Interreg CENTRAL EUROPE

Co-funded by the European Union

ZEB4ZEN

ZEB4ZEN

Zero energy buildings for zero Energy neighbourhoods

Version 2

10 2026



D4.2.2 VIRTUAL REALITY TOOL PILOT TESTING

A. Introduction

Following the development and deployment of the VR tools in Deliverable 4.2.1, this deliverable documents the testing phase performed in the pilot cities (Quedlinburg, Karlovac, Palmanova, Zamość). The purpose of the testing is to ensure the reliability, usability, and effectiveness of the VR platforms in supporting energy planning in heritage-sensitive neighbourhoods.

Testing activities were conducted with the direct involvement of local stakeholders, including municipal staff, planners, conservation experts, and community representatives. This iterative process ensured that the tools not only met technical requirements but also supported participatory decision-making.

1. Objectives

The main objectives of the VR tool testing phase are to:

- Validate the technical performance of the tools in real urban contexts.
- Assess usability and accessibility for different user groups (technical experts, public officials, non-technical stakeholders).
- Evaluate the effectiveness of visualization and decision-support features in planning scenarios.
- Collect feedback for refinement and future scaling.

2. Methodology

2.1. Structure of testing activities

2.1.1. Version 1 for the cities of Karlovac, Palmanova and Quedlinburg

The testing activities of the version 1 (Karlovac, Palmanova and Quedliburg) were carried out in the form of an online training on the 11th of June 2026.

The interface supports both dark and light modes and offers automatic translation for the languages of the pilot cities (German, Italian, Croatian) as well as English (see **Figure 1** and Figure 2).

The following functionalities were presented and tested. First a comprehensive overview of all projects and pilot cities was shown, allowing administrators to adjust details such as project descriptions directly within the detailed view as shown in Figure 4. This section also includes a resource list and a sharing feature with four options, including public and password-protected access (see Figure 3).

General functionalities include a measurement tool (**Figure 5**), which enables the user to measure height, 2D and 3D lines and areas; a shadow analysis tool (Figure 6) showing the shadows on any given date and time as well as an info point manager to allow administrative users to add info points onto the map (Figure 7).

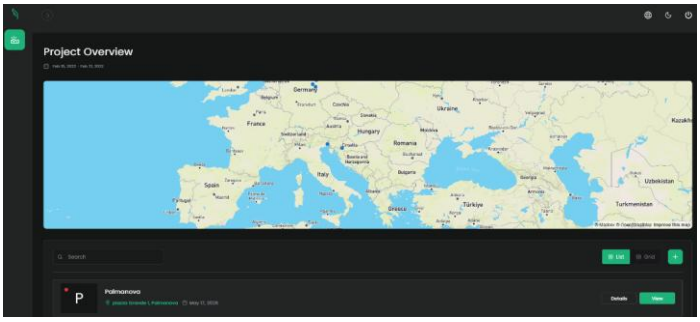


Figure 2 The Project Overview after logging in to the Platform

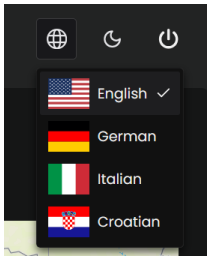


Figure 1, Translations available for the platform as well as the dark mode option

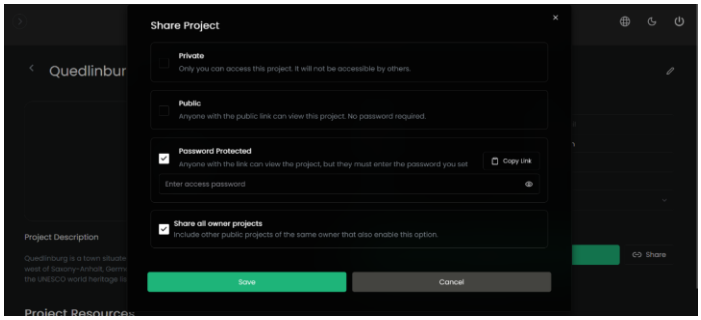


Figure 3 Sharing Options for the Plaform

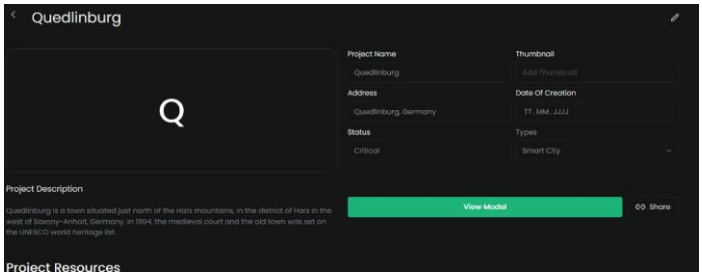


Figure 4 Editable Project Details

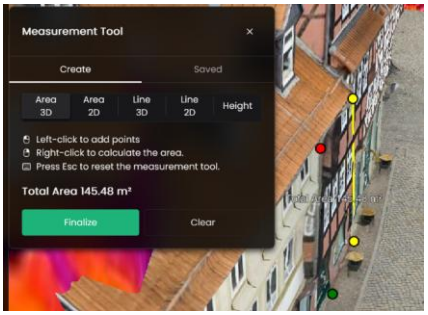


Figure 5, The measurement tool of the platform



Figure 6, The shadow analysis tool of the platform

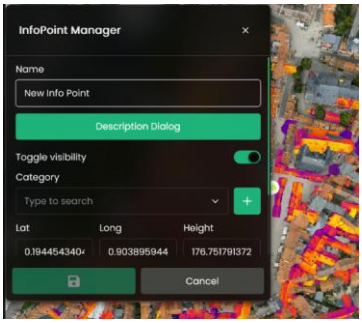


Figure 7, Info point manager of the platform

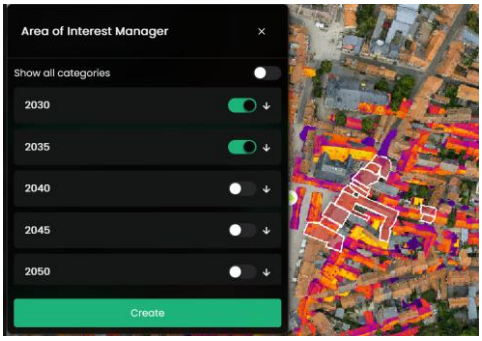


Figure 8, AOI Manager of the platform

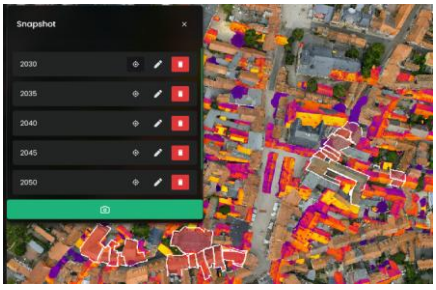


Figure 9, Snapshot feature of the platform

As shown in Figure 10 the layout is divided into two panels: the left panel displays the projects and pilot city-specific areas of interest, while the right panel features the timeline view, energy measure selection, and 2D/3D models, such as thermal city visualizations. A split-screen function enables direct comparisons between views. Additionally, the Model Instances feature supports the import and visualization of 3D models, such as solar panels like shown in Figure 11. Figure 8 depicts the AOI manager showing the areas of interest of the according time period additionally to a snapshot feature showing a snapshot of the AOI's as depicted in Figure 9.

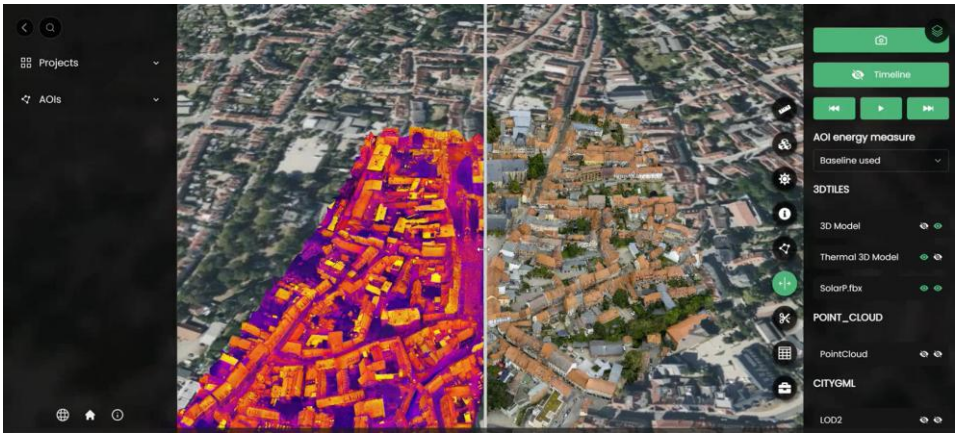


Figure 10, Layout and Thermal 3D Model of Quedlinburg in Split View

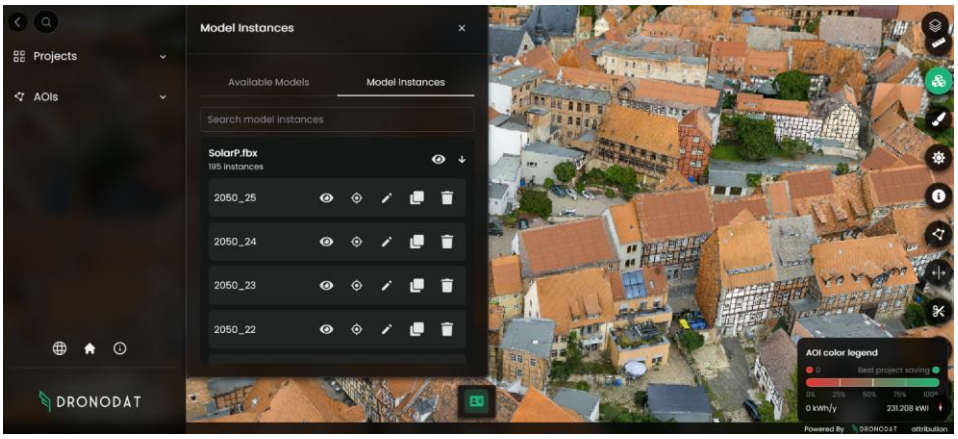


Figure 11 The Model Instances Feature in Use to showcase BIPV Panels on the Roofs in Quedlinburg

Figure 12 shows the Meta Data Tool displaying project metadata, with fixed fields (e.g., cadastral number, block ID, building ID) that cannot be edited, while the remaining fields are adjustable by administrators. The Renewable Energy Measures Tool consists of two parts: first shown in Figure 13, a data visualization feature that presents filterable, Excel-style data (by measure, energy baseline, energy effect, and yearly performance), which administrators can modify. Second, as shown in Figure 14, a timeline feature that visualizes the implementation of energy measures in five-year increments, turning buildings green upon implementation and dynamically displaying additional elements like PV systems.

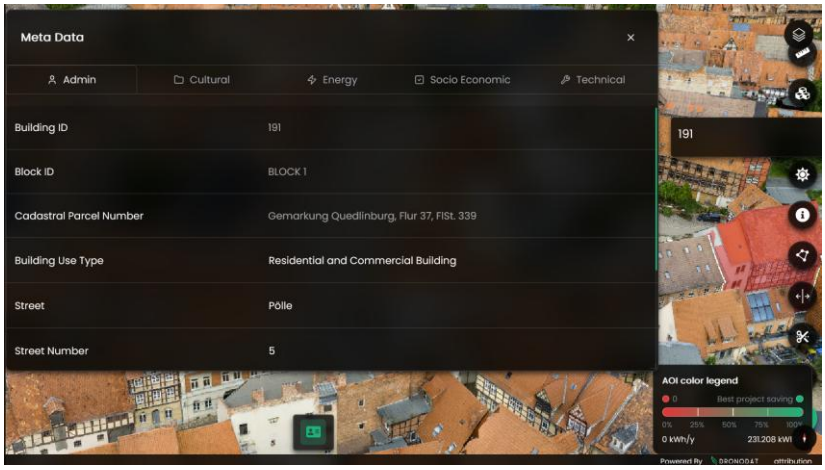


Figure 12 The Meta Data Tool in Use for Building 191 in Quedlinburg

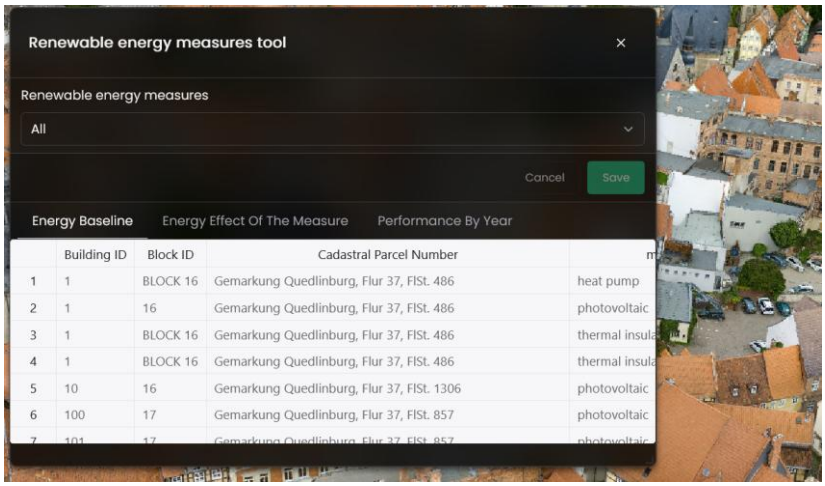


Figure 13 The Renewable Energy Measures Tool for visualizing the Energy Data of different Renewable Energy Measures



Figure 14, The Timeline Feature showcasing the implementation of Photovoltaics in Quedlinburg



Figure 15 The AOI leads to the Solar Park in Palmanova

Figure 15 shows how, in Palmanova specifically, the AOI (Area of Interest) panel includes a "jump" function to navigate to the Solar Park, which is located outside the city. Clicking on a specific building in the AOI panel zooms the camera to its location.

Specifically for Karlovac, two additional buttons are available: one for displaying public lights (Figure 16) which is also integrated in the timeline view, and another for public parking spaces (Figure 17).

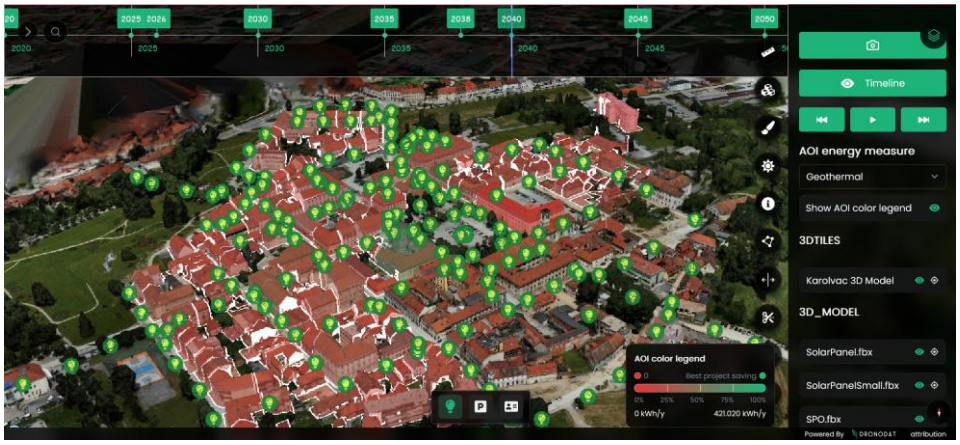


Figure 16, Public Lighting in Karlovac integrated in the Timeline View

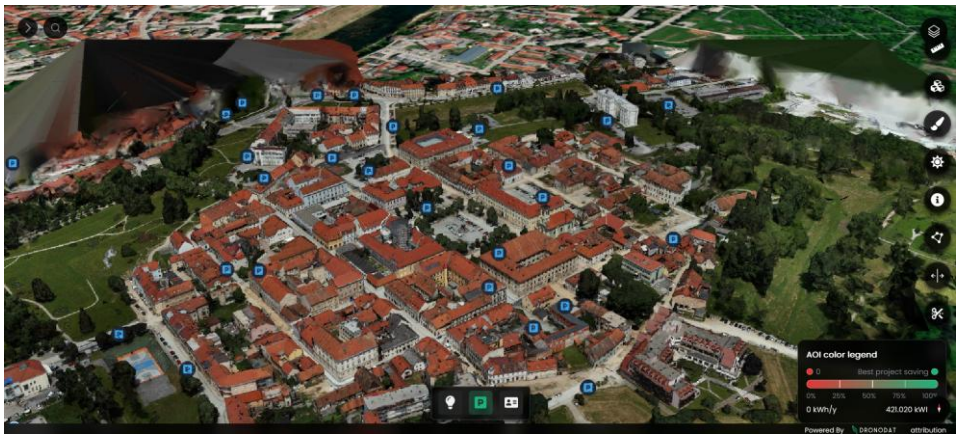


Figure 17 Public Parking Spaces in Karlovac

2.1.2. Version 2 for the city of Zamosc

TEXT

2.2. Target groups

Target groups for the platform are municipal staff, conservation authorities, energy agencies, and citizens. While municipal staff can operate the platform as administrators, meaning they can change parameters, add new tables, update the energy-related values, and modify the cultural heritage information of buildings, citizens do not have permission to make any modifications. Their functionality is limited to a passive role, allowing them only to view the results of the action plans and their impact on the neighbourhood and the district.

2.3. Feedback collection tools

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Feedback are collected through commentary at the end of the testing seminar and through chat tool (for the platform developed by PP 6).

3. Technical Specification of Testing

The VR Tool and with that the testing operates as a cloud-based, web-accessible platform hosted on EU servers to ensure data protection compliance and reliable access across all partner countries. As no local installation is required, the tool is accessed via browser.

The technical foundation is built on WebGL technology, which enables high-quality 3D visualization without the need for high-end hardware. A modular backend ensures efficient session management, concurrent multi-user access, and secure data exchange. Even large datasets, such as 3D models or point clouds, are processed with high performance, allowing smooth operation on mid-range hardware.

For simulation and visualization, the tool utilizes a comprehensive range of datasets. including spatial data such as point, as well as 3D models and meshes. Orthophotos provide aerial imagery with geospatial references, while 2D drawings represent technical plans and architectural layouts. These are complemented by Level of Detail (LOD) models, which offer varying levels of detail for efficient rendering, and UAV-derived Digital Elevation Models (DEM), generated from drone surveys.

A core component is the building metadata, which is divided into five categories.

- Administrative data
- Cultural heritage data
- Technical data
- Energy baseline data
- socio-economic data

Another key dataset focuses on Energy Efficiency and Renewable Energy (EE/RES) measures.

To ensure performance, reliability, and usability, the VR tool adheres to the following benchmarks:

- Loading Times: Under 10 seconds on standard broadband (100 Mbit/s).
- Concurrent Users: Supports up to 100 users per session without performance degradation.
- Browser Compatibility: Fully functional on Chrome, Firefox, and Edge (desktop environments).
- Responsive Design: Adapts seamlessly to various screen resolutions.
- Rendering Optimization: Smooth interaction even on mid-range hardware.
- Data Security: HTTPS encryption, GDPR-compliant policies, and daily backups.
- Data Integrity: Role-based access control (Admin, User, Guest) to restrict sensitive content.

4. Functional Testing

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4.1. Overview over functionalities

The functionalities can be divided into two categories: cross-cutting functionalities which are generally available across all three models, as well as city/project specific functionalities, develepoed specifically for the needs of the pilot cities.

4.1.1. Cross-cutting Functionalities

- Project overview after login (**Error! Reference source not found.**)
- Editable project details for administrators (Figure 4)
- Resource list & sharing feature with four access options (Figure 3)
- Dark/light mode and automatic translation (German, Italian, Croatian, English) (Figure 1)
- Dual-panel layout (Figure 10)
- Split-screen for instant before-and-after comparisons (Figure 10)
- Measurement tool for capturing and saving 3D, 2D, and height measurements (Figure 5)
- Shadow analysis tool to make sun and shadows visible at any given point of date and time (Figure 6)
- Info point manager for adding individualized information to specific points of the map (Figure 7)
- Model Instances: import and visualization of 3D models (e.g. for solar panels/BIPV) as shown in Figure 11
- Meta Data Tool: fixed fields (cadastral number, block ID, building ID) are locked while the remaining fields are editable by admins (Figure 12)
- Renewable Energy Measures Tool: filterable Excel-style data tables and a timeline in five-year increments (buildings turn green upon implementation and PV systems appear dynamically) as shown in Figure 13 and Figure 14
- AOI Manager showing the Areas of interest in the different implementation phases (Figure 8) additionally to a snapshot feature Figure 9

4.1.2. City Specific Functionalities

Karlovac	Palmanova	Quedlinburg	Zamosc
An additional button showing public lighting development. (Figure 16)	A ‘jump’ function in the AOI panel to navigate to the Solar Park located outside the city. (Figure 15)		
An additional button showing public parking space development. (Figure 17)			

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4.2. Navigation and 3D Visualization

The VR tool's interface is structured to provide a seamless and immersive exploration of pilot cities and their energy transition scenarios. The layout is divided into two primary panels: the left panel displays projects and pilot city-specific areas of interest (AOI), while the right panel features a timeline view, energy measure selection, and 2D/3D models, such as thermal city visualizations. A split-screen function enables direct comparisons between different views, enhancing spatial analysis. Additionally, a measurement tool allows users to capture and save 3D, 2D, and height measurements, which is particularly useful for assessing renovation feasibility or design parameters.

The dual-panel layout was seen useful due for its clarity and efficiency. The split-screen feature proved especially valuable for comparing "before-and-after" scenarios. The measurement tool was seen as practical for its precision and ease of use, enabling planners to quickly assess spatial constraints or opportunities for interventions like solar panel installations. In Palmanova, the AOI panel's 'jump' function allowed users to instantly navigate to external locations, such as the Solar Park outside the city. Similarly, in Karlovac, the ability to toggle public lighting and parking spaces directly within the interface was tested successfully.

Areas for Improvement included a clear learning curve for new users. The interface is intuitive, for non-expert stakeholders (for example citizens or municipal staff) an additional guide might be required to fully utilize the split-screen and measurement tools. A quick-start tutorial or interactive tooltips could improve accessibility.

4.3. Scenario Management (BAU vs. ZEN Scenarios)

The Renewable Energy Measures Tool plays a central role in this process, consisting of two key components. A data visualization feature that presents filterable, Excel-style tables of energy measures, baselines, effects, and yearly performance as well as a timeline feature that visualizes the implementation of measures in five-year increments.

The timeline visualization was particularly effective in communicating long-term impacts to stakeholders. The ability to see immediate visual feedback (e.g., buildings changing color) when adjusting scenario parameters, was appreciated since it made complex data more tangible and engaging. The filterable data tables allowed administrators to quickly identify high-impact measures and prioritize them based on technical, economic, or environmental criteria.

Non-technical users might struggle to understand how to create or modify scenarios from scratch. A guided scenario-building mode with predefined templates (e.g., "Maximize CO_2 Reduction" or "Minimize Costs") could simplify the process.

4.4. Administrative and Sharing Features

The VR tool supports real-time collaboration, allowing multiple users to access the platform simultaneously. During the training, participants tested the sharing feature, which offers four access options including public access as well as Password-protected access. Additionally an automatic translation for the pilot city languages (German, Italian, Croatian) and English was provided. The Meta Data Tool (Figure 6) was also demonstrated, where administrators can edit adjustable fields (e.g., project descriptions, energy baselines) while fixed fields (e.g., cadastral number, block ID, building ID) remain locked to ensure data integrity.

The sharing and access control features were highly praised for their flexibility, enabling secure collaboration between project partners, municipal staff, and external consultants. The automatic translation feature was particularly valuable for cross-border teams, eliminating language. The Meta Data Tool worked as intended, with administrators able to update project details efficiently while preventing accidental edits to critical identifiers.

Areas of improvement include a buffer or security net for multiple users editing the same dataset simultaneously. Implementing a locking mechanism (e.g., "This field is being edited by [User]") would avoid conflicts.

4.5. Evaluation of Virtual Reality Tool 1 (PP5)

The ZEB4ZEN VR Tool demonstrated strong technical performance during testing. As a cloud-based, browser-accessible platform hosted on EU servers, it ensured reliable access and data protection compliance across all pilot cities. Built on WebGL technology, the tool delivered high-quality 3D visualization without requiring high-end hardware, while its modular backend efficiently managed concurrent multi-user access, session handling, and secure data exchange.

The VR tool's cloud-based nature eliminates the need for local installations, making it easily deployable across devices. The dual-panel interface provided an intuitive and efficient workflow for exploring energy transition scenarios. The Scenario Management system, powered by the Renewable Energy Measures Tool, is especially helpful since users could filter and edit energy measures in Excel-style tables, Visualize implementation timelines in five-year increments as well as adjust parameters in real time, receiving immediate visual feedback that made complex data tangible and engaging. Adiitional features such as Automatic, flexible sharing options as well as locked metadata fields added to the platforms usefulness.

Initial feedback from pilot cities and users highlighted the tool's intuitive design, tangible visualizations, and administrative features as successes. The timeline visualization was praised for its ability to communicate long-term impacts clearly, while the real-time feedback mechanisms were appreciated for making complex energy data accessible to non-experts.

4.6. Summary of Findings

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Areas for improvement were identified including:

- Learning Curve for Non-Experts: While the interface is intuitive for technical users, citizens and municipal staff might require additional guidance to fully utilize features such as split-screen and measurement tools. Quick-start tutorials or interactive tooltips were suggested to improve accessibility.
- Scenario Complexity: Non-technical users found it challenging to create or modify scenarios from scratch. A guided scenario-building mode with predefined templates (e.g., "Maximize CO_2 Reduction") could simplify the process.
- Overwriting Safety Net: When multiple users edited the same dataset simultaneously, there was no warning system to prevent overwriting. Implementing a locking mechanism would avoid conflicts.

The platforms **modular, cloud-based, and data-driven design** makes it highly adaptable to a wide range of applications that require **immersive visualization, collaborative planning, and decision-support systems**. Some potential areas where the platform could be theoretically extended or repurposed are the following:

- Urban Planning and Smart Cities
- Architecture and Construction
- Environmental and Climate Adaptation
- Education and Training
- Industrial and Infrastructure
- Cultural and Tourism Development

5. Conclusions

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The VR platform is a cloud-based, web-accessible platform designed by Dronodat to support energy-efficient urban planning in historical neighborhoods. Testing in Quedlinburg, Karlovac, and Palmanova confirmed its technical reliability, with strong performance in loading times, concurrent user support, and data security. Its 3D visualization as well as real-time feedback features enable stakeholders to explore, compare, and prioritize energy transition scenarios effectively.

User feedback highlighted the tools intuitive interface and collaborative capabilities, though some improvements are needed, such as simplified scenario creation for non-experts, better mobile usability, and conflict management for concurrent edits. These refinements would enhance its accessibility and practicality for a broader range of users.

While developed for energy planning, the tool's modular design and data compatibility make it adaptable to other applications, such as urban development, architecture, or environmental management, with minor adjustments.