Deliverable Report

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

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OVERVIEW / EXECUTIVE SUMMARY

This deliverable presents a methodology for assessing the visibility of rooftop and façade-mounted renewable-energy technologies in monument-protected areas. This has been identified as one of the cross-cutting obstacles in PED implementation in Monument Protected Areas across the EU. This report presents the methodology using the example of the city of Prague. The report brings together the principles of the Czech National Monument Protection Authority (NPÚ), the officially documented visual-composition datasets of the Územně analytické podklady (ÚAP), and a digitally reproducible workflow based on Prague's 3D city model and the Grasshopper/Rhino simulation environment. The objective is to create a transparent, evidence-based approach that supports early-stage feasibility assessments for renewable-energy solutions - particularly photovoltaic systems - while respecting cultural-heritage values.

The report shows how far and near viewpoints relevant for heritage protection can be systematically identified, transformed into analytical inputs, and evaluated using ray-tracing visibility simulations. Far-viewpoint analysis is based on officially monitored vedute, panoramas, and other city-level viewpoints documented in ÚAP Chapters 3.4.1 and 3.4.2. Near-viewpoint analysis uses street-level geometry generated via the Gismo plugin and pedestrian-eye-level sampling. The results demonstrate how visible and non-visible parts of roofs and façades can be precisely mapped and how these maps can be integrated with solar-potential data to support planning and decision-making.

A test case within the UNESCO part of Prague illustrates the workflow and confirms that only a subset of surfaces - primarily inner courtyards, north-facing parts of buildings, and shielded rooftops - remain fully outside all protected views. The approach shows how municipalities, designers, and heritage authorities can integrate visual protection principles with renewable-energy planning, creating a reproducible and scalable methodology for Positive Energy Districts in heritage contexts.

RECOMMENDATIONS:

This deliverable presents the recommended workflow for assessment of visual acceptance of new technologies in culturally valuable built environment with defined visibility criteria and available 3D model. While it demonstrates the workflow using specific software, this workflow can be replicated using suitable software and is not limited to the presented ones.

1 INTRODUCTION

The integration of renewable-energy technologies into historic urban environments presents both an urgent societal need and a complex heritage-protection challenge. Positive Energy Districts (PEDs) require the deployment of local renewable-energy systems, but monument-protected areas introduce strict constraints that limit where such technologies can be installed. This deliverable addresses this challenge by proposing a methodological concept for assessing rooftop and façade visibility in a way that is consistent with Czech heritage-protection requirements and aligned with the broader objectives of the MonuPED project.

The starting point for the methodology is the position of the Czech National Monument Protection Authority (NPÚ), which recognises the necessity of the energy transition while emphasising that measures to address climate change must not cause a "crisis of cultural heritage." NPÚ stresses that the preservation of historic roofscapes, façades, vedute, and urban silhouettes is essential for maintaining the authenticity and cultural value of protected cities. Its methodological guidance therefore requires careful, individualised assessment of visual impacts, with particular attention to long-established viewpoints, street-level experiences, and the spatial relationships that define the character of historic settlements.

To operationalise these principles, the methodology integrates NPÚ's conceptual framework with the spatial datasets of Prague's Územně analytické podklady (ÚAP). ÚAP Chapters 3.4.1 and 3.4.2 identify official vedute, panoramas, and selected urban views that form the city's visual structure. These documented viewpoints form the basis for the far-viewpoint analysis in this study. Street-level viewpoints, which are not comprehensively included in the ÚAP, are generated using Gismo-based street geometry and a regular pedestrian-level sampling grid.

A key element of the methodology is the use of Prague's official LoD2 3D city model in combination with Rhino, Grasshopper, Ladybug Tools, and Gismo. This environment enables reproducible ray-tracing visibility analyses across dozens or hundreds of viewpoints. By combining far- and near-viewpoint evaluation, the methodology produces a detailed classification of surfaces according to their visibility in protected views. These visibility layers can then be linked to solar-potential calculations and feasibility studies, creating an integrated basis for making informed decisions about renewable-energy implementation in heritage-protected urban districts.

Overall, this deliverable establishes a data-driven, simulation-based approach that supports a balanced integration of renewable-energy technologies with the preservation of Prague's cultural-historical identity. It forms a methodological building block for MonuPED's broader goal of mainstreaming Energy-Transition solutions in monument-protected areas.

2. STANCE OF THE CZECH NATIONAL MONUMENT PROTECTION AUTHORITY (NPÚ)

The National Monument Protection Authority (NPÚ) begins its methodological statement by clearly acknowledging two parallel realities. On one hand, it recognises the increasing pressure of climate change and the societal necessity of transitioning to renewable energy sources [1]. It explicitly states that the installation of photovoltaic and other solar devices corresponds to the needs of contemporary society. On the other hand, NPÚ emphasises that this transition must not undermine the values for which cultural monuments, historic urban areas, and cultural landscapes are protected. In their words, **"řešení klimatické krize nesmí přivodit krizi kulturního dědictví"** - a warning that the pursuit of decarbonisation cannot come at the cost of losing what makes historic environments meaningful and irreplaceable. [2]

NPÚ stresses that historic buildings, architectural heritage, and cultural landscapes form a small portion of the Czech Republic's territory, yet they hold exceptional cultural, social, and economic significance. Their value lies in the preserved historic character, authentic materials, craftsmanship, and the accumulated layers of history and meaning. These qualities are not interchangeable, and once lost, they cannot be recreated. For that reason, NPÚ insists that any introduction of new technologies - photovoltaic panels, solar thermal collectors, or other modern devices - must be approached through sustainable long-term principles that preserve cultural-historical values while acknowledging present-day energy needs.

Legally, the authority grounds its position in the Act on State Monument Care [3], which obliges the State to protect cultural monuments as part of irreplaceable national heritage. NPÚ explains that the law distinguishes between **the protection of individual cultural monuments** and **the protection of areas** such as conservation zones, reservations, and protective buffer zones. Each type of protection is tied to specific values and reasons for their declaration, meaning that evaluating a proposed installation requires more than looking at a single building in isolation. In protected urban and landscape areas, the overall character of the environment - roofscapes, façades, street views, dominant landmarks, vedutas, and the spatial structure of settlements - forms part of the protected value. Any change that would harm these collectively protected features may be grounds for refusal of a photovoltaic installation. NPÚ explicitly states that decisions must be based on the **actual protected values** that would be affected, not merely by referring to the methodology itself .

A core component of NPÚ's stance is the insistence on **individualised assessment**. The authority repeatedly warns that protected areas differ enormously in their historical character, urban structure, architectural consistency, and landscape context. Even within one conservation zone, different sub-areas may require different approaches. For this reason, NPÚ avoids blanket rules such as universal bans; instead, it evaluates each case based on how the installation would interact with the specific cultural-historical values of the site. Some areas, such as the historic cores of towns, sites inscribed on the UNESCO World Heritage List, or visually exposed roofscapes, tend to be more sensitive. Others, such as industrial buildings, modern structures, or visually shielded surfaces, may offer more flexibility. However, in all cases, visual impact remains a central criterion. NPÚ gives great weight to **veduty, distant views, dominant landmarks, views from public spaces and elevated points**, as well as to the character and continuity of roofs and façades. If a photovoltaic installation disrupts these established visual relationships, it is likely to be considered unacceptable.

NPÚ also emphasises that installing photovoltaic systems always creates a **new historical layer** on the building or within the landscape. Whether this new layer is acceptable depends on several factors: the degree of structural intervention, reversibility, the scale of the visual change, colour and material contrast, and the way the installation respects the architecture and composition of the building. The methodology therefore distinguishes between non-integrated, partially integrated, and fully integrated systems, each requiring different levels of scrutiny. Even in cases where a system is technically feasible, NPÚ insists on a proper evaluation of visual impact, including studies that simulate the resulting appearance, because inappropriate placement can alter a building's silhouette, disrupt architectural lines, or introduce visual noise into protected views.

Because of the complexity of heritage protection, NPÚ notes that methodological guidance cannot provide universal answers for every situation. Instead, it outlines principles whose purpose is to safeguard cultural-historical values, while leaving room for case-specific judgement. Local NPÚ offices are responsible for applying these principles in their respective territories, and in difficult or ambiguous cases, they consult with the NPÚ General Directorate to ensure consistency across the country. The authority also emphasises the need for ongoing coordination, noting that both solar technologies and heritage-protection experience evolve over time. As a result, the current methodology is understood as a dynamic document that will require updates as new knowledge emerges.

Finally, NPÚ emphasises the importance of **transparent communication** with the public. The authority sees it as its responsibility to explain not only decisions, but also the underlying values and reasoning. This includes helping owners, designers, and municipalities understand how renewable-energy installations can be approached in a way that respects and preserves the integrity of cultural heritage. The overall stance of NPÚ is therefore neither strictly prohibitive nor unconditionally permissive. It is based on careful weighing of benefits and impacts, with the overarching goal of ensuring that historic environments continue to convey their cultural, architectural, and landscape significance to future generations while society adapts to the challenges of climate change.

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3 NEAR AND FAR VIEWPOINTS

The National Monument Protection Authority (NPÚ) does not define "far" and "near" viewpoints as formal categories. Instead, Czech monument protection relies on a set of long-established visual concepts that describe how historic buildings, urban structures, and landscapes are perceived. These concepts together form the visual framework within which photovoltaic installations are assessed. For the Roofs & Facades Study, they can be grouped into two functional scales: long-distance views and close-range views; while remaining in line with the NPÚs designations. The methodological document [2] defines and describes the following terms.

Far Viewpoints: Veduty, Dominant Views, and Elevated Perspectives

Long-distance and elevated viewpoints are among the most sensitive elements in Czech monument protection. NPÚ emphasises that many historic towns and cultural landscapes are recognised and valued precisely because of the way they appear from afar. Their silhouettes, roofscapes, and relationships between landmarks form a key part of their cultural-historical identity.

Veduty - Established Long-Distance Views

Veduty are among the most important visual features NPÚ protects. They represent long-standing, culturally established views of historic cities or their landmarks. NPÚ describes veduty as "ustálené a zažité hodnoty historických sídel," emphasising their traditional role in how people perceive and recognise historic towns (p. 5 - 6).

Examples include the classic views from Petřín to Malá Strana and Hradčany, from Karlův most toward the Castle, or views of Český Krumlov and Mikulov from surrounding hills. Any visual disturbance in these perspectives - such as a photovoltaic installation visible on a historic roof - can undermine precisely the qualities that justify heritage protection.

Pohledy shora - Views from Above

In many cities and towns, elevated positions such as hills, castle terraces, church towers, or lookout platforms offer panoramic views over historic roofscapes. NPÚ highlights these viewpoints because roofs often play a decisive visual role when seen from above. Changes to the rhythm, material, or silhouette of roofs can be especially disruptive when the view encompasses an entire historic core (p. 5) .

Pohledy z odstupu - Distant Landscape Views

Distant views provide an understanding of how a settlement sits in the landscape. Here, the overall silhouette, the prominence of certain buildings, and the continuity of rooflines become key. NPÚ notes that such views help define the "významový kontext" of towns and cultural landscapes (p. 5 - 6)

A photovoltaic installation that becomes visible in these distant perspectives risks altering the broader perception of the settlement.

Pohledy na dominanty - Views Toward Landmarks

Dominant architectural or natural features - church towers, castles, important civic buildings - serve as orientation points and symbols of historic towns. NPÚ treats the visibility and integrity of these landmarks as essential. Any new element that intrudes into a view toward a dominant structure may disrupt the intended compositional hierarchy of the town (p. 5 - 6)

Together, these concepts form the set of "far viewpoints" that NPÚ actively protects. For the study, these viewpoints are taken from sources such as Prague's conservation documentation and legally designated protected panoramas, ensuring alignment with the visual structures NPÚ recognises as culturally significant.

Near Viewpoints: Street-Level Views, Public Spaces, and Everyday Urban Experience

While distant views define the broader image of a town, NPÚ places equal importance on how historic environments are perceived from street level. These “near” viewpoints concern the everyday visual experience of inhabitants and visitors, where details of façades, roofs, materials, and compositions are most tangible.

Průhledy ulicemi - Street Vistas and View Corridors

NPÚ considers street-level views an essential part of the cultural value of historic towns. Street vistas reflect the structure of the urban environment and often reveal important architectural features or compositional axes. Because people encounter these views constantly, any visible modern addition - especially on roofs or upper parts of façades - can immediately affect the character of the place (p. 5)

Pohledy z veřejných prostranství - Views from Public Spaces

Squares, streets, promenades, courtyards and parks form the shared visual environment of a town. NPÚ stresses that public spaces play a central role in the presentation of architectural heritage. They shape how buildings are perceived, how façades and roofs relate to one another, and how the character of the urban fabric is experienced (p. 5 - 6)

Any technological installation visible from these spaces - particularly in conservation zones - has the potential to disturb the cohesion of the historic environment.

Pohledové uplatnění v uličním prostoru - Visual Presence in the Street Space

This term refers to a building’s contribution to the street environment. NPÚ notes that roof shapes, façade compositions, and architectural details are integral to the identity of historic streets, and that even small visual changes can disturb the perceived integrity of the urban space. For example, altering the pitch of a roof or introducing contrasting materials can break the established visual rhythm (p. 9 - 10)

Pohledové vztahy v historickém sídle - Visual Relationships Within the Historic Settlement

At close range, NPÚ pays attention to how buildings relate to each other spatially. These relationships - between roof edges, façades, alleyways, courtyards and public spaces - form the intimate character of historic towns. They are highly sensitive to visual disturbances. If a photovoltaic panel becomes visible in these close-range relationships, it can disrupt the composition and diminish the authenticity of the setting (p. 5 - 7) .

Together, these concepts define the “near viewpoints” that matter in the NPÚ context. They capture how people experience historic environments from ground level and why visual consistency is crucial when considering new technological interventions.

4 CITY INTEGRATION OF THE DEFINITIONS FOR THE CITY OF PRAGUE

Integration of ÚAP Visual-Composition Data into the Roofs & Façades Study

The Roofs & Façades Study builds upon the NPÚ terminology and heritage-protection logic by adding a second, complementary layer of analysis: the **city-level visual-composition data** provided in the *Územně analytické podklady hl. m. Prahy (ÚAP)* [4]. While NPÚ establishes the conceptual understanding of which types of viewpoints matter for heritage protection, the ÚAP identifies and documents **where** these viewpoints occur within the spatial structure of Prague. This makes the ÚAP an essential foundation for translating heritage requirements into a **repeatable, simulation-based methodology**.

Chapters **3.4.1 "Historické veduty a panoramata"** [5] and **3.4.2 "Vybrané pohledy na město"** [6] form the visual component of the ÚAP. They outline the key vantage points and compositional relationships that contribute to the visual character of Prague. Integrating this information into the study ensures that the visibility analyses of rooftop and façade technologies are not based on arbitrary or subjective choices, but instead reflect **the officially recognised visual structure of the city**.

Historic Vedute and Panoramas (ÚAP Chapter 3.4.1) [5]

ÚAP Chapter 3.4.1 identifies and describes the **historic vedute, panoramas, and principal long-range views** that shape the visual identity of Prague. These views reveal the form of the city as a whole - its skyline, silhouette, roofscape, and the relationships between major architectural landmarks. The ÚAP notes that these view compositions are "považovány za obzvlášť důležité jevy ve struktuře města" and that they represent a stable reference for understanding Prague's character (

In the context of the Roofs & Facades Study, this information provides:

• Official Far-Viewpoint Locations

The mapped vedute and panoramas offer a set of clearly defined external viewpoints from which the city is typically observed. These locations can be imported directly into the 3D modelling environment as **fixed vantage points** for assessing visibility of rooftop installations.

• Defined Visual Axes and Dominance Relationships

The ÚAP describes which architectural dominants and urban elements are visually significant within these views. This allows the study to evaluate whether a proposed rooftop or façade intervention interferes with the silhouette or visual hierarchy of the historic townscape.

• Consistency with the City's Spatial-Planning Documents

Since the ÚAP is a statutory analytical document, integrating its vedute and panoramas ensures the methodology is compatible with the city's planning framework and provides a traceable basis for communication with municipal stakeholders.

Using ÚAP 3.4.1, the study translates NPÚ's general requirement to protect vedute and distant views into a **mappable, simulation-ready dataset**, supporting the identification of sensitive roof areas visible from these long-range viewpoints.

Selected Urban Views (ÚAP Chapter 3.4.2) [6]

ÚAP Chapter 3.4.2 documents **selected views within the interior of the city**, emphasising places that are significant for the perception of Prague's urban composition. These viewpoints do not capture the entire city in panorama; instead, they highlight specific spatial relationships that are characteristic of Prague's internal structure - street-space sequences, axial alignments, compositions of squares, and the visual role of architectural dominants within the urban fabric (

For the Roofs & Facades Study, this chapter provides the basis for the **near-viewpoint layer** of the visibility analysis:

Representative Street-Level Viewpoints

The documented locations represent typical or compositionally important pedestrian viewpoints within the historic environment. They serve as fixed reference points for assessing street-level visibility of rooftop and façade-mounted technologies.

Documented Urban Axes and Spatial Sequences

The views captured in 3.4.2 illustrate how characteristic streets, squares, and urban corridors frame façades and rooflines. These relationships help determine which surfaces are visually exposed within the everyday experience of the city.

Integration with Pedestrian-Focused Visibility Assessment

By incorporating the officially recognised views, the study ensures that near-viewpoint assessments correspond to the city's established urban-compositional logic, making the results comprehensible and defensible in discussions with heritage authorities.

Through ÚAP 3.4.2, the study aligns the evaluation of façade or rooftop visibility with the **real, documented visual experience of Prague**, beyond only the conceptual categories described in NPÚ guidance.

Purpose of Integrating ÚAP Data into the Methodology

The ÚAP provides the **spatial and geographic grounding** needed to operationalise NPÚ's visual-protection principles in a digital workflow. While NPÚ defines *what types* of views must be respected, the ÚAP shows *where these views exist* and *how they function* in the landscape and urban structure of Prague.

Integrating ÚAP Chapters 3.4.1 and 3.4.2 thus enables the study to:

- base visibility analyses on **official, mapped viewpoints**,
- apply NPÚ's visual criteria with geographic precision,
- ensure methodological transparency in early design phases,
- support both heritage authorities and designers with **predictable, evidence-based outputs**, and
- create a direct interface between municipal planning tools and renewable-energy feasibility assessment.

This combination of NPÚ's conceptual framework and ÚAP's spatial data strengthens the credibility and usability of the Roofs & Facades Study in practical decision-making processes

The dataset *"Vyhlídkové body - stanoviště sledovaných pohledů"* [7]identifies **251 observation points** across Prague, each defined by precise coordinates, terrain elevation and a description of its visual function. These viewpoints were established to support the city's monitoring of visual relations and to provide a consistent basis for evaluating how the historic urban landscape is perceived from public spaces. Their inclusion ensures that the study reflects the same reference system used by Prague's planning and analytical authorities when assessing changes in the built environment.

Incorporating these viewpoints into the visibility-analysis workflow makes it possible to link heritage-protection principles with specific, geolocated vantage points that the city systematically tracks. Because the ÚAP dataset includes panoramic viewpoints, elevated long-distance positions, and a wide variety of city-interior outlooks - such as embankments, bridges, terraces and lookout points - it captures a representative cross-section of how Prague is visually experienced. Using these officially documented locations as input for 3D simulations creates a transparent and reproducible foundation for assessing whether rooftop or façade-mounted technologies may intrude into visually sensitive public views.

It is important to note that the ÚAP viewpoint dataset is composed of **fixed observation points**, and therefore primarily supports the analysis of long-range and mid-range visibility conditions. Routine pedestrian-level perspectives within the street network, which play a significant role in the everyday perception of roof edges and façades, are not comprehensively represented and are addressed separately in the near-viewpoint methodology. Nevertheless, for the assessment of visibility from key publicly accessible viewpoints across the city, the ÚAP dataset provides a robust and city-approved analytical basis that anchors the study in formally documented visual relationships and supports consistent decision-making across design proposals.

5 EVALUATION IN THE 3D SOFTWARE

3D model

The city of Prague maintains a comprehensive three-dimensional digital model that covers the entire metropolitan area and serves as an official reference dataset for planning, analysis, and decision-making. The model represents the full built structure of the city, including buildings, bridges, terrain, and vegetation, and is developed and maintained by the Institute of Planning and Development of the City of Prague (IPR Praha). According to IPR, the model is constructed from airborne laser scanning (LiDAR) combined with high-resolution aerial photogrammetry, and is continuously updated as new surveying campaigns are carried out. This makes the 3D model one of the most complete and current representations of Prague's urban form available for analytical use. [8]

As documented on Geoportál Praha website [9], the 3D model provides detailed geometry for all buildings and bridges in the city, capturing roof shapes, slopes, dormers, chimneys of significant size, turrets, and other volumetric rooftop features. Buildings [10] are represented as solid volumes corresponding to **Level of Detail 2 (LoD2)**, meaning that characteristic roof geometry is included while façade details - such as windows, architectural ornamentation, or surface textures - are not modelled. In addition to built structures, the model incorporates a digital terrain model (DTM) and generalised representations of vegetation, enabling an accurate depiction of the topographic setting and natural elements that influence visibility, shading, and urban landscape perception.

The 3D model is distributed through Prague's open-data infrastructure, making it freely accessible to the public and to professional users. Geoportál Praha provides downloadable datasets for buildings and bridges in standard GIS and 3D formats such as **SHP** and **GML**, along with terrain and vegetation layers that can be combined with analytical tools. In parallel, IPR Praha operates an online 3D viewer that allows users to navigate the model in a web browser, inspect buildings, and query selected attributes. The availability of both raw data and an interactive viewer ensures that the model can be used flexibly - either as a lightweight visual reference or as a full analytical dataset suitable for import into software environments like Rhino, Grasshopper, QGIS, or ArcGIS Pro.

In addition to geometric data, the 3D model includes **attribute information** for individual buildings, such as the number of floors, selected administrative identifiers, and basic usage classifications. These attributes - documented on IPR Praha's information pages - enable analysts to link the 3D geometry with thematic datasets, including heritage status, energy demand, ownership structures, and planning regulations. This combination of spatial geometry and attribute data makes it possible to perform multi-criteria analyses that integrate architectural, regulatory, and functional considerations. For the purposes of the Roofs & Façades Study, this enables the evaluation of photovoltaic feasibility alongside conservation constraints, ensuring that visibility analysis can be interpreted together with other relevant planning or heritage parameters.

Because the model incorporates detailed roof geometries, complete building volumes, and the surrounding terrain, it provides a robust basis for **ray-tracing and line-of-sight calculations** needed in visibility studies. This is particularly relevant for assessing the visual impact of rooftop photovoltaic installations from officially monitored viewpoints across the city. The inclusion of terrain and generalised vegetation allows sightlines to be evaluated in realistic context, accounting for elevation differences, natural obstructions, and changes in perspective that influence whether a rooftop surface is visible from key public vantage points. As a result, the model supports heritage-sensitive analyses by enabling precise simulation of how proposed rooftop or façade changes may appear when viewed from Prague's culturally significant panoramas and urban observation points.

At the same time, the 3D model's **Level of Detail 2** specification introduces inherent limitations that must be acknowledged when interpreting results in sensitive heritage contexts. While major roof forms are accurately represented, the model does not include fine architectural detail such as small chimneys, balustrades, statues, dormer ornamentation, or façade articulation. Rooftop technical equipment is also not comprehensively captured. Furthermore, the vegetation layer does not reflect seasonal variation and represents tree canopies only in simplified volumetric form. These constraints mean that the visibility of smaller elements may be either over- or under-estimated, and supplemental on-site verification or higher-detail modelling may be required for critical cases in protected heritage zones. The model also reflects conditions at the time of the latest aerial survey, meaning that recently constructed buildings or modifications may not yet be present.

Despite these limitations, the Prague 3D model remains an indispensable foundation for the Roofs & Façades Study due to its citywide coverage, uniform data structure, and direct support from IPR Praha. Its combination of LoD2 roof geometry, complete building stock representation, and openly accessible data formats allows for consistent, reproducible simulations across the entire city. When used together with the officially monitored viewpoint dataset, the model enables a robust analytical workflow in which visibility, solar potential, and heritage constraints can be assessed within the same spatial framework. This makes the 3D model a critical component of any methodology seeking to balance renewable-energy implementation with the preservation of Prague's historic urban landscape.

Rhino, Grasshopper, Ladybug Tools and Gismo

Rhinoceros (Rhino), developed by Robert McNeel & Associates [11], is a widely used 3D modelling software known for its ability to handle complex geometries with high precision. It supports NURBS, meshes, and point-cloud data, which makes it suitable for importing large-scale city models such as Prague's publicly available LoD2 dataset. Rhino is commonly used in architecture, urban design and simulation workflows because it can process detailed spatial models while allowing precise manipulation of geometry.

Grasshopper [12], included as a native visual programming environment inside Rhino, enables users to build procedural and parametric definitions without writing conventional code. Grasshopper supports plug-ins that extend its capabilities in environmental analysis, data processing, geometric transformations, GIS integration, and simulation workflows. Its node-based structure allows step-by-step control of data, geometry, and simulation parameters, which makes it suitable for building repeatable workflows such as visibility analysis from multiple viewpoints.

Ladybug Tools [13] is an open-source suite of environmental analysis plugins that run inside Grasshopper. The tools allow users to analyse climate data, solar exposure, radiation, daylighting, view obstruction, and general environmental conditions.

The core application **Ladybug** focuses on climate and radiation analysis. The extended suite includes **Honeybee** (energy/daylighting), **Dragonfly** (urban microclimate), and additional components. All tools are based on transparent algorithms documented in the official GitHub repositories.

Ladybug Tools integrates well with city-scale 3D models because:

- it reads mesh and brep geometry from Rhino,
- it supports large numbers of sampling points,
- it can analyse visibility, solar vectors, shading, and radiation within the same environment.

This makes it a suitable platform for the type of view-based assessment required in the Roofs & Façades concept.

Ladybug "Visibility Percent" provides a **numeric indicator** of how much of the surrounding environment is visible or obstructed.

All of these components rely on **ray-tracing algorithms** within the Grasshopper environment and are commonly used for urban visibility, view obstruction and façade exposure studies. They are well suited for evaluating:

- whether a roof or façade is visible from a given viewpoint,

- how visible surfaces change across multiple viewpoints,
- what percentage of a surface is exposed to a particular observer location.

These tools do **not** inherently classify views as heritage-relevant - but they accurately compute visibility, which can then be cross-referenced with the official ÚAP viewpoint dataset.

Gismo [14] is a free, open-source Grasshopper plugin for GIS and environmental analysis. It enables automatic generation of 2D and 3D urban environment and terrain geometry based on a location's latitude - longitude coordinates or address and a chosen radius. The plugin connects directly to open data sources such as **OpenStreetMap** [15] (for buildings, roads and other map features) and **OpenTopography** [16](for terrain), and converts those datasets into Rhino/Grasshopper geometry that can be used in further analysis workflows.

For work with street networks, Gismo provides a dedicated group of **OpenStreetMap components**. The key element is the **"OSM Shapes"** component, which generates OpenStreetMap shapes for a given location and radius. These shapes include linear features such as **road axes**, rivers, railways and other line elements, as well as polygon footprints for buildings, parks and other areas, and point features such as trees or points of interest. The component allows filtering by OSM keys and tags, so that only selected feature types (for example, streets and roads) are retrieved for the specified area.

On top of the basic shape import, Gismo also includes **"OSM 3D Road"** and related components that can be used to generate 3D road geometry from OpenStreetMap linework. These tools convert the imported road axes into 3D solids or surfaces, positioned on the terrain model obtained via the plugin's terrain components. This functionality is documented in the plugin's release notes and examples, where the authors explicitly show 3D roads generated from OSM polylines as a context for further analyses.

In the context of the Roofs & Façades Study, these capabilities make Gismo suitable for building a **street-based input layer for near-viewpoint analysis**. Using the OSM Shapes component, the project can extract street centerlines and other relevant linear elements within a defined radius around selected areas of the historic city. These street axes can then be sampled at regular intervals in Grasshopper to create a set of representative pedestrian-level viewpoints along the public realm. Because the geometry is derived directly from OpenStreetMap via Gismo, the resulting viewpoint network corresponds to the actual structure of streets and squares, rather than idealised or manually sketched lines

Gismo's reliance on open data also introduces constraints that are important to acknowledge. The completeness and accuracy of street and building data depend on the state of OpenStreetMap for the selected area; in places where mapping activity is limited, some roads or attributes may be missing or out of date. The plugin caches downloaded OSM and terrain files locally, and users must manually clear these caches if they want to force an update to the latest OpenStreetMap data. These characteristics are documented in user discussions and official guidance and should be considered when interpreting near-viewpoint results, especially in areas where recent changes to the street network or public space may not yet be reflected in the underlying OSM data.

6 CONCEPT FOR A SELECTED LOCATION

Selected location

Figure below shows the selected location for the concept development and testing. The block of buildings is located on the Rašínovo Nábřeží street in Prague. The location itself is within the UNESCO reservation of Prague and therefore no RES installations are possible here. The location has been selected as an illustration due to the proximity of 7 viewpoints listed in the UAP document within 500 meters.

Figure 1: Selected building block; © Google

Table 1: Viewpoints coordinates

Viewpoint Name	S-JTSK X	S-JTSK Y	S-JTSK Z
View from the Railway Bridge Downstream	- 743661.430	- 1045188.744	199.4
View from the Northern Bastion of the Vyšehrad Ramparts	- 743173.596	- 1045429.919	233.0
View from the Basilica of St. Peter and Paul at Vyšehrad	- 743419.772	- 1045501.568	279.3
View from the Smíchov Riverside below the Imperial Footbridge	- 743763.428	- 1045304.929	190.3
View from Rašín Embankment near the Vyšehrad Tunnel	- 743556.594	- 1045524.270	195.1
View from the Park by Hořejší Embankment	- 743785.825	- 1044995.347	194.5
View from the Vyšehrad Staircase Overlook	- 743508.706	- 1045585.876	228.0

Geometry considerations

In order to maximize the calculation efficiency, minor adjustments in geometry have to be conducted. The 3D model of Prague contains geometry of individual buildings. This means, also separation walls between buildings on the same block are modelled. These walls are not visible and should not be considered in the calculations.

Workflow for the far viewpoints

The XYZ coordinates of the viewpoints has to be introduced into the Grasshopper environment. The 3D model of Prague is developed in the S-JTSK coordinate system, while the list of viewpoints is created using the WGS84 coordinate system. Conversion has therefore to be undertaken.

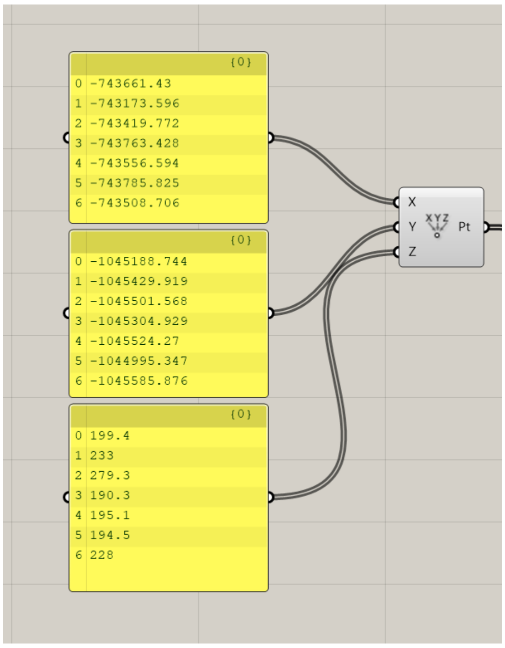

Figure 2: Creation of control points in Grasshopper

The generated points serve as the first input for the *LB Visibility percentage* component. The base *Geometry* component contains all the roof and façade elements of the selected block. Using this information and the grid specifications, the grid of testing points is created for the base geometry. The grid size (raster) is set to 1 meter, sufficient for basic assessment of visibility. The offset distance of the grid points from the base geometry is set to 0.1 m to ensure the limitation of errors in calculation due to positioning of the testing points right into the surfaces of the building. Surrounding buildings and terrain are contained within the context *Geometry* component. This represents the potential view obstacles between the viewpoints and the tested geometry. The *_geo_block_* parameter is set to *True* to set the tested geometry as opaque and therefore also blocking the view to the testing points.

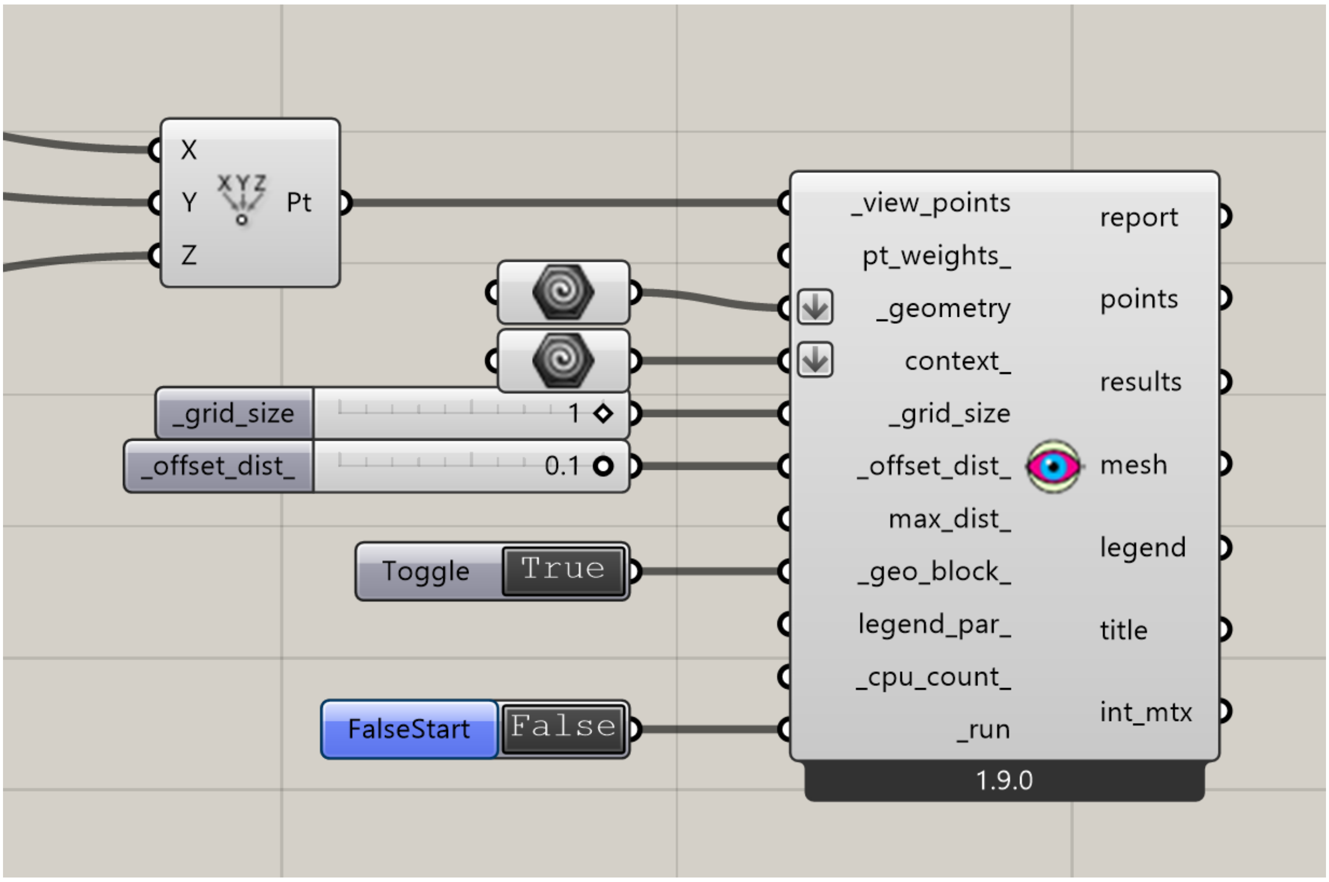

Figure 3: Basic setup for the Visibility percentage analysis

Resulting visibility percentage describing the amount of viewpoints with unobstructed view to a specific location on the roof or a façade is shown below.

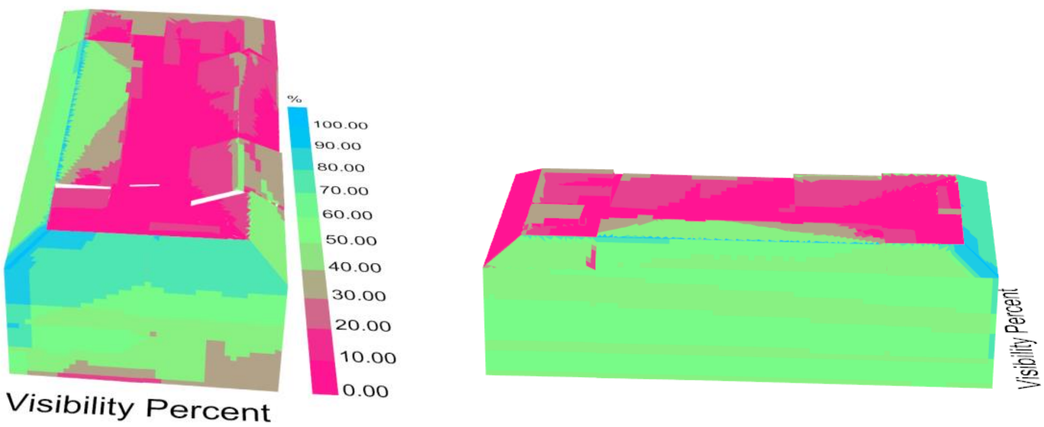

Figure 4: Visualisation of the initial visibility results

To filter the test points not visible from any viewpoint a simple equation assessment is carried out using, checking the validity of *visibility percentage=0* and then using the *Dispatch* component to separate the two possible results (true/false).

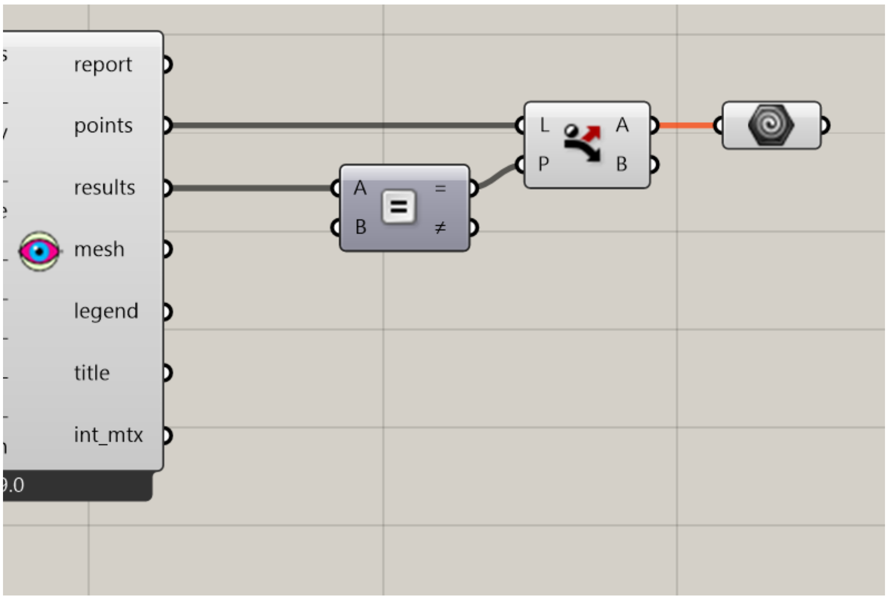

Figure 5: Filtering of non-visible control points only in Grasshopper

Only 10 238 points out of 19 923 considered test points are not visible from any of the considered viewpoints. These are mainly located in the courtyard and on the northern façade and roof.

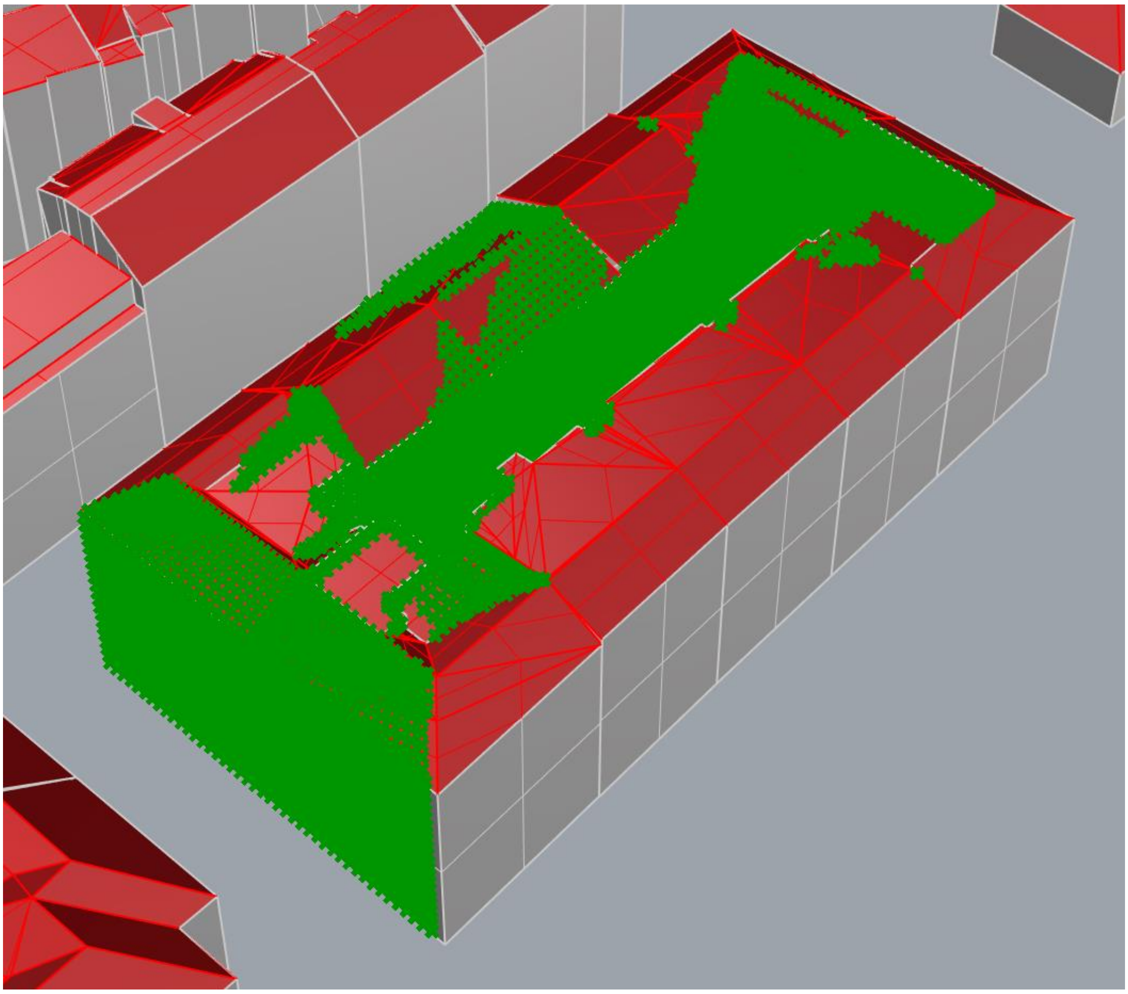

Figure 6: Control points not visible from any of the selected view-points

Workflow for the near viewpoints

Gismo plugin for Grasshopper is utilized to define the road geometry based on the OSM data. The following figure shows the script needed for import of the road geometry in the radius of 100 meters from the center of the selected block. The left side of the script serves as common inputs for the script including the location, base point for import in the 3D model, and the radius specification.

The middle part contains two components – *OSM shapes* and *Terrain generator*. The first imports the 2D geometry of the roads. The second one creates the 3D model of the terrain. The right part of the script then projects the 2D geometry onto the 3D terrain in order to accurately interpret the road geometry.

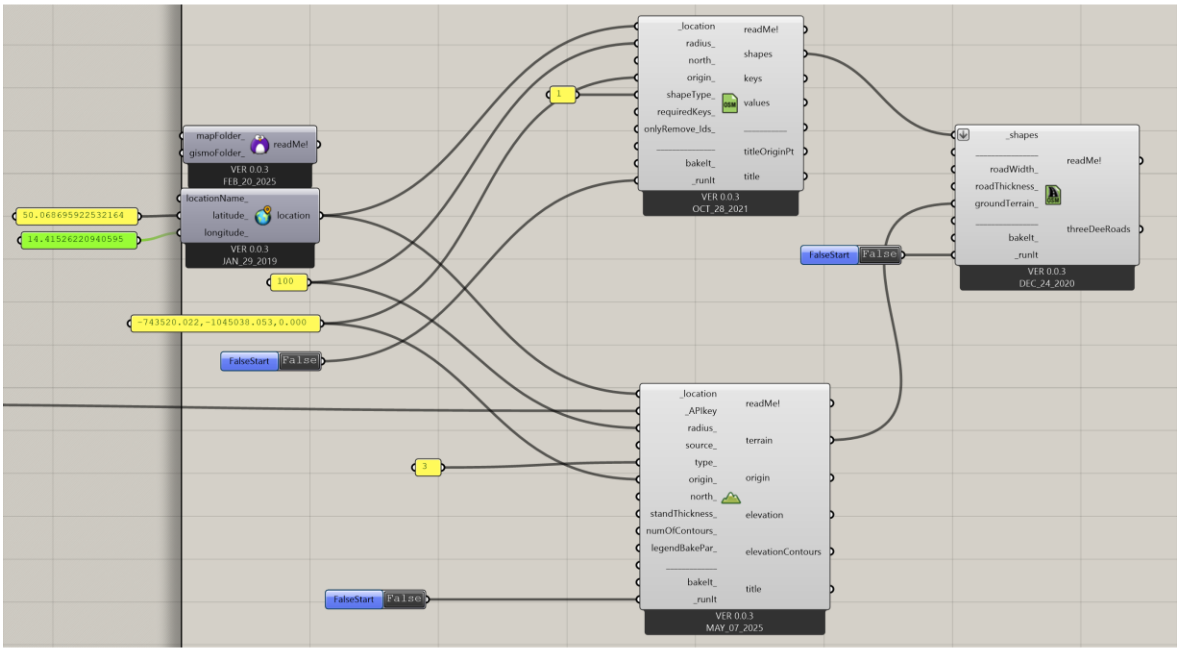

Figure 7: Import of terrain and road information using Gismo in Grasshopper

Using the geometry of the roads and streets created using Gismo, the new set of viewpoints has to be created and the previously described script updated. The figure below shows the creation of a grid of points based on the road geometry. Grid size of 10 meters has been selected to sufficiently populate the streets. Offset of the testing points is set to 2 meters to simulate the viewpoint of a pedestrian with a sufficient margin of safety.

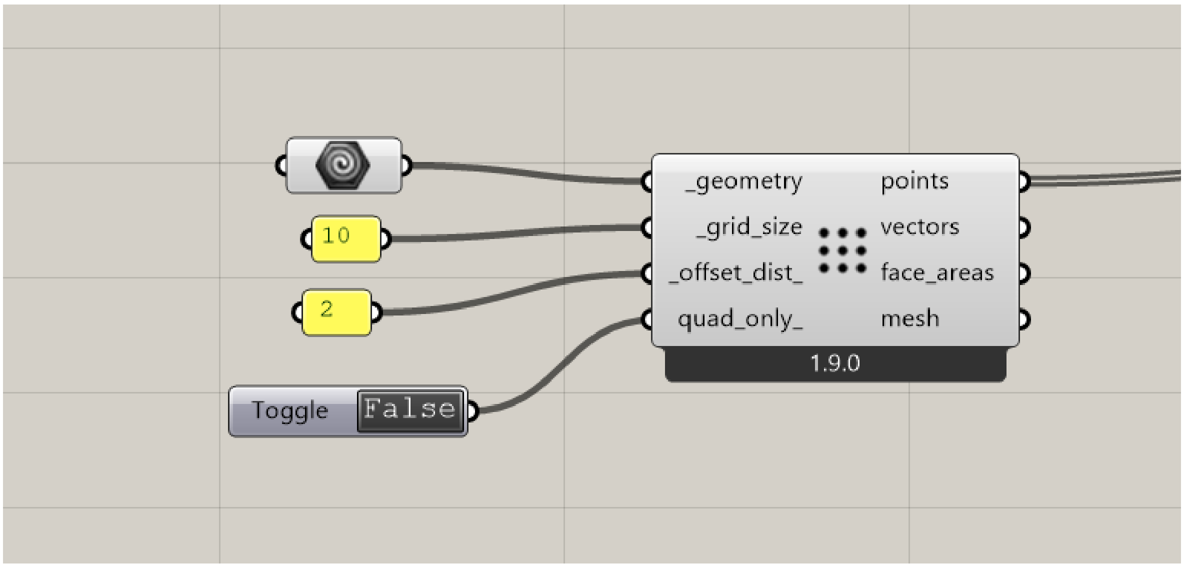

Figure 8: Generation of street-level view-points

The resulting visibility study shows, that only the rooftops and the courtyard fulfill the requirements for non-visibility from the streets in the historical city centres.

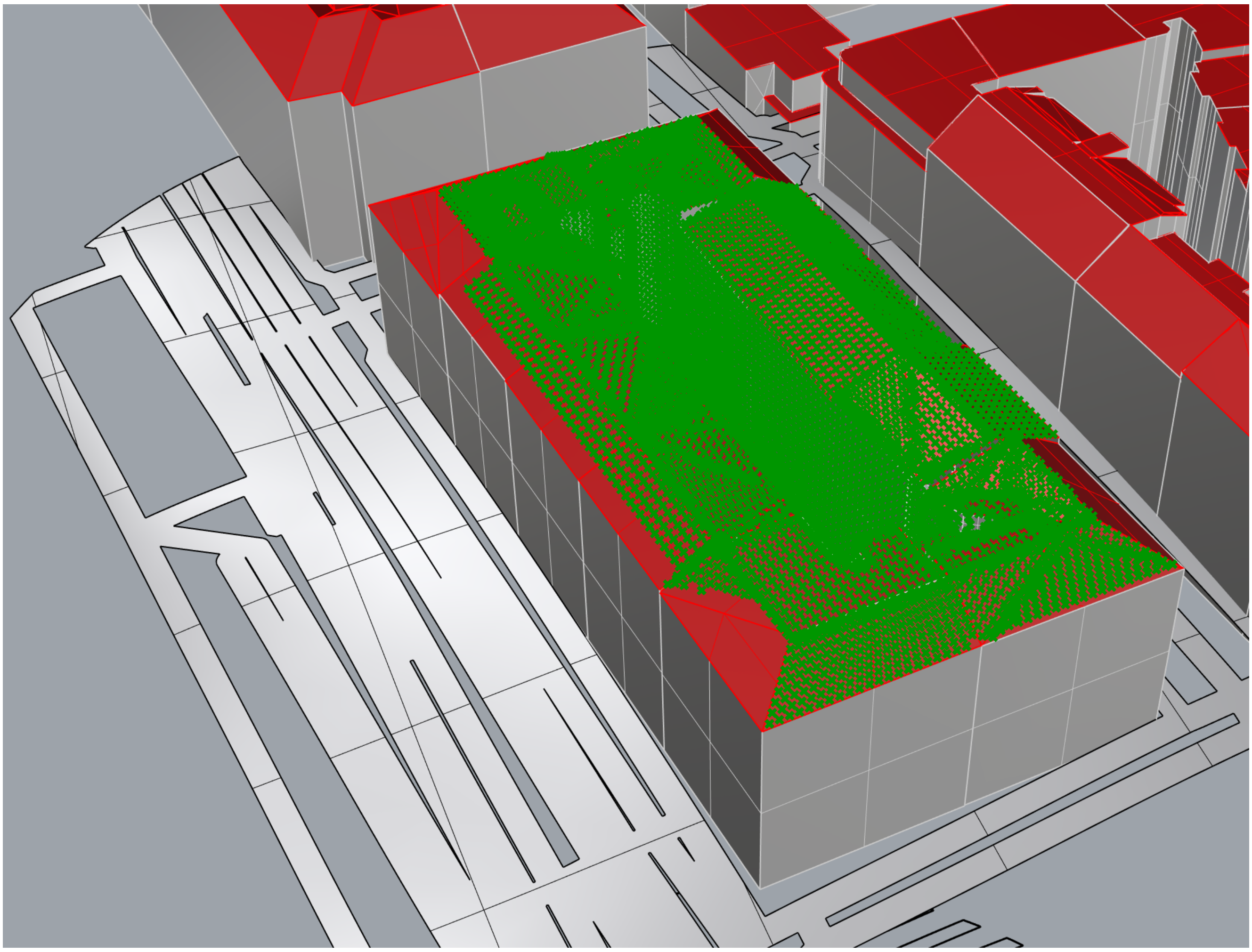

Figure 9: Test points not visible from any street-level view-points

Final invisibility

Final invisibility combines the results from both – far viewpoints and the views from the street. Only 8 823 points meet all the criteria for the installation of new elements in terms of visibility.

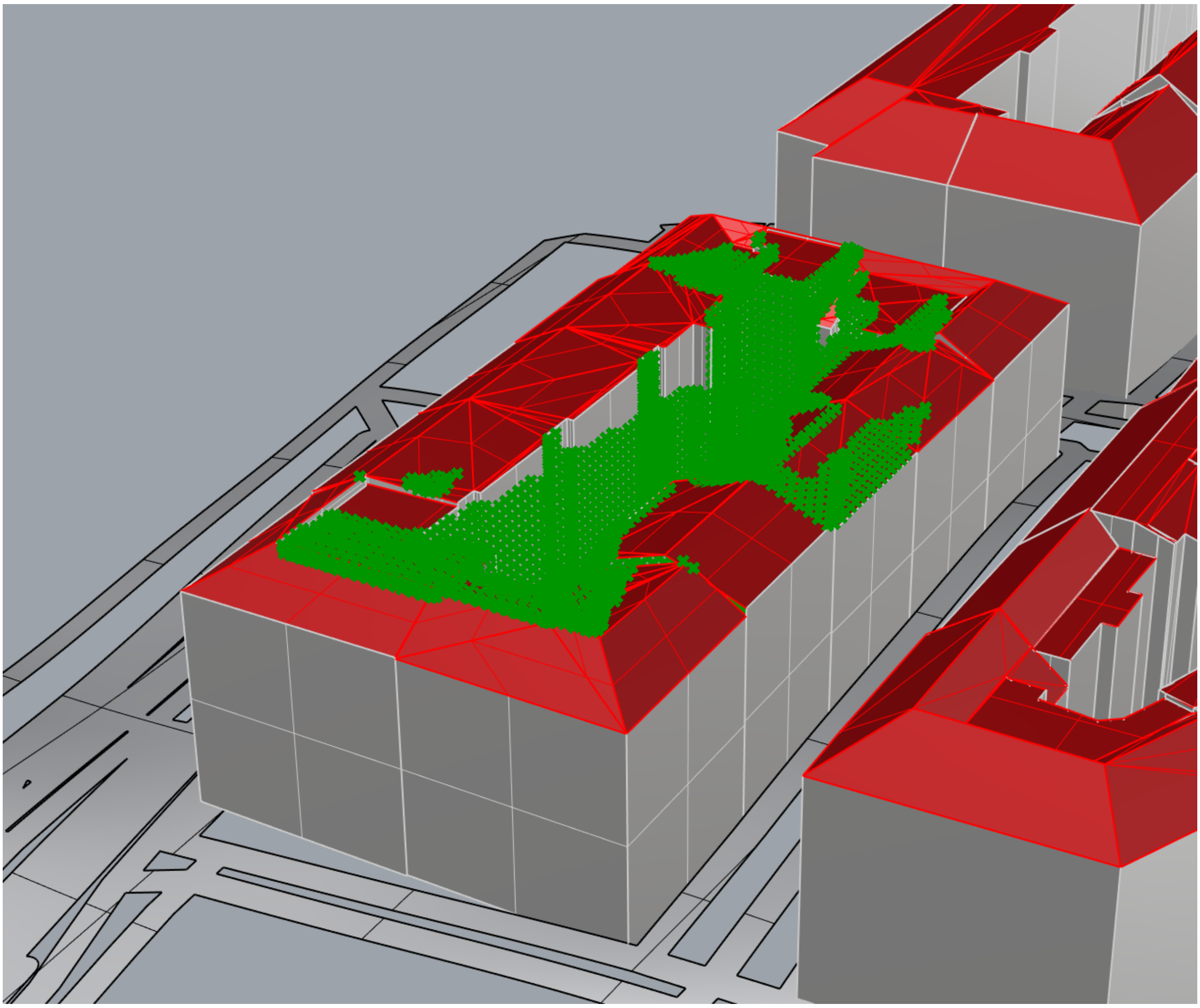

Figure 10: Points not visible from any significant view-points and street-level view-points

Further implications

The Roofs & Facades visibility study can be directly linked to the solar potential calculations and feasibility studies to assess the economical and aesthetical aspects of any RES installations where the monument protection influences the outcome of the planning processes. Figure below compares the total annual solar potential of the roofs and facades of the selected block (7229 MWh) and the solar potential of their portion not visible from any considered viewpoints (1098 MWh)

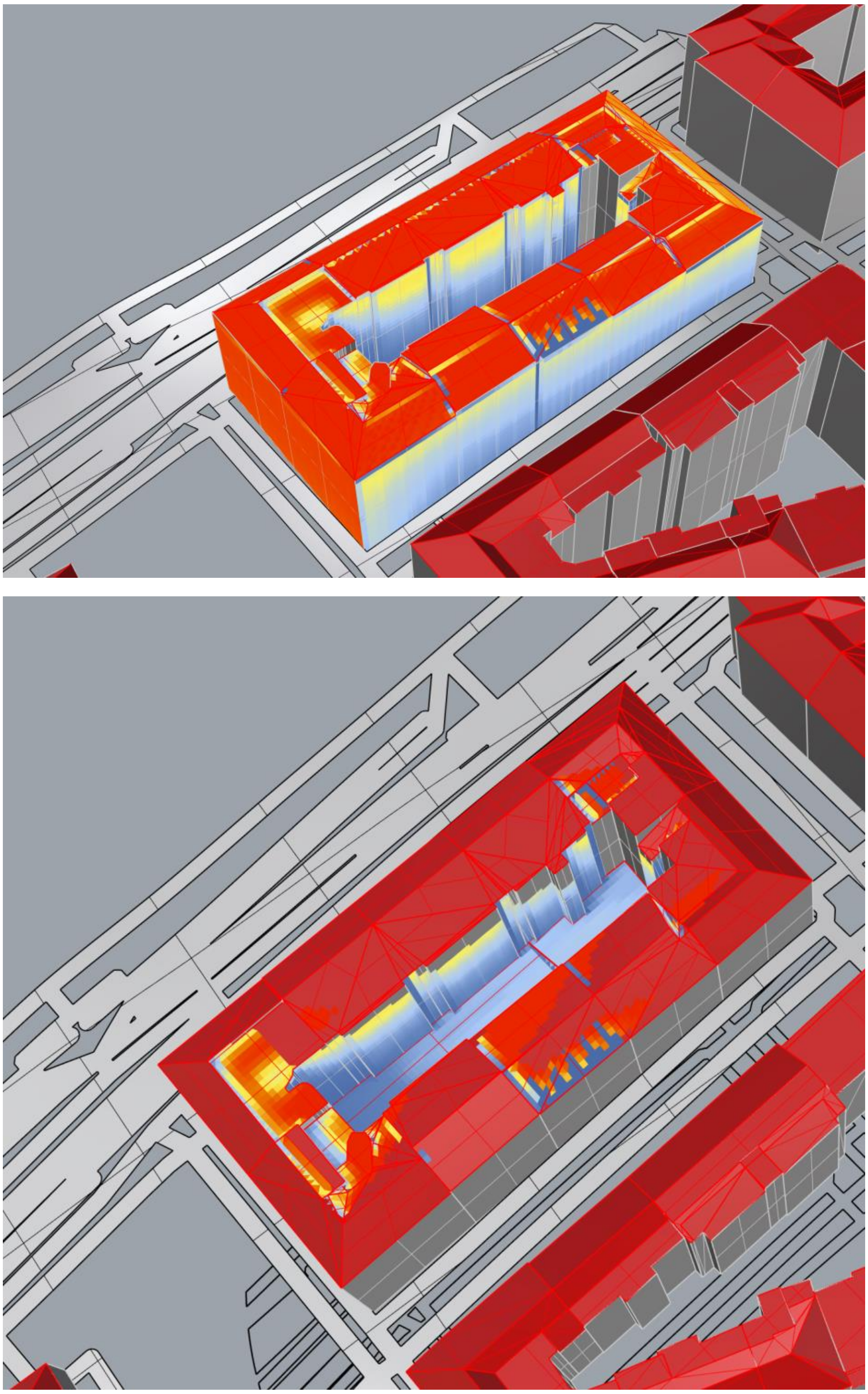

Figure 11: Visualisation of the annual solar irradiance of the test points not visible from the significant view-points or street-level view-points

7 CONCLUSIONS

This deliverable demonstrates that visibility analysis for rooftop and façade-mounted renewable-energy systems can be systematically and reproducibly undertaken by combining NPÚ's heritage-protection principles, Prague's ÚAP visual-composition datasets, and the city's LoD2 3D model within a Grasshopper-based simulation workflow. The results confirm that it is possible to identify surfaces that remain fully outside all relevant protected views - both far and near - and that these surfaces constitute the primary candidates for renewable-energy placement in sensitive heritage environments.

The test case on Rašínovo nábřeží illustrates the method's practical value: of nearly 20,000 tested points, only around 8,800 meet the full visibility criteria, demonstrating both the constraints and the opportunities that exist in dense historic urban fabric. The methodology shows that non-visible surfaces are typically located in internal courtyards, shielded roof areas, and north-facing façades. This provides a structured, evidence-based foundation for feasibility studies, architectural design, and municipal decision-making in monument-protected areas.

A significant added value of this approach lies in its compatibility with solar-potential calculations. By linking visibility results with energy-generation potential, planners can quantify not only where installations are allowable from a heritage standpoint, but also how much renewable-energy capacity can realistically be achieved under these constraints. This supports balanced, transparent decision-making and reduces conflicts between heritage authorities, designers, and investors.

The methodology is scalable and can be applied to other parts of Prague or to other cities with comparable datasets. It supports MonuPED's broader ambition to mainstream governance, co-investment, and technology solutions for PEDs in monument-protected areas. Future work will focus on refining near-viewpoint sampling, incorporating vegetation seasonality, improving façade classification, and combining visibility maps with economic viability and energy-modelling tools.

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