenge. The real implementation of PEDs in protected areas will always be a combination of interventions in place and a virtual coupling of consumption and production. As projects like Horizon 2020 POCITYF have already shown, the virtual PED concept is a partial answer; in other words, **where the energy refurbishment hits the rock, the virtualization comes in**. Unlike traditional PEDs confined to specific geographic boundaries, Virtual PEDs operate within "virtual boundaries," integrating energy assets and consumption patterns across dispersed locations to achieve a collective net-positive energy balance. Such an approach requires good data inputs to ensure that the coupling can be achieved. Instrumental to this goal is good energy mapping, digital twins, and tools for matching stakeholders. All these constitute the backbone of MONUPED approach. The project focuses on developing and testing digital tools, small-scale technical interventions, and process-oriented outputs that respect heritage values while facilitating renewable energy production and energy efficiency. These outputs are developed in close collaboration with stakeholders and mostly tested in real-world urban settings through Living Labs established in Leipzig (DE), Alba Iulia (RO), and Prague 6 (CZ).

Figure 1: A dystopian future of Prague's heritage protection reservation using AI, by Wojciech Bełch

The Monument Protection Challenges that each partner country and city are facing are numerous and often only recognized when the investor needs to carry out a deep retrofit or wants to add renewables. Throughout the first phase of the project, the following limitations were identified:

Regulatory Constraints:

- Strict monument protection rules often prohibit or limit alterations needed for renewable energy systems or energy efficiency upgrades.
- Regulations are typically case-specific and unpredictable, with little guidance, making it difficult for owners to anticipate outcomes.

Complex and Fragmented Planning and Approval Processes:

- Lengthy, unclear, and inconsistent approval procedures discourage investment and complicate project development.
- Decision-making processes are often non-transparent and lack standardized evaluation criteria.

High Capital Requirements and Extended ROI:

- Heritage-compatible solutions (e.g., tailored insulation, non-intrusive PVs) are more expensive, extending the return on investment period and requiring significant upfront funding.

Lack of Co-Investment and Financing Mechanisms:

- There is a lack of established investment models for collective or third-party financing, especially for "virtual PEDs" where renewable energy is generated outside the MPA boundaries.

3 THE MONUPED SOLUTIONS

Central to the answer to the challenges described are the tools that we can use to map, assess, and cope with the limitations of the monument protection on the way to increased energy efficiency and energy production from renewables.

The MONUPED toolkit will be one of the central outcomes, as it provides the technical and digital backbone for the implementation of PEDs in MPAs. The toolkit includes:

- digital tools, focused on GIS-based solutions, simulation models, and user-oriented applications,
- small-scale technical Interventions, exploring physical or infrastructural measures for enhancing energy performance in protected buildings,
- process-oriented outputs, contributing conceptual studies and regulatory guidance aligned with heritage and climate goals.

Each element of the toolkit is designed with a strong emphasis on interoperability, heritage compliance, and real-world usability. By aligning tool development with the feedback loops from Living Labs and findings about regulatory and economic limitations, the toolkit aims to support both planning authorities and private actors in navigating the complex field of PED implementation in heritage contexts. The tools are developed for four main use cases: 1) Planning & Analysis (e.g., Energy Maps), 2) Design & Feasibility (e.g., Digital Twin), 3) Implementation Support (e.g., Thermal Profiling), and 4) Approval & Regulation (e.g., Roofs & Facades Studies). Altogether, they comprise a modular and scalable suite, consisting of five digital tools, two small-scale technical solutions, and two process-oriented concepts.

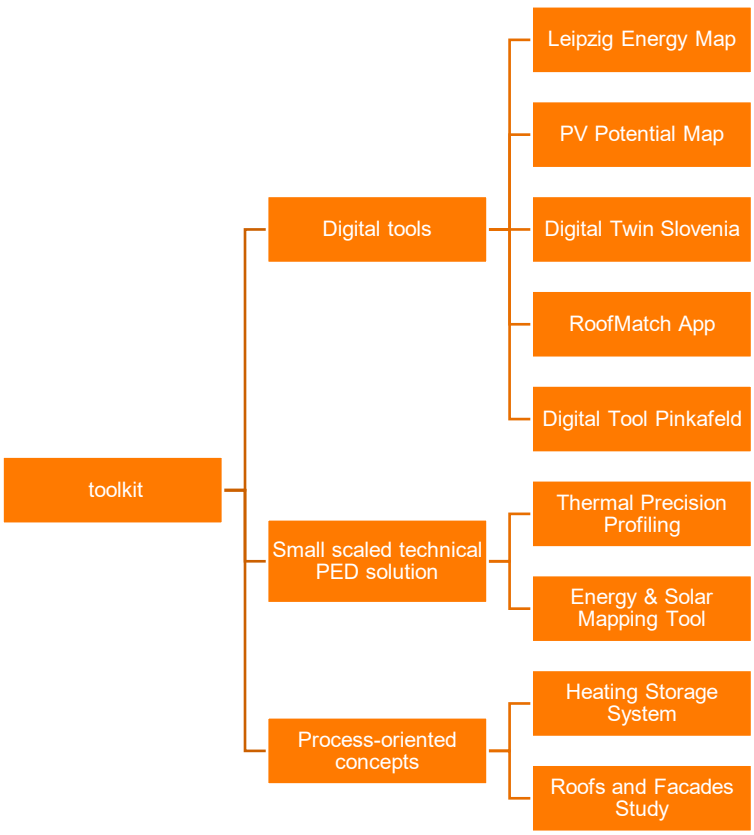

Figure 2: MONUPED Toolkit: 5 digital Tools, 2 small scaled technical solutions and 2 process-oriented concepts.

Each tool has been conceptualized and is being developed independently by project partners based on local use cases and stakeholder needs. The tools and solutions are at various stages of technical readiness and will be validated through context-specific applications in the MONUPED Living Labs (Leipzig, Alba Iulia, and Prague 6) and additional testing environments such as Pinkafeld and Koper. Below is the description of each of the solutions' use case.

3.1 Leipzig Energy Map

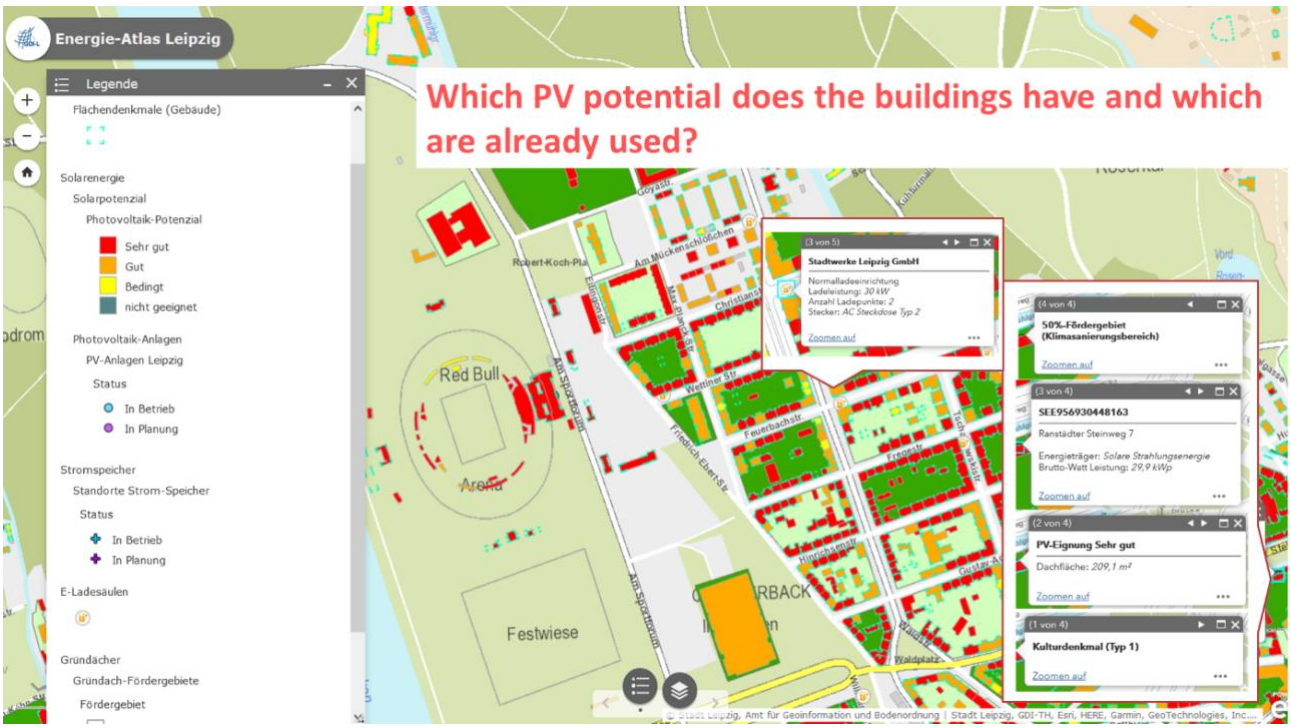

Figure 3: Leipzig Energy Map: visualization of the solar potential per building, listed building, existing PV system, location of the e- charging station (source: own illustration LPZ)

The main use case of the Leipzig Energy Map is to serve as a centralized, interactive tool for visualizing the current status and potential of renewable energy sources—such as solar, wind, and geothermal—across the city, thereby supporting strategic urban planning and climate action. Designed for both internal municipal use and public access, the tool enables city departments to analyze building-level and neighborhood-level energy data, identify optimal areas for energy transformation, and streamline decision-making processes. Simultaneously, it empowers property owners—especially those of heritage buildings—with tailored information and guidance on renewable energy integration, fostering broader participation in Leipzig's energy transition.

3.2 PV Potential Map Prague 6

Figure 4: Result of 3D simulation on the roofs of the selected block (left) and result of GIS simulation (right)

The main use case of the *Photovoltaic Potential Map Prague 6* is to provide building owners and municipal stakeholders with an accurate, easy-to-use tool for assessing the solar energy potential of rooftops across the Prague 6 district. By integrating GIS-based mapping with expert-calibrated 3D ray-tracing simulations and real weather data, the tool enables quick and realistic estimation of rooftop insolation. This supports informed decision-making for PV installation feasibility studies, reduces reliance on potentially biased contractor information, and empowers municipal planning by identifying priority areas for renewable energy investment, subsidy targeting, and PED development, especially in areas with monument protection constraints.

3.3 Digital Twin Slovenia

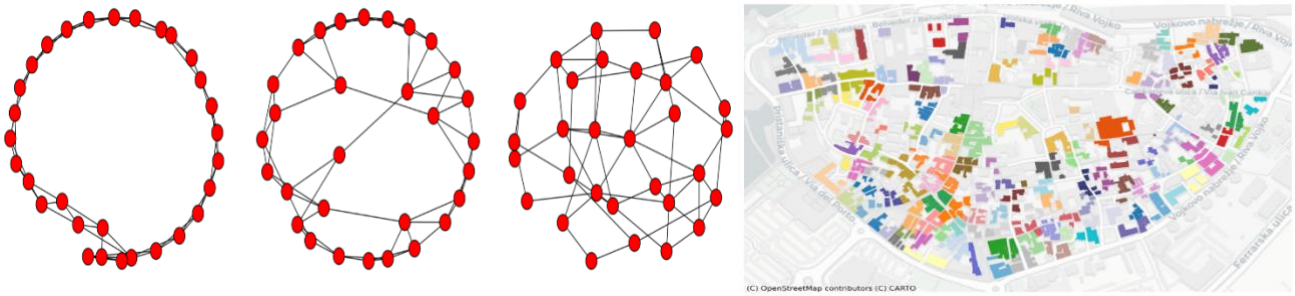

Figure 5: A diagram illustrating the creation of a social network (reflects the spatial proximity of residential units); Initial connections established between apartments in same neighbourhood clusters, edges rewired to create small-world network (Watts–Strogatz model). Graphical illustration of a test case in the use case Koper Old town.

The main use case of the Digital Twin Slovenia tool is to simulate and analyze how cultural heritage regulations, subsidies, and social dynamics influence property owners' decisions to implement energy-efficient retrofits and adopt solar energy solutions in heritage-protected urban areas, specifically demonstrated in the Koper Old Town. By employing an agent-based model grounded in the Theory of Planned Behaviour and incorporating real-world cadastral, demographic, and policy data, the tool enables policymakers to test and optimize various decarbonization strategies. It forecasts behavioral responses to regulatory and financial interventions, supporting more informed, data-driven decision-making aimed at achieving net-positive energy districts while preserving historical urban character.

3.4 RoofMatch App

	Potential receiver		Potencial funder	
Have Property	☑	☑	☑	☒
Appropriate for Investment	☑	☒	☒	☒
Have Investment Money	☒	☒	☑	☑

Figure 6: Basing use cases for the RoofMatch App.

The main use case of the RoofMatch App is to facilitate the connection between owners of rooftops suitable for photovoltaic (PV) installations, particularly those unable or unwilling to invest directly, such as owners of monumentally protected or multi-tenant buildings, and investors interested in funding renewable energy projects. By acting as a matchmaking platform, the tool helps overcome common barriers such as technical constraints, fragmented ownership, or regulatory limitations. Through its layered functionalities, including PV output simulation, economic feasibility assessment, and certified provider matchmaking, the app enables virtual Positive Energy Districts (PEDs) by allowing clean energy generation to be virtually attributed to buildings that cannot host PV systems themselves.

3.5 Digital Tool Pinkafeld

Figure 7: Pinkafeld Town Hall, Source: Wikimedia.org

The main use case of the Digital Tool Pinkafeld is to support municipal decision-making for energy-efficient renovation of heritage buildings, exemplified by its application to the 19th-century Pinkafeld Town Hall—one of the municipality's highest energy consumers. Faced with the challenge of cutting CO_2 emissions by at least 60% while preserving the building's historic façade and improving thermal comfort, the tool enables facility managers, heritage authorities, and retrofit designers to collaboratively evaluate renovation strategies. It does so through a data-driven workflow that begins with AI-assisted ingestion of archival plans and sensor data, followed by digital twin creation, performance-gap analysis, and multi-objective optimisation of retrofit scenarios. The resulting recommendations respect heritage constraints, reduce lifecycle costs, and are presented in an auditable, reproducible format to inform transparent public investment planning.

3.6 Thermal Precision Profiling

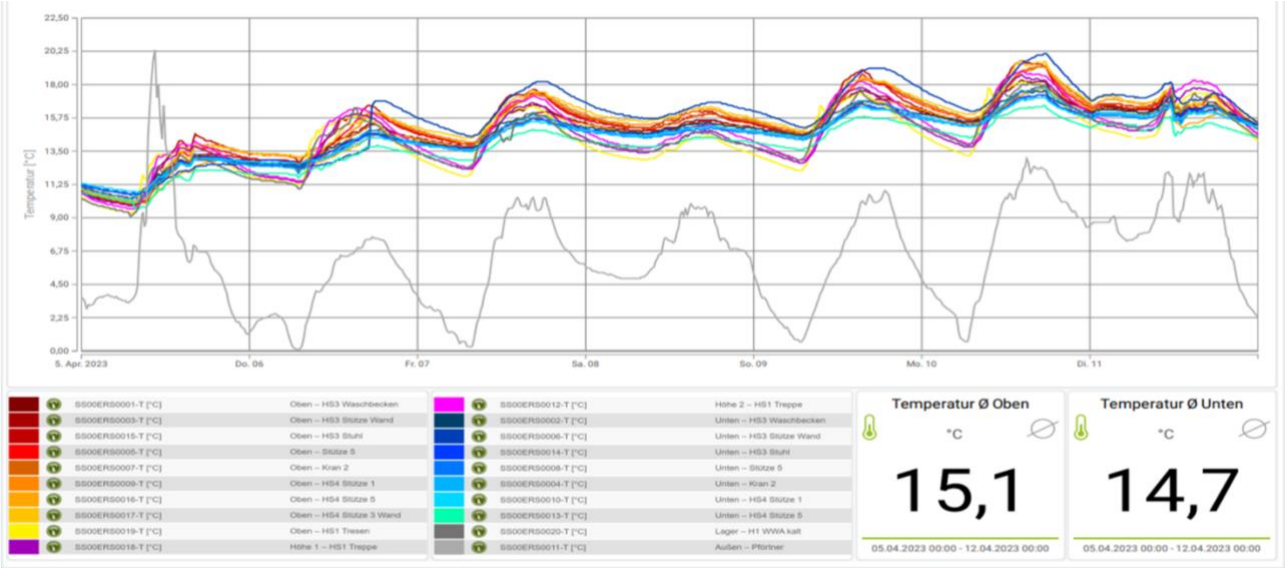

Figure 8: Example of temperature data from LoRaWAN sensors in cenero.one. Source: Cenero.one GmbH

The main use case of the Thermal Precision Profiling Tool is to support the transition of existing and monument-protected buildings to low-temperature heating systems by providing detailed, room-level thermal performance data through controlled stress tests. By simulating real-world scenarios—such as stepwise or instant reductions in flow temperature—the tool enables building owners, engineers, and facility managers to assess whether comfortable indoor conditions can be maintained at lower temperatures without major infrastructure upgrades. This evidence-based approach helps identify the minimum necessary retrofit measures, ensures compliance with monument protection regulations, and informs strategic decisions in retrofitting, investment planning, and district-level decarbonisation efforts.

3.7 Profile Energy & Solar Mapping Tool

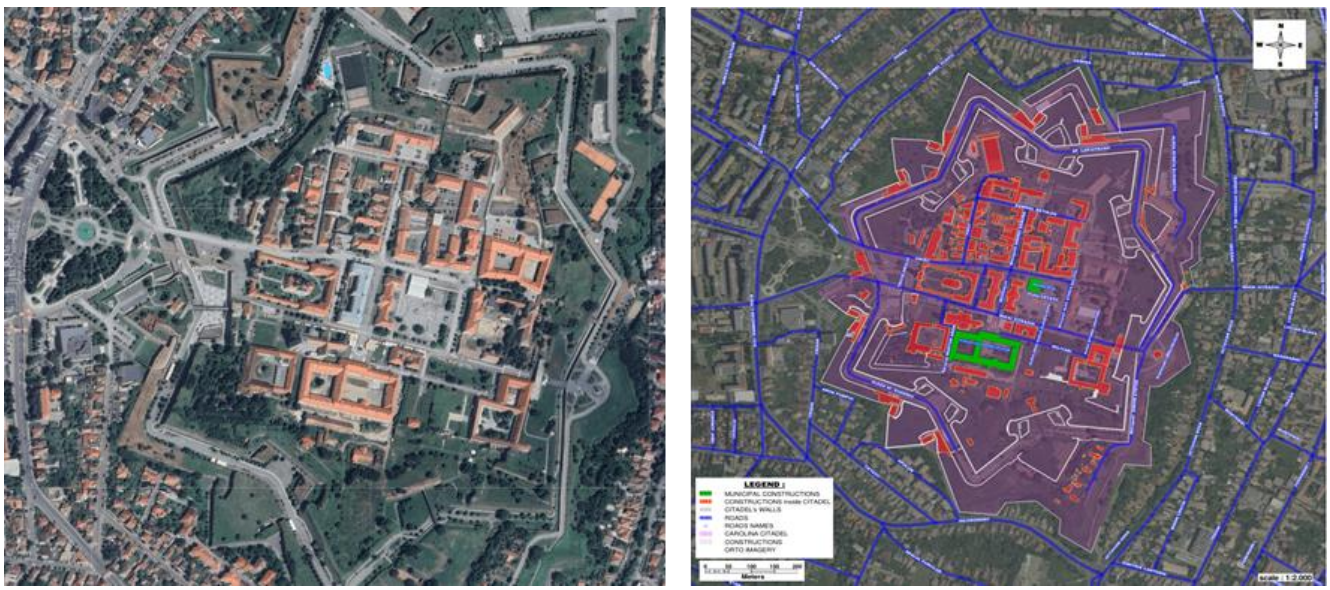

Figure 9: Satellite view (left; Google Earth) and GIS view (right; QGIS municipality) of the Citadel area – Alba Iulia (Romania)

The main use case of the Energy & Solar Mapping Tool is to support early-stage decision-making for improving energy efficiency and integrating renewable energy—especially solar—within historic urban areas, starting with the Alba Carolina Fortress in Alba Iulia. By providing accessible, map-based visualizations and simplified estimations of energy needs, building characteristics, and solar potential, the tool enables local authorities, building owners, and planners to identify viable energy retrofit

solutions that respect heritage preservation constraints. It facilitates initial assessments prior to formal audits or detailed technical planning, helping stakeholders understand opportunities, limitations, and compliance considerations for sustainable interventions in monument-protected buildings and districts.

3.8 Heating storage system in Leipzig

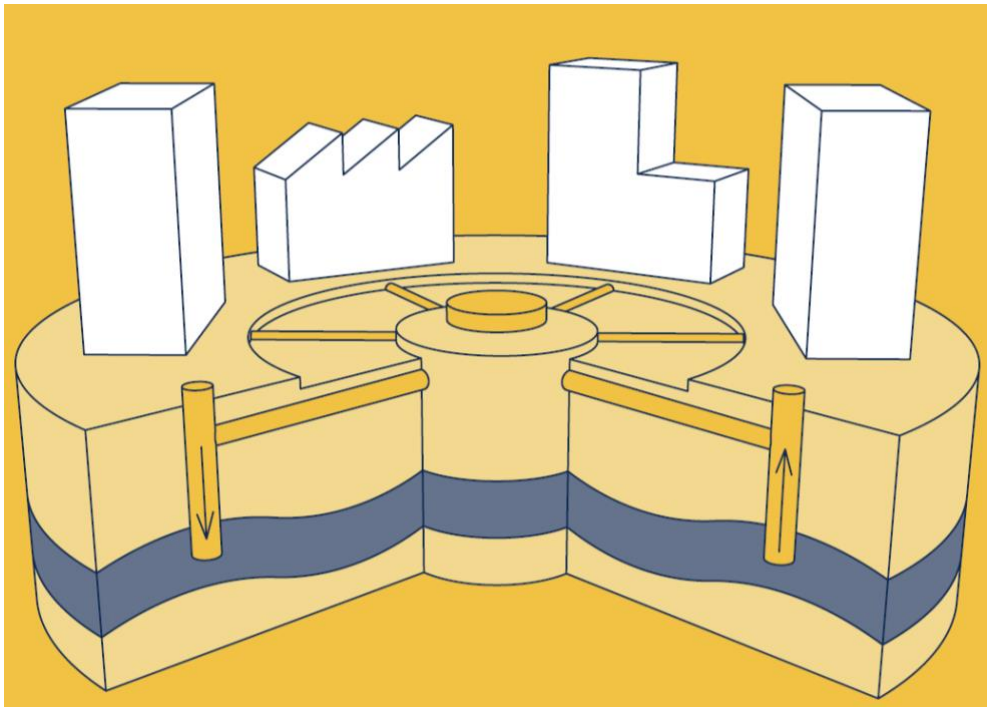

Figure 10: Graphic representation of the community-shared heat storage system

The main use case of the Heating Storage System in Leipzig is the development of a community-shared geothermal heat storage network in the Leipzig West Living Lab, specifically around the Leipziger Baumwollspinnerei. The system would utilize geothermal probes installed on nearby available land—such as a parking lot, public street, or kindergarten grounds—to serve surrounding heat consumers and prosumers who cannot otherwise access renewable heating due to spatial, financial, or regulatory constraints (e.g., monument protection). This shared infrastructure would allow prosumers to store surplus heat during summer and retrieve it in winter, offering a flexible and inclusive solution for sustainable heat supply in dense urban environments. The system is envisioned to be operated by Cenero, but implementation is contingent upon the outcome of ongoing legal and economic feasibility assessments.

3.9 Roofs and Facades Study

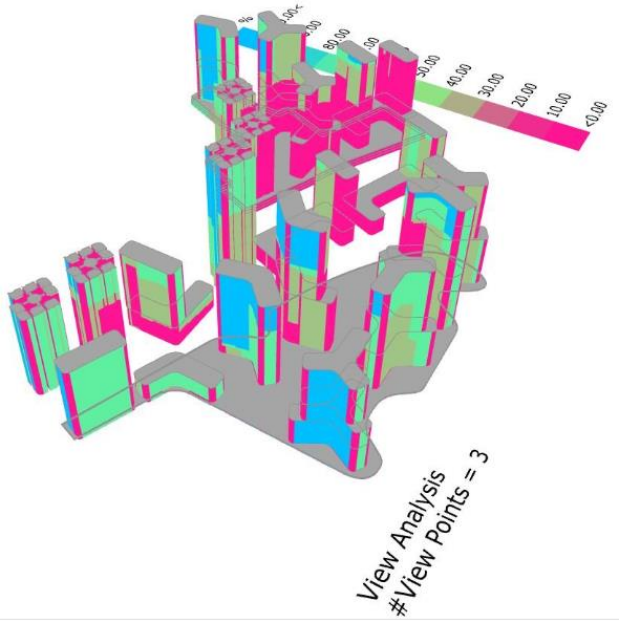

Figure 11: Digital analysis of visibility from selected viewpoints (LadybugTools)

The main use case of the **Roofs and Facades Study** concept is to support early-stage planning and decision-making for the installation of energy-related technologies—such as photovoltaic panels, thermal collectors, or heat pumps—in monument-protected areas by providing a visual, simulation-based assessment of their visibility from significant near and far viewpoints. Using 3D city models, Ladybug Tools, and Rhino/Grasshopper, the tool enables design professionals and heritage authorities to objectively evaluate the visual impact of proposed installations, streamline approval processes, and target in-person site visits more effectively. This helps reconcile heritage preservation requirements with the integration of renewable energy technologies in historic urban environments.

4 RESULTS AND IMPACTS EXPECTED

MONUPED is focused on impacts. It has been a long period of stakeholders going around each other within the Sustainability of Monument Protected Areas. In the context of the participating countries with their often-restrictive monument protection culture, it is important to have realistic yet ambitious goals. The impacts were set in accordance with the DUT impact matrix into the following four aspects:

What – Domain P.E.S.T.	**How – results and innovations**
1) Expansion and Dissemination of **Knowledge Base** **2)** Encouragement of **Collaboration** and Streamlining of **Approval Processes** 3) Advancement of **Policy and Regulations Dialogue** **4)** Support for Mainstreaming of **PED Solutions** 5) Exploration of Potentials of **Digital Tools** for Planning and Engagement 6) Development and **testing** of small-scale technical PED solutions 7) Identification and **Empowerment** of Owners and Investors	1) Expansion and dissemination of knowledge about existing PED solutions in MPA/MPBs 2) Enhanced collaboration between owners and investors 3) Dialogue between research, cities, investors, and monument protection 4) New investor matching tools 5) Digital tools for PED planning, approval processes, and stakeholder engagement 6) Small-scale solutions in Leipzig and Alba Iulia 7) Local LL ecosystems
How much	**Who – end users, beneficiaries**
1) Increased awareness and a deeper understanding of suitable solutions (3 LLs + 2 case studies) 2) improvement of stakeholder collaborative processes (3 LLs + 2 case studies) 3) Platforms for dialogue (3 LLs + 2 case studies) 4) 1 tool 5) 5 tools 6) 2 interventions 7) 3 ecosystems	1) PED ecosystemic stakeholders (investors) 2) Investors, prosumers, MPAs 3) MPAs, cities/project partners on behalf of investors 4) Prosumers/investors/cities 5) Cities, investors, MPAs 6) Investors, citizens 7) Owners, investors

Figure 12: MONUPED Impacts envisioned by 2027

5 WHERE WE STAND

As of the end of June 2025, the three MONUPED Living Labs—in Leipzig, Prague, and Alba Iulia—are entering the stakeholder engagement phase. Each lab is tailored to its local monument protection context and is beginning to test and co-develop tools and concepts designed to support Positive Energy Districts (PEDs) in heritage-sensitive areas.

In **Leipzig**, the Living Lab is located in the Baumwollspinnerei complex, a historically significant industrial site now repurposed for commercial and cultural uses. The same site was already put into operation during the SPARCS project and it is now further advanced. The focus here is on energy efficiency retrofitting, heating decarbonization, and energy sharing within a monument-protected environment. Two key innovations under development and early-stage testing are the **Thermal Precision Profiling Tool**, designed to assess the feasibility of low-temperature heating networks, and the **Leipzig Energy Map**, a city-scale GIS-based tool that visualizes renewable energy potential and infrastructure readiness. Stakeholders include property owners (MIB AG), tenants, energy technology firms like Cenero.one GmbH, and multiple departments of the Leipzig city administration. Workshops and co-creation activities have been initiated to align technological solutions with local regulatory and social contexts, particularly in relation to the city's climate neutrality strategies.

In **Prague 6**, the Living Lab is set in a district with a diverse mix of heritage-protected buildings, including the Břevnov Monastery and possibly another educational facility. The lab focuses on developing digital tools that help reconcile monument preservation with renewable energy integration. Tools under development and being tested include the **PV Potential Map** Prague 6, a GIS-based tool estimating rooftop solar energy potential; the **Roofs and Facades Study**, which uses 3D modeling to assess visibility of PV installations; and the **RoofMatch App**, a co-investment matching platform linking building owners with potential green energy investors. Stakeholders such as the Czech Bishops Conference, CVUT, and local municipal representatives are actively involved. The lab is engaging users through design workshops and usability testing to refine these tools and generate replicable strategies for energy planning in protected areas.

The **Alba Iulia** Living Lab is centered around the historic Vauban Citadel, part of Romania’s national heritage, and on the UNESCO tentative list. This lab is advancing the **Energy & Solar Mapping Tool**, which combines GIS and sensor data to estimate energy demand and solar potential in historic buildings. The tool is intended to support the city’s strategy for developing a Positive Energy Block within the fortress area. Engagement activities have begun with a diverse set of local stakeholders, including city officials, NGOs, university researchers, and private sector actors. Through co-creation workshops, the lab is identifying user needs and regulatory obstacles, while aligning with Alba Iulia’s Climate Change Mitigation and Adaptation Plan (PAASC). The aim is to ensure that the technical solutions developed are applicable within the strict renovation and heritage preservation requirements of the area.

Each Living Lab serves as a real-world testing ground for the MONUPED toolkit, connecting digital innovation with policy, finance, and community perspectives to support climate-neutral development in monument-protected contexts.