Energy Poverty Zero

Deliverable

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Work Package 2

Deliverable D2.3 - Industrialised retrofit potential assessment tool: *EP-0 tool*

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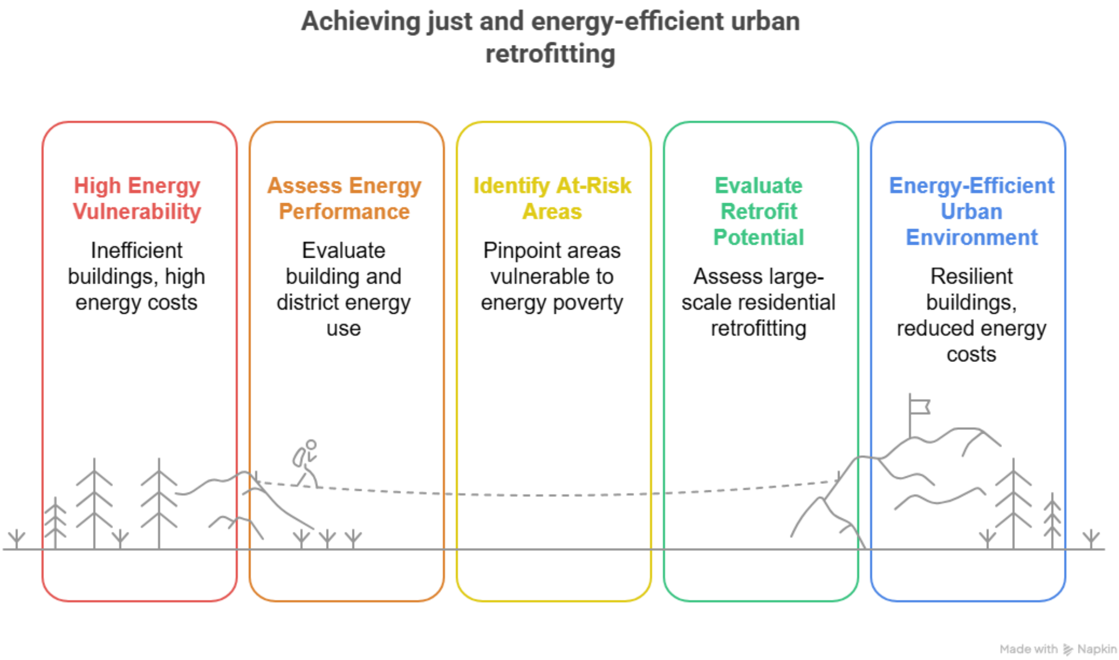
I. Preliminary information

A. Executive Summary

The Energy Poverty 0 (EP-0) project has developed and implemented an innovative ICT solution, the EP-0 tool, specifically designed for municipalities, public authorities, and social housing organizations. This tool offers an efficient and user-friendly method for assessing the current energy performance of buildings and urban districts, identifying areas most at risk of energy poverty, and evaluating the potential for large-scale residential retrofitting.

A key feature of the EP-0 tool is its ability to support the spread of industrialized prefabricated retrofit solutions, while also enabling a preliminary assessment of investment efforts, as well as available incentives and subsidies.

The primary users of the tool are technical personnel within municipalities, who played a preliminary role in shaping its core functionalities. Their insights were gathered and documented in the project's earlier deliverable, D2.1 – Summary of Cities' Expectations and Needs. In addition, social housing companies stand to benefit significantly from adopting the EP-0 tool in their energy renovation initiatives, as well as social and non-governmental organizations who support vulnerable populations in having energy services and adequate comfort in their homes. These stakeholders have also participated in the tool's final testing phase to provide feedback and express their interest in its results.



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The main goal of the EP0 tool is to streamline the evaluation and planning process for energy and vulnerability interventions at the district level. It begins with an assessment of the current condition of residential buildings and generates tailored energy retrofit scenarios, offering varying degrees of energy savings and emissions reductions. The tool also evaluates the financial viability of renovation investments at both the building and district scales. By quickly estimating required investments and highlighting available public incentives, the EP-0 tool empowers decision-makers to prioritize energy renovation projects, especially in neighbourhoods most affected by energy and social vulnerabilities, and support a just transition to more energy-efficient and resilient urban environments.

This document presents the deployed version of the EP0 tool, along with the main documentation and resources required for access, implementation and replication.

🔗 Access the EP-0 tool and resources

📌 EP-0 tool
🌐 Launch the tool
A web-based platform for mapping and analysing energy and social vulnerability in urban areas.

📁 Zenodo repository
📥 Open-access release
Includes source code, methodology, and documentation under an Apache 2.0 open-source license.

📰 Learn more
📄 Read the article
An overview of how the EP-0 tool supports fair, data-driven energy transition strategies.

How to cite
Pistore, L., Dhiman, J., Fuccaro, M., Alonso, R., & Buffa, S. (2025). EP-0 tool: an open-source web-based platform for analysing and mapping energy and social vulnerability, and guiding district-scale retrofit strategies. Zenodo. https://doi.org/10.5281/zenodo.15910447

B. Grant Agreement expectations

According to the grant agreement, the EP-0 tool is designed to build upon a comprehensive dataset that includes both the technical and technological characteristics of buildings (such as location, construction features, and energy systems) and social information related to the composition of the inhabitants. Based on this baseline data, the tool performs an analysis of the current state of buildings and generates multiple rehabilitation scenarios.

Specifically, the tool incorporates an algorithm that operates using building archetypes and a combination of qualitative and quantitative inputs, including year of construction, orientation, construction materials, roof and wall specifications (e.g., transmittance), type of windows and fixtures, as well as heating and cooling systems, where applicable. In parallel, the tool factors in social data pertaining to the tenant population and the broader district context.

The resulting retrofit scenarios, which users can filter according to specific priorities or goals, span various levels of energy efficiency improvements. These scenarios are designed to be linked to industrialized prefabricated retrofit solutions, housed in a dedicated repository accessible through the tool. This repository enables users to explore the most appropriate solutions, each accompanied by indicative economic and environmental impact estimates.

The analysis produced by the EP0 tool supports a preliminary evaluation of potential retrofit actions for individual buildings. Users can compare different scenarios based on feasibility and strategic objectives, and are provided with actionable retrofit solutions to guide implementation planning. Furthermore, the tool incorporates a specific methodology (developed and tested within the project) to identify the most vulnerable populations across city districts. This functionality, detailed in a dedicated methodological document, enables a more targeted and socially responsive approach to energy renovation planning.

II. Deliverable

A. Objectives and target users

The EP0 tool serves as a powerful, data-driven visualization platform tailored to the specific needs of various stakeholders involved in energy renovation and social policy.

The **primary users** of the tool are technical staff members employed by **municipalities** or **social housing organizations**. These users are expected to have a general background in building and energy, enabling them to effectively navigate the tool, interpret its outputs, and apply the results in planning and decision-making processes. The tool allows these professionals to assess buildings' performance and social vulnerability across districts, strategically plan and prioritize renovation efforts, and implement fairer and more effective energy policies. This results in optimized resource allocation, accelerated retrofitting programs, and more sustainable urban development.

Banks and funding institutions, including energy help desks and aid organizations, can leverage the tool's analytical capabilities to support the targeted distribution of subsidies and financial aid. By identifying areas with the highest need (based on both technical and social indicators) they can ensure impactful investments that maximize both social and environmental returns. For **National Energy Poverty Observatories**, the EP0 tool provides a mechanism for monitoring and identifying concentrations of energy poverty within urban areas. It supports data-informed policymaking, enabling more precise targeting of public funds and aligning interventions with national and EU climate and social equity objectives. In addition, researchers and projects focused on energy poverty can benefit from the methodologies embedded in the tool. These methodologies can support in-depth studies on energy poverty and serve as a foundation for future research initiatives or project development in the field of energy vulnerability and building renovation.

To ensure the EP-0 tool meets real-world needs of its intended users, a series of interviews and roundtable discussions were held with municipalities and social housing organizations in France and Italy. The insights gathered during these sessions are summarized in *Deliverable D2.1 – Summary of Cities' Expectations and Needs*. Based on these contributions and the conceptual development process, the EP-0 tool was designed around the **following core objectives:**

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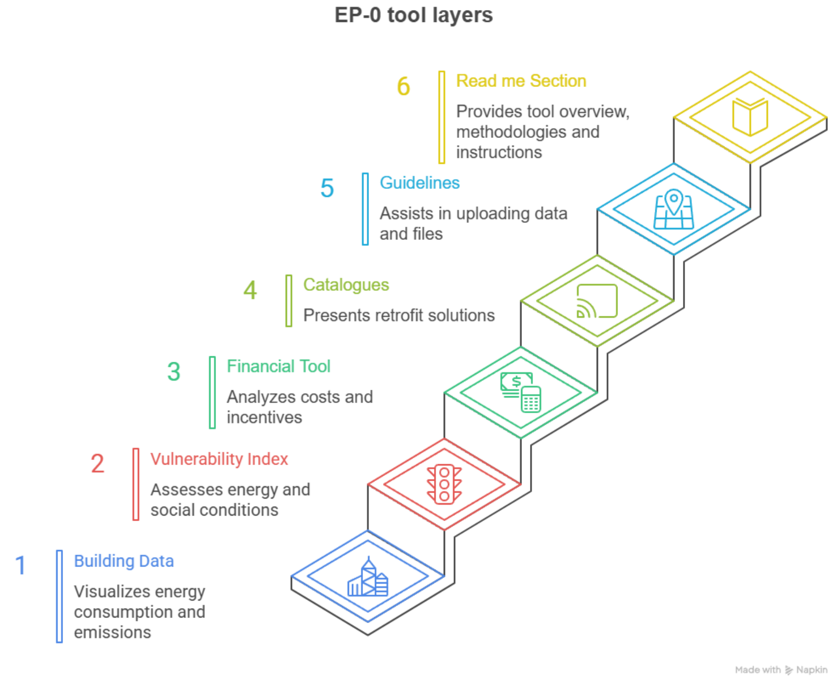
1. **Assess the current state of buildings**, based on parameters such as year of construction, geometry, energy consumption for heating and cooling (kWh/m²/year), and CO_2 emissions (kg/m²/year).
2. **Enable the grouping of similar buildings** to support the aggregation and scaling of retrofit interventions.
3. **Evaluate different areas within a municipality** using a vulnerability assessment framework, incorporating a global vulnerability index and a set of detailed vulnerability indicators.
4. **Provide preliminary retrofit scenarios**, reflecting different levels of energy performance improvement and integrating a range of retrofit interventions.
5. **Provide access to a repository of prefabricated, ready-to-apply retrofit solutions**, including data on environmental performance, installation requirements, costs, benefits, and technical specifications.
6. **Support preliminary economic and financial assessments**, including the estimation of costs and financial indicators, and identification of relevant incentives and subsidies.

These objectives were achieved through the foundational work conducted during the stages of the project, as documented in *Deliverables D2.2, D2.3 (V1), and D2.4*.

B. System architecture and functional layers

The tool integrates multiple functionalities, including the following key layers:

- **Building Data:** visualizes building-level energy consumption, emissions, and geometric data. Uses archetype-based pre-simulated scenarios to assess baseline performance and propose retrofit scenarios.
- **Vulnerability Index:** applies a scientifically grounded, multi-dimensional methodology based on socio-economic, building condition, and energy cost indicators to compute a Global Vulnerability Index (GVI). The results are visualized using a traffic light system (Red–Critical, Orange–Moderate, Yellow–Mild).
- **Financial Tool:** allows a preliminary cost and economic analysis, including net renovation costs, amortization plans, payback periods, and incentive optimization. It also provides access to main country-based web information on subsidies and incentives.
- **Catalogues:** presents retrofit solutions organized by intervention category, complete with technical descriptions and application guidance.
- **Guidelines:** designed primarily to assist users in uploading GeoJSON files (typically exported from an IES model).
- **Read me section:** offers an overview of the tool's purpose and features, access and use instructions, usage information on the different tool's layers and functionalities.



By combining archetype-based energy simulation with scalable vulnerability mapping, the EP-0 tool offers a comprehensive, data-driven solution for tackling energy poverty and planning sustainable urban retrofitting initiatives.

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C. Methodological background

1. Integration with archetype-based pre simulated data

In the **Building Data** layer, the tool automatically classifies buildings based on their year of construction and shape factor (S/V). The layer is integrated with the **iNSPiRe project's database**[1] of pre-simulated climate-based building archetypes, as detailed in *D2.3 V1*. Year of construction and shape factor are used in the backend to group buildings into archetypes representing common construction and energy profiles. Each archetype is associated with pre-simulated data on:

- **heating and cooling energy consumption (kWh/m² · year);**
- **CO_2 emissions (kg/m² · year);**
- **retrofit scenarios**, including technical solutions, indoor comfort parameters, energy and economic results.

This allows the tool to provide instantaneous baseline average assessments (Figure 1) and propose preliminary retrofit packages without the need for new simulations, accelerating the initial analysis process for large scale urban assessments.

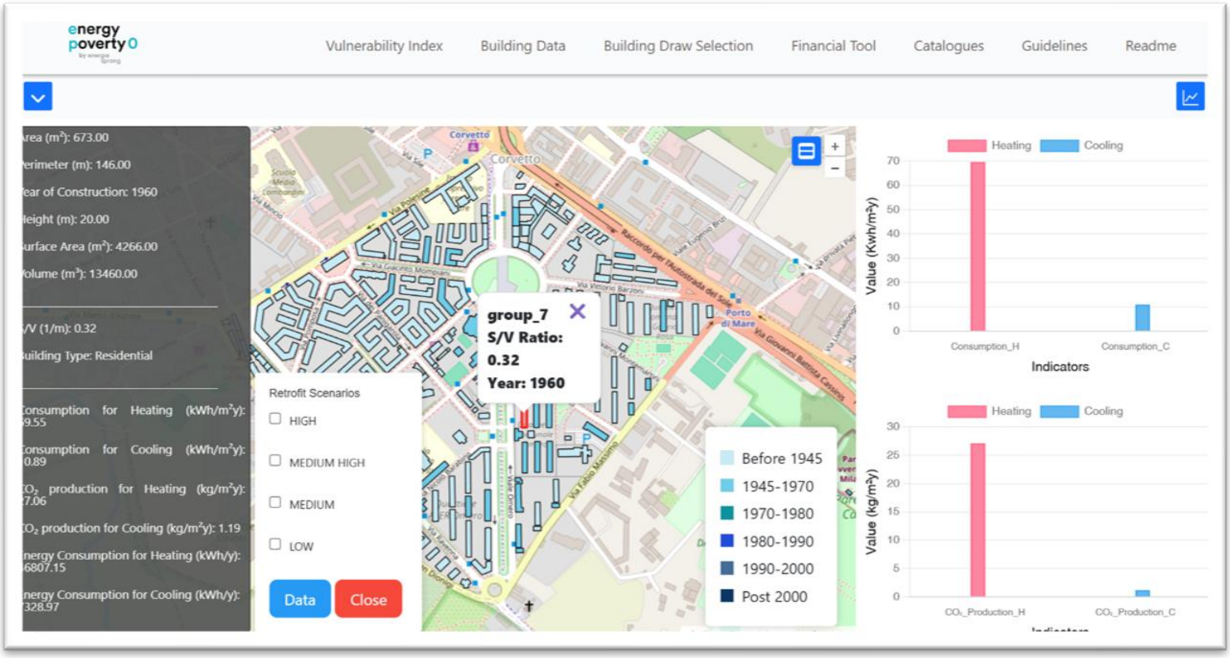
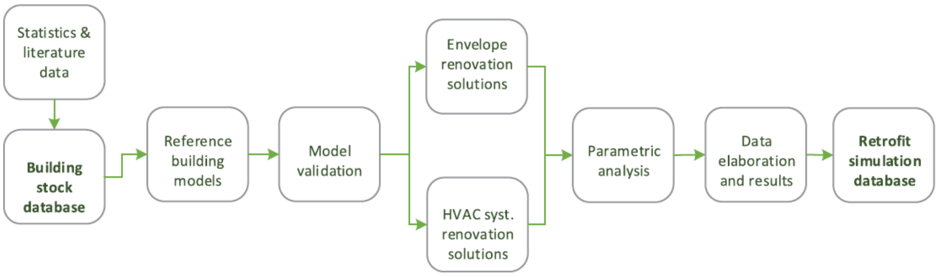


Figure 1. Building baseline data

[1] Dipasquale C., Fedrizzi R., Bellini A., Gustafsson M., Ochs F., Bales C., Database of energy, environmental and economic indicators of renovation packages for European residential buildings, Energy and Buildings, Volume 203, 2019, 109427, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2019.109427.

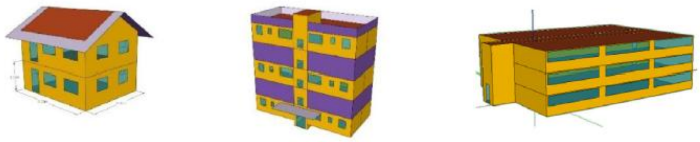
Cases are mapped across the projects' pilots and other tested cases, for a total of 15 pilots: 1 in Belgium, 4 in France, and 10 in Italy.

Due to the limited availability of digitized data and the challenges faced to acquire them from pilot cases, significant effort was made to minimize the amount of data required for the EP-0 tool. To support this, a data collection guideline was developed and shared with project partners. This document, linked in Annex A, outlines the essential data inputs, provides recommended data formats and templates, and includes practical instructions to streamline the data collection process.



(a)

Reference buildings geometry characteristics.



	SFH	s-MFH	l-MFH
Number of storeys	2	3 to 7	3 to 7
Building width/depth	6.5 x 8 m	16.3 x 7.6 m	19.25 x 24 m
Area per storey	50 m²	50 m²	65 m²
S/V ratio	0.90	0.61 to 0.48	0.32 to 0.26
Orientation	45° South-West	45° South-West	45° South-West
Glazing ratio	South 20%; North 10%; East, West 12%	North, South 20% East & West no windows	North, South 20% East & West no windows

(b)

Figure 2 iNSPiRe project. Workflow, simulation inputs, and reference buildings characteristics. Source: Dipasquale et al. (2019) - Database of energy, environmental and economic indicators of renovation packages for European residential buildings

To provide building-level data on heating and cooling energy consumption, CO_2 emissions, and retrofit scenarios, the EP-0 tool integrates the iNSPiRe database, which offers valuable insights into the energy performance of a wide range of building archetypes across different climate zones and energy demand profiles. This integration enables the use of **baseline data derived from reference buildings** (Figure 2), categorized by year of construction and **surface-to-volume (S/V) ratios**, facilitating consistent and realistic modeling of energy behaviour.

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In summary, from the iNSPiRe database approach, archetypes used to group buildings within the tool fall under the following groups:

Table 1 Clusters for buildings' grouping according to reference archetypes

CLUSTERS		S/V		
		0.9	0.61-0.48	0.32-0.26
Years of construction	pre 1945			
	1945-1970			
	1970-1980			
	1980-1990			
	1990-2000			
	post 2000			

The same iNSPiRe database was also used in the EP-0 tool to generate **retrofit scenario outputs**. This database includes the results of numerous building energy simulations conducted on the aforementioned reference buildings, each incorporating various retrofit packages (Figure 3 and Figure 4). Within the EP-0 tool, these simulation results are used to present **multiple requalification scenarios**, each corresponding to different levels of energy efficiency improvements. This approach ensures that the proposed scenarios are grounded in pre-simulated data, enhancing the tool's practicality for planning retrofitting interventions. If simulation results for a particular group are not available in the iNSPiRe database, the tool automatically assigns buildings to the closest group with available results. This assignment is based on the building's year of construction and surface-to-volume S/V ratio. Both the building's values and the corresponding ranges for each group are first normalized. The building is then assigned to the nearest group by calculating the Euclidean distance in the normalized features environment.

Energy indicator	Mediterranean				Nordic			
	15	25	45	70	15	25	45	70
Windows type	Double	Double	Double	Double	Triple	Triple	Triple	Triple
MVHR	Yes	Yes	No	No	Yes	Yes	No	No
Air-tightness n50 (vol/h)	0.6	1	1.5	1.5	0.6	1	1	1.5
Insulation façade (cm)	3	2	0	0	6	4	10	0
Insulation roof (cm)	3	2	5	0	6	4	10	0

Figure 3 Example of adopted envelope renovation packages for a small multi-family home built between 1945–1970 in the Mediterranean and Nordic climates.[1]

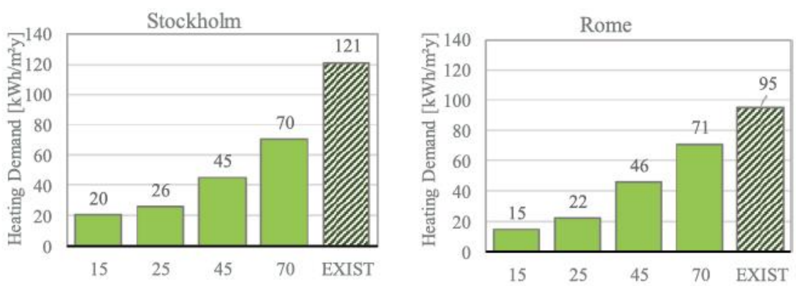

Figure 4 Example of heating demands before (EXIST) and after renovation (15, 25, 45 and 70 kWh/m²) for s-MFHs in Nordic (left) and Mediterranean (right) climates.[1]

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For the scopes of the tool, the following retrofit packages and configurations are been taken into consideration (Table 2).

Table 2 Parametric variables taken into consideration for retrofit scenarios generation

Parametric variables	Values
Climate	Continental HDD-CDD implementation in future development
Building typology	Residential
Building's energy retrofit levels	15, 25, 45, 70 kWh/m^{2}y
Heating and cooling systems	Air to Water Heat Pump (AWHP), Geothermal Heat Pump (GWHP), Gas boiler
Distribution systems	Radiators, Fan coils
Supply temperature	45 °C
Solar thermal collectors inclination	30°
Specific tank volume	100 l/m^2
Photovoltaic modules inclination	30° - 90°

Outputs for retrofit scenarios include: indoor parameters, retrofit solutions, energy, DHW and RES fraction, and economic aspects, as shown in Figure 5.

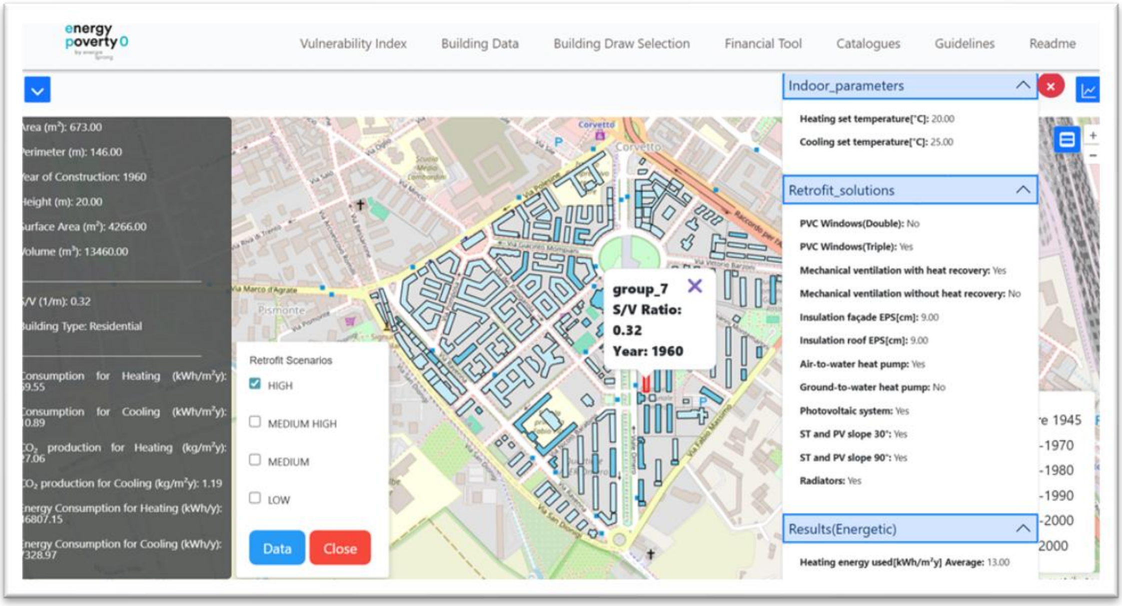
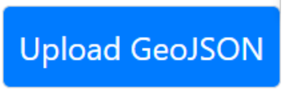


Figure 5. Retrofit scenarios



The tool also allows users to temporarily visualize a pilot case by uploading a GeoJSON file in the format specified in the [Guidelines](). Uploaded cases will appear at the bottom of the pilot's box.

To support the **aggregation of similar buildings** and enable **economies of scale in energy retrofits**, the EP-0 tool also allows users to select and group multiple buildings. These buildings are automatically categorized according to the predefined **building archetypes**, facilitating cluster-level analysis. The dashboard then provides **summary information** for each cluster, namely the number of buildings and average energy consumption, enabling more efficient planning and prioritization of large-scale retrofit interventions (see Figure 6 and Figure 7).

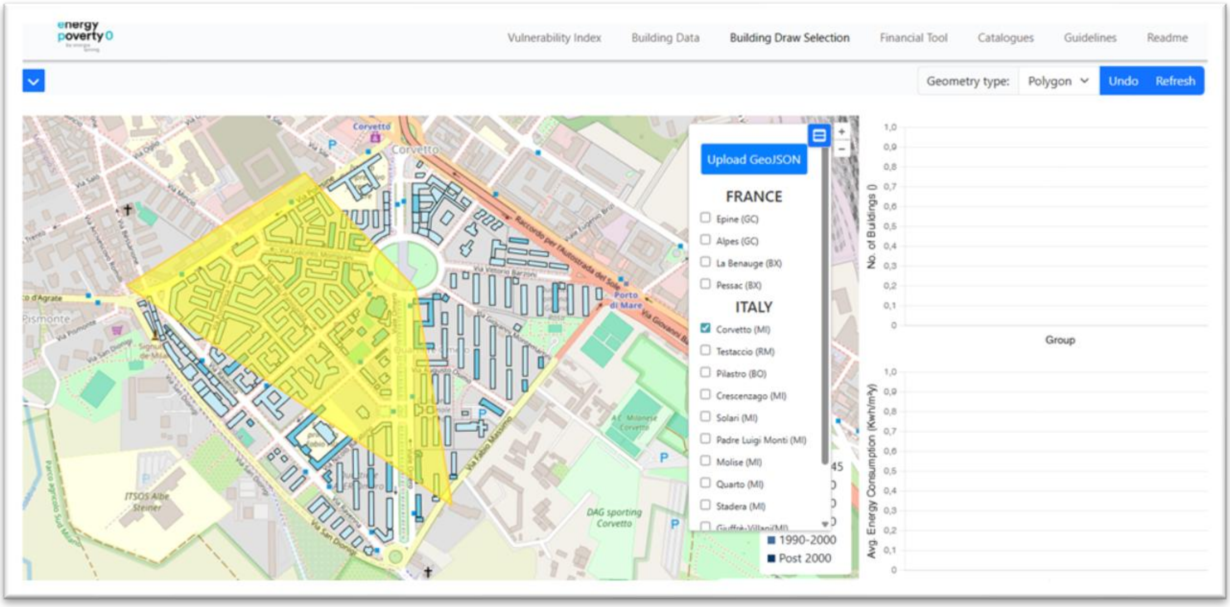


Figure 6. Polygon tool for multiple buildings selection

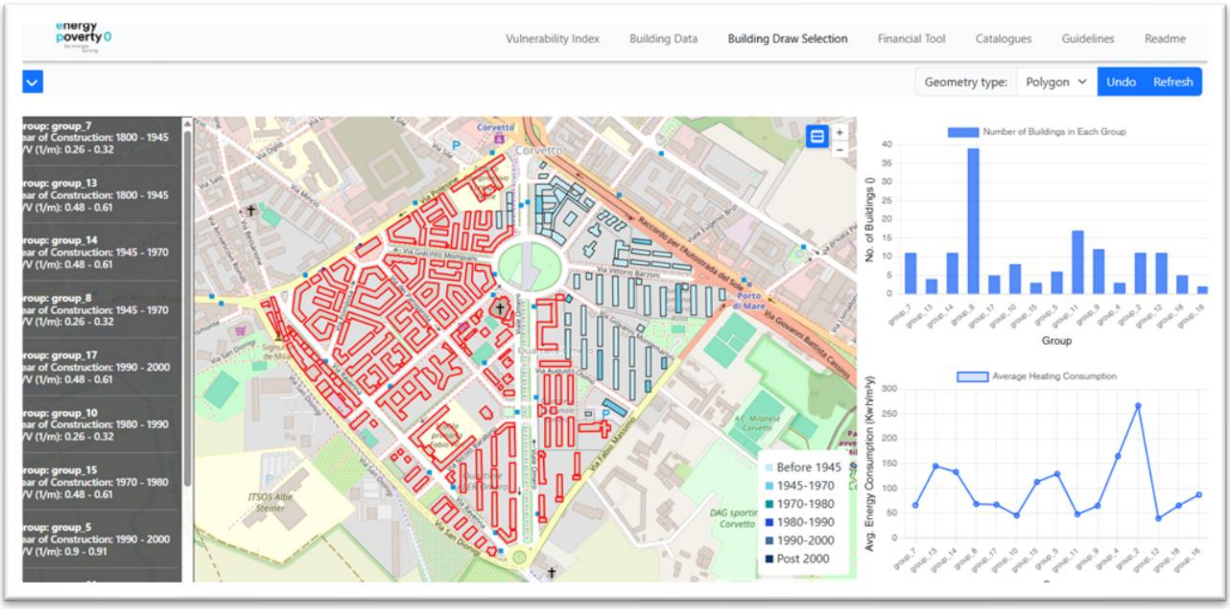


Figure 7. Multiple buildings selection and basic information per group

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2. Energy and social vulnerability assessment

The EP-0 ICT tool's **Vulnerability Index** layer is based on a scientifically-based replicable methodology, designed to map social and energy vulnerability at the census section level using publicly available, periodically updated data. This methodology relies on EU best practices and regulations, e.g., the Energy Poverty Advisory Hub (EPAH) framework and handbook, and academic literature on multidimensional vulnerability indicators, as detailed in *D2.3 V1*.

The methodological core is structured around **three dimensions of vulnerability** (Figure 8):

i. **Socio-economic factors**: including indicators such as average household income, unemployment rate, educational level, renting households, foreign-born population, and age-related vulnerability (e.g., elderly or very young populations).
ii. **Building conditions**: measured through the percentage of buildings in poor state of conservation and the proportion of buildings constructed before national energy efficiency regulations came into force.
iii. **Energy cost**: assessed using the energy expenditure-to-income ratio, identifying households at risk of excessive financial stress due to energy bills.

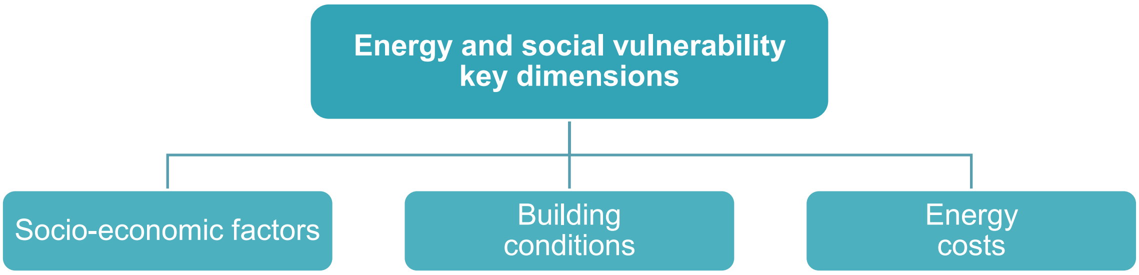

Figure 8. Key dimensions of energy and social vulnerability

Each indicator is collected from public data sources (e.g., national statistical institutes, tax records, national energy statistics). The process follows six structured steps:

1. **Data collection and single indicators calculation**: publicly available datasets are gathered at the most suitable feasible level (e.g., census section). Indicators are computed individually, ensuring local relevance and comparability.
2. **Spatial mapping**: Geographic Information System (GIS) shapefiles or GeoJSON files are used to visualize the calculated indicators spatially, supporting district-scale comparisons.
3. **Thresholds' definition**: for each indicator, vulnerability thresholds are defined relative to regional averages. This approach ensures contextual sensitivity, acknowledging economic and social disparities within countries.

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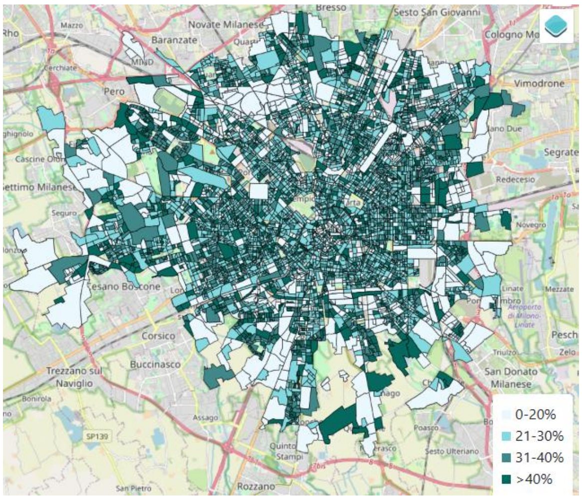
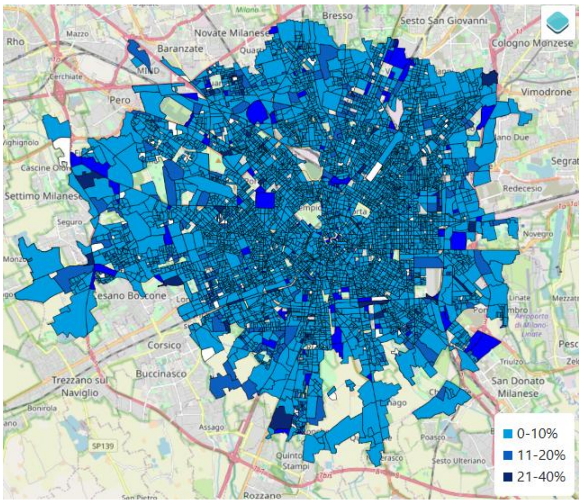
4. **Assignment of preliminary vulnerability levels**: census sections are categorized into two vulnerability levels (L1 = moderate, L2 = high) per dimension based on the threshold exceedance.
5. **Computation of the Global Vulnerability Index (GVI)**: the three individual dimension levels (i.e., socio-economic, building conditions, energy cost) are aggregated into a composite index using a "traffic light" system: red for critical, orange for moderate, yellow for mild.
6. **Visualization and policy use**: final vulnerability scores are visualized in the tool, allowing users to identify high-priority zones for intervention. This spatial mapping supports urban energy planning, funding prioritization, and social policy development within public authorities.

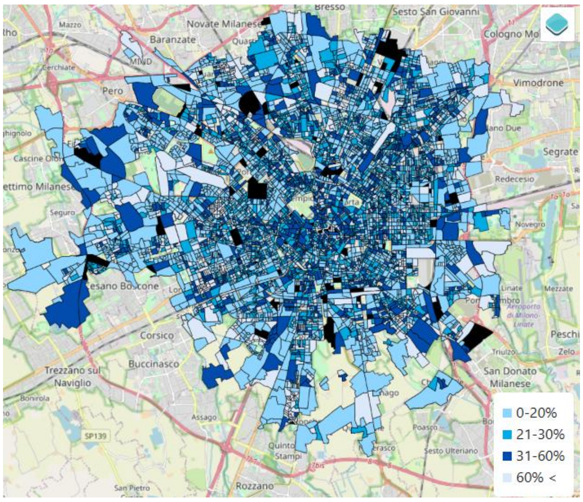
Vulnerable people by age



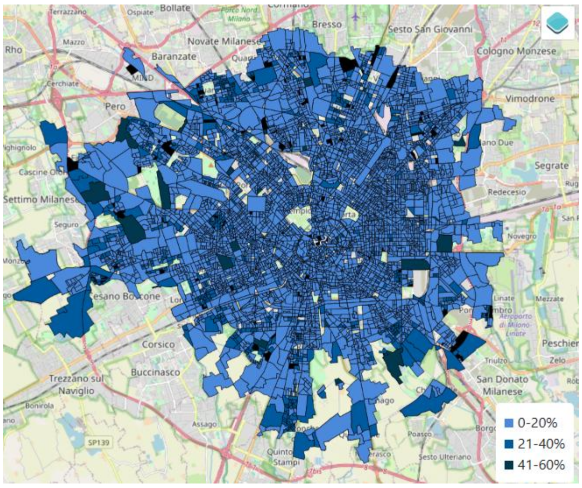
Unemployment rate



Rented households



Education level



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Foreign population

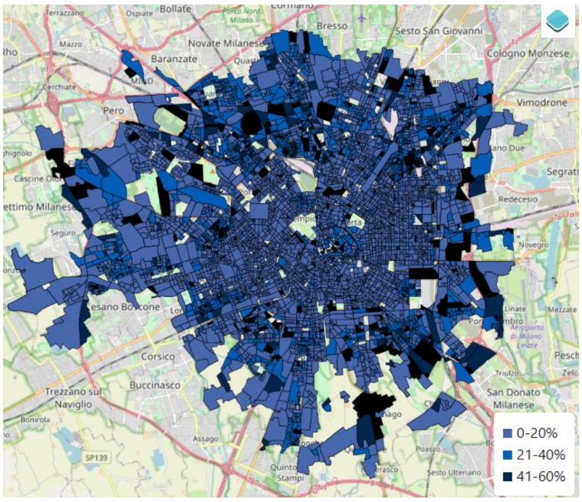

Figure 9. Map of energy and social vulnerability indicators for the City of Milan

This methodology enables large-scale, scalable, and data-driven vulnerability assessments without relying on intrusive or resource-intensive household surveys. It is designed to be adaptable to different national contexts and extendable to new areas through standardized data preparation procedures. The test case on the Municipality of Milan is showcased hereafter for the different energy and social vulnerability indicators (Figure 9) and for the Global Vulnerability Index (Figure 10). For further guidance, a full methodological document is included in the tool's **Readme** section and it is included in this document as Annex B.

Figure 10. Global Vulnerability Index map of the City of Milan

3. Financial and economic evaluation

The EP-0 platform integrates a dedicated **Financial Tool** to support economic feasibility assessments of energy retrofit interventions, particularly targeting vulnerable groups exposed to energy poverty. The tool is built upon the research and development detailed in *D2.4-Identification of financing tool for vulnerable populations*.

This layer (Figure 11) offers a quick and user-friendly pre-feasibility assessment, allowing users to evaluate:

- **investment cost (average, €):** average renovation cost derived from archetype data;
- **interest rate (%)** and **loan duration (years):** key financing parameters to model debt structure;
- **energy savings (€/m²· year):** annual energy savings, either user-provided or retrieved from simulation results;
- **financing scheme:** selection of the applicable incentive's share.

Upon data input, the tool calculates and displays:

- **total cost of financing (€):** total loan repayment over the financing period;
- **loan amount (€):** principal loaned amount;
- **incentives share (%)** and **reduction of initial costs (€):** the share of renovation cost covered by subsidies or grants.

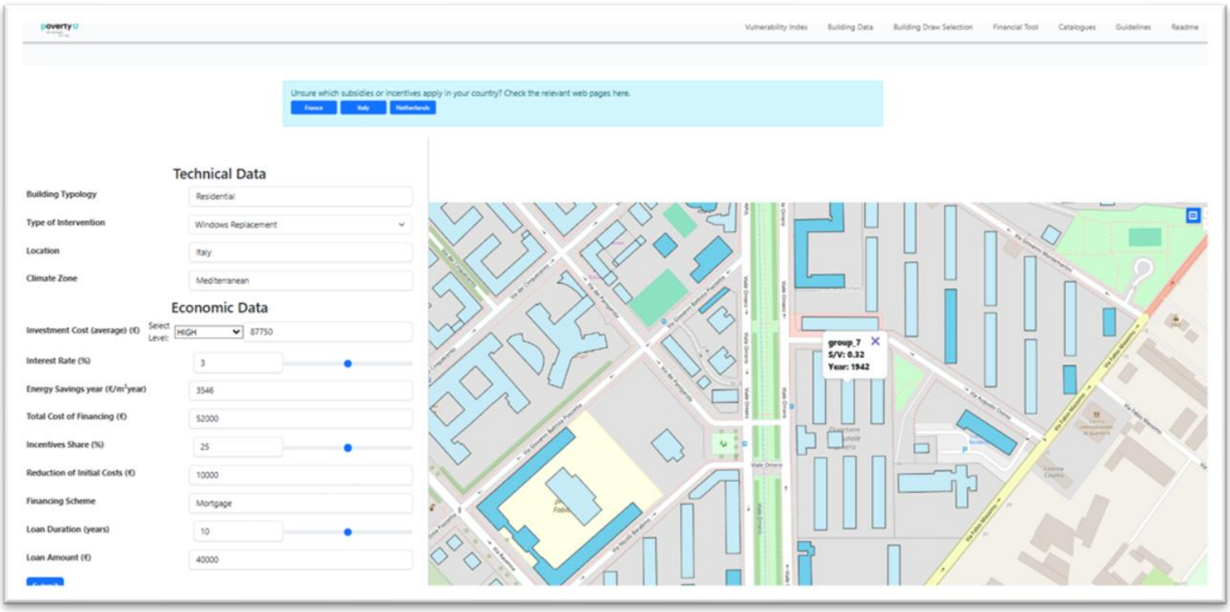

Figure 11. Financial tool landing page

The tool finally calculates:

- amortization plan (€/month);
- balance between savings and financing (€);

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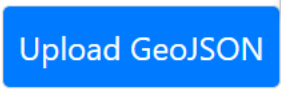
- incentive optimization (€);
- internal rate of return (€);
- net present value (€);
- net renovation costs (€);
- net economic contribution of incentives (€);
- payback period (years).

The tool offers embedded links and information related to national incentive programs for project's pilots countries, i.e., France, Italy (Figure 12), and The Netherlands, allowing the user to find the most relevant and accurate information on national subsidies and incentives. This ensures that users can easily access up-to-date information on available subsidies and financial support.



As for the Building data layer, the tool enables users to temporarily visualize a pilot case by uploading a GeoJSON file that follows the format outlined in the Guidelines. Once uploaded, the cases will be displayed at the bottom of the pilot's box.

The Financial Tool simplifies complex financial assessments into clear insights for decision-makers, municipalities, and social housing providers, enabling users to evaluate multiple financing scenarios and identify the most accessible and financially viable options for vulnerable households, while also supporting resource allocation.

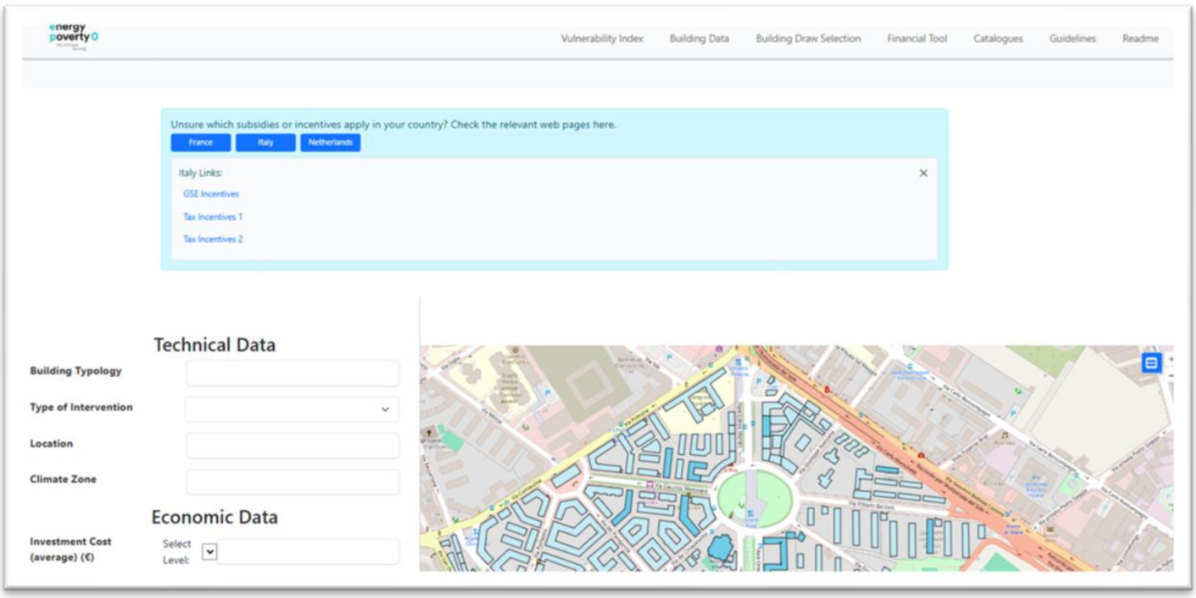


Figure 12. Financial tool: incentives information

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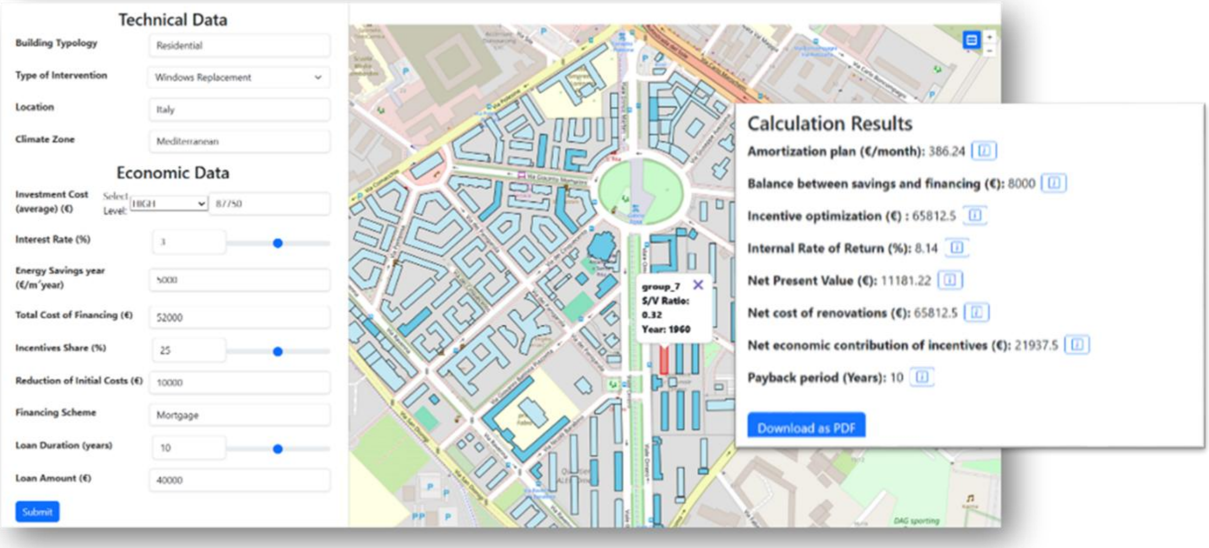

Figure 13. Financial tool: inputs/outputs and results

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4. Development of the repository of retrofit solutions

Another key component of the EP-0 tool is the development of the [Catalogues](#) of prefabricated retrofit solutions, which serves as both a knowledge base and a decision-support resource to assist users in selecting appropriate renovation interventions. This functionality is based on the work detailed in *Deliverable D2.2 – Presentation of the Retrofit Solutions* and its annexes, and provides structured information on a range of prefabricated solutions to support informed and technically sound decision-making. Retrofit solutions are systematically grouped into distinct technical categories reflecting the key intervention areas (Figure 14 and Figure 15):

- **thermal envelope** (e.g., prefabricated façade panels, roof modules, low floor insulation);
- **energy systems** (e.g., prefabricated HVAC, renewable energy integration, MEP pods);
- **solutions improving building and living comfort** (e.g., external lifts, modular balconies, monitoring systems).

This categorization allows for the evaluation and comparison of diverse technological options across heterogeneous building contexts. Users are also allowed to download the technical template to propose additional solutions to be added in the catalogue.

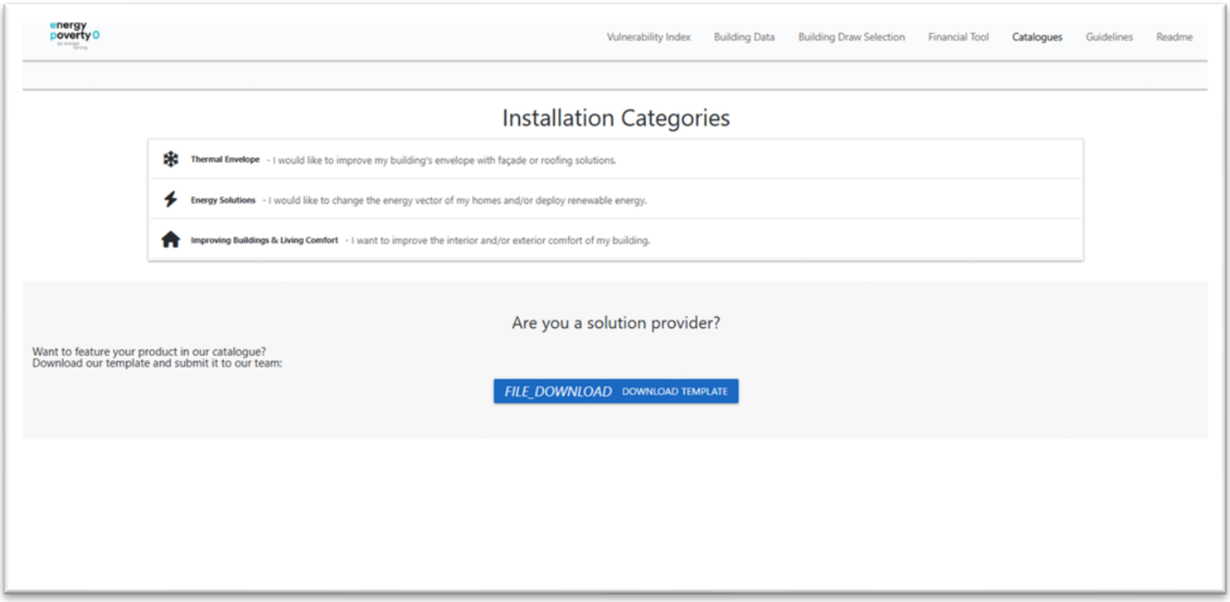

Figure 14. Catalogues landing page

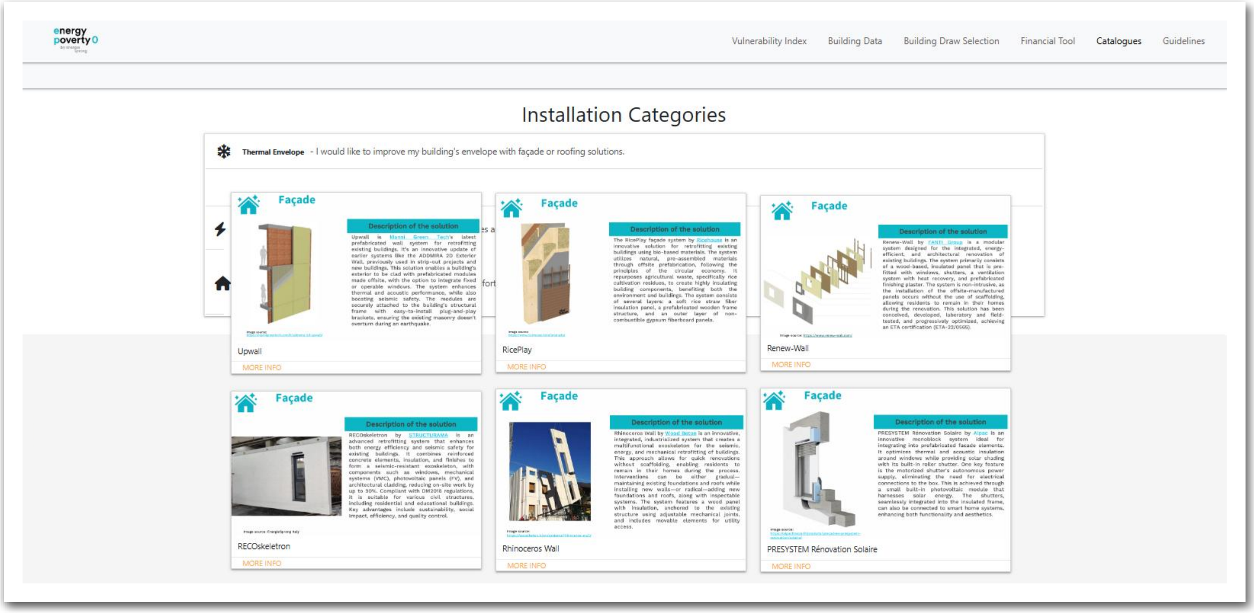

Figure 15. Catalogues: presentation of solutions

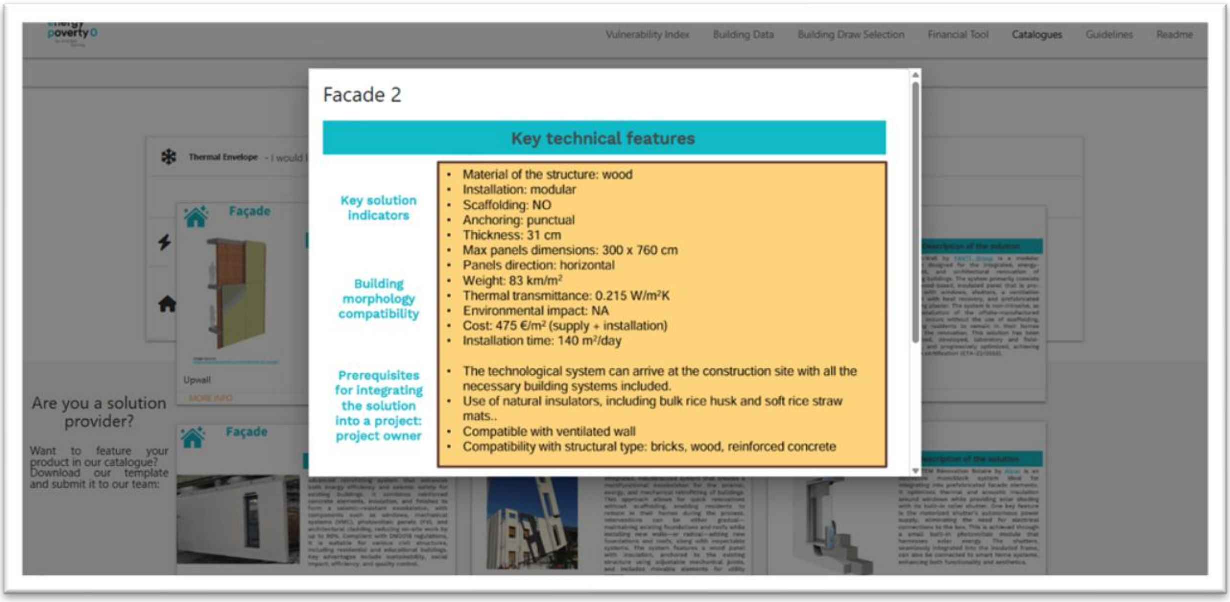

Figure 16. Catalogues: technical information

For each solution included in the repository, technical characterization is provided (Figure 16). The solution sheets include multiple performance indicators such as:

- structural compatibility and installation requirements;
- energy efficiency and thermal properties;
- integration with renewable energy systems;
- environmental impact (CO_2 footprint, circularity aspects);
- seismic performance (where applicable);

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- co-benefits identification;
- installation time and disruption minimization;
- cost ranges (purchase, installation and maintenance);
- expected lifespan and end-of-life recyclability.

The repository has been developed through the integration of publicly available factsheets data and case studies from EnergieSprong pilot projects in Italy, France, and the Netherlands, as well as technical inputs from desk research and from the EnergieSprong Italy's public documentation on solutions. This iterative approach ensures that the repository reflects not only the state-of-the-art technical solutions but also practical lessons learned from real-world implementation.

The repository is designed to serve as a core information source for the EP-0 tool, enabling users to explore, compare, and select appropriate solutions based on specific building configurations and renovation goals, provided with an overview of economic, environmental, and operational data, supporting municipalities and building owners in informed decision-making processes. By including this structured repository, the EP0 project contributes to the scalability and replicability of industrialized retrofit processes, enabling standardization while maintaining sufficient flexibility to adapt solutions to diverse national, regional, and local contexts.

5. Guidelines

The **Guidelines** page on the EP-0 tool platform provides **practical instructions for data collection** (Figure 17), including the **minimum required building and district-level data**, suggested **data formats and templates** (Figure 18 and Figure 19), and guidance on how to handle missing or non-digitized information. It is designed to help users, primarily municipal and housing technical staff, to streamline the input process for energy and vulnerability assessments.

The entire guideline, provided in Annex A of this report, and templates, can be downloaded by the user as reference or working materials.

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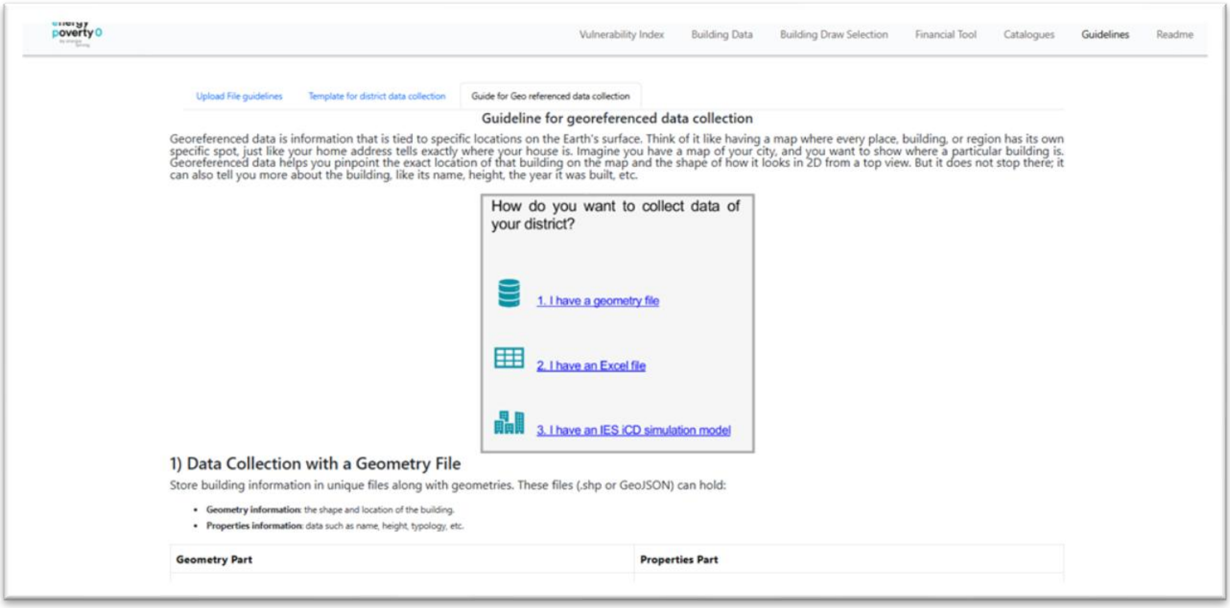

Figure 17. Guidelines: information for georeferenced data collection

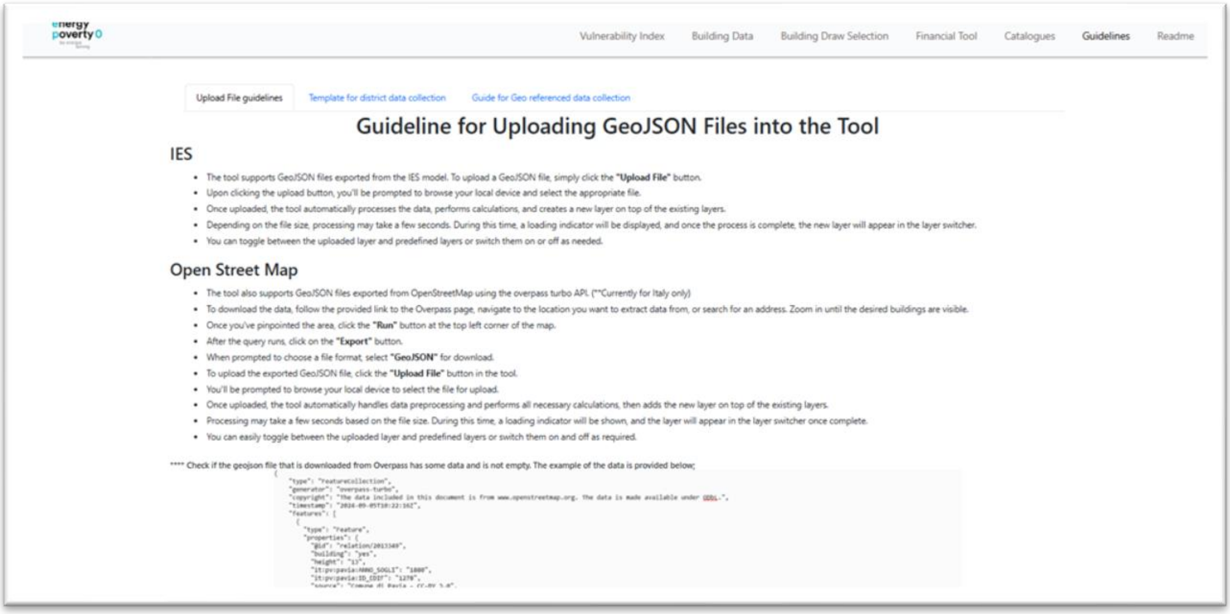

Figure 18. Guidelines: information for GeoJSON input files

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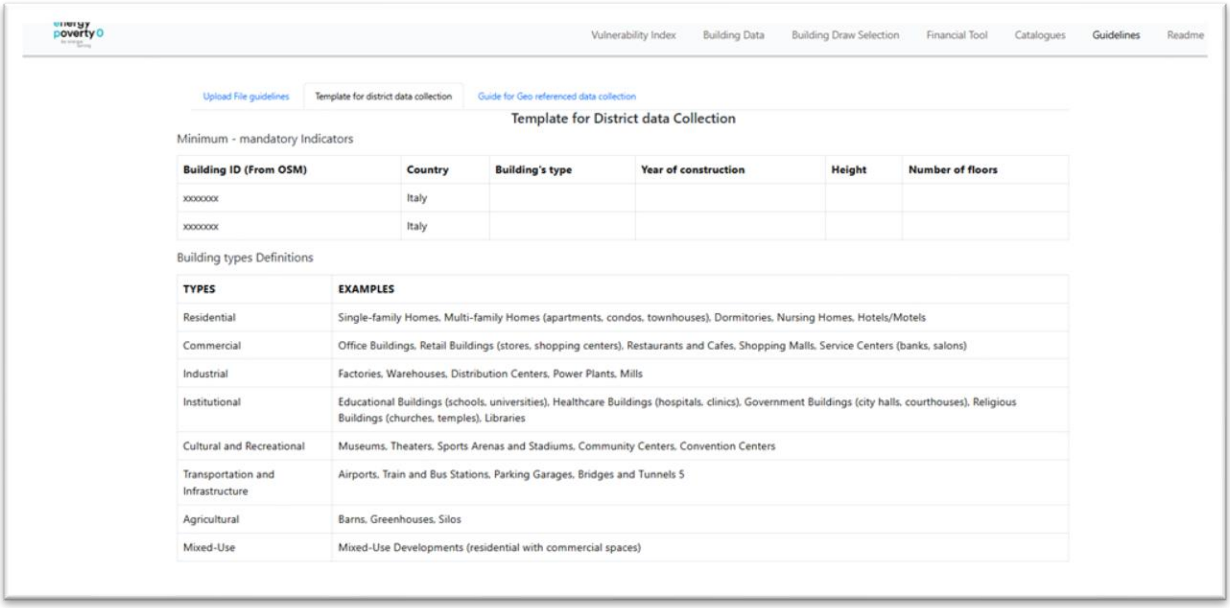

Template for District data Collection

Minimum - mandatory Indicators

Building ID (From OSM)	Country	Building's type	Year of construction	Height	Number of floors
xxxxxxx	Italy				
xxxxxxx	Italy				

Building types Definitions

TYPES	EXAMPLES
Residential	Single-family Homes, Multi-family Homes (apartments, condos, townhouses), Dormitories, Nursing Homes, Hotels/Motels
Commercial	Office Buildings, Retail Buildings (stores, shopping centers), Restaurants and Cafes, Shopping Malls, Service Centers (banks, salons)
Industrial	Factories, Warehouses, Distribution Centers, Power Plants, Mills
Institutional	Educational Buildings (schools, universities), Healthcare Buildings (hospitals, clinics), Government Buildings (city halls, courthouses), Religious Buildings (churches, temples), Libraries
Cultural and Recreational	Museums, Theaters, Sports Arenas and Stadiums, Community Centers, Convention Centers
Transportation and Infrastructure	Airports, Train and Bus Stations, Parking Garages, Bridges and Tunnels 5
Agricultural	Barns, Greenhouses, Silos
Mixed-Use	Mixed-Use Developments (residential with commercial spaces)

Figure 19. Guidelines: simplified templates for data collection

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6. Readme section

The **Readme** section serves as an introductory and navigational guide to the EP-0 tool (Figure 20). It helps users understand the platform's structure and access the main features efficiently. This page provides an overview of the core modules: **Vulnerability Index**, **Building Data**, **Building Draw Selection**, **Financial Tool**, **Catalogues**, and **Guidelines**.

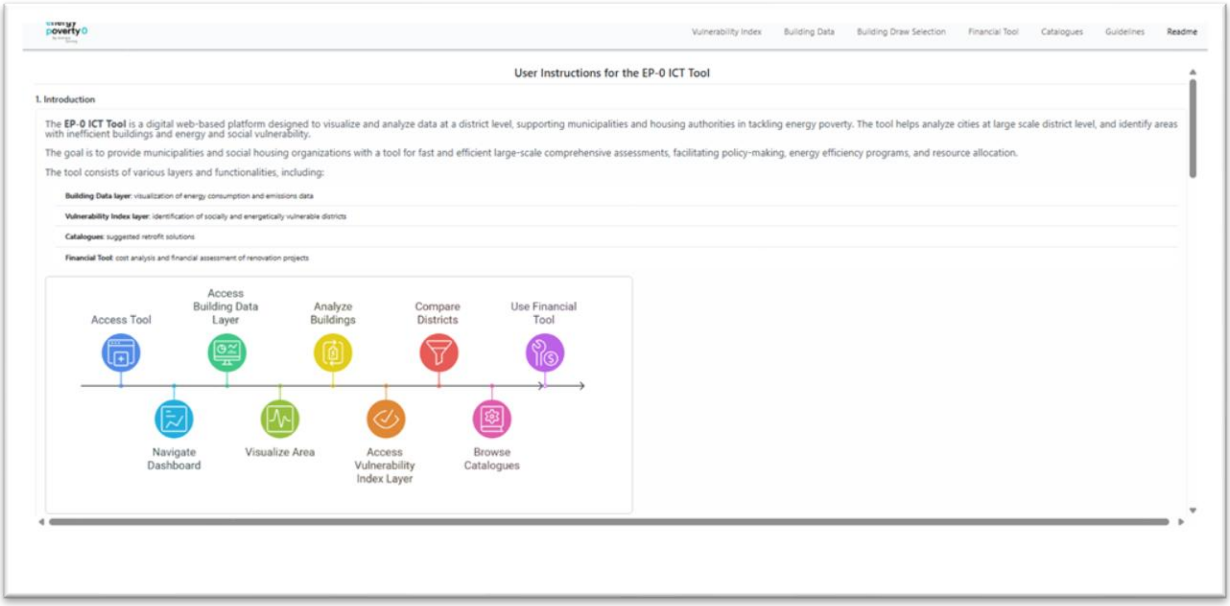

Figure 20. Readme section

In the form of users' instructions, attached also to this report as Annex C, this section provides:

- **Tool structure overview:** a clear outline of the tool's main sections and functionalities, presented to guide first-time users through the key modules available.
- **Navigation guidance:** tips on how to access each module, such as uploading data, selecting buildings, viewing vulnerability indices, launching retrofit scenario analyses, consulting the catalogue of solutions, running preliminary financial assessments, and accessing support documentation.
- **Uploading instructions:** includes brief directions or pointers on using features such as GeoJSON file uploads for building geometry and data, as further indicated in the guidelines section.
- **Context and resources:** methodological document, short descriptions or tooltips that explain the purpose of each component (e.g. what each tool module does and why it's relevant) and help users orient themselves within the platform.

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D. Technical architecture and data processing overview

As deeply described in *D2.3 V1*, the EP-0 tool integrates **GIS technologies**, **custom Python algorithms**, and **interactive web interfaces** to assess building performance, simulate retrofit scenarios, and evaluate energy poverty at district scale.

1. GIS and data structures

The tool uses **geospatial data** (coordinates, elevation, boundaries) sourced from **OpenStreetMap (OSM)**. Data is structured in **vector formats** and converted to **GeoJSON**, enabling compatibility with GIS libraries and tools. Features are organized using the Feature and FeatureCollection standards.

2. Basic workflow

- **Backend setup**: Python libraries (GeoPandas, GeoJSON, Pandas) manage spatial data.
- **Data acquisition**: via OSM, Overpass API, or custom scripts using OSMNx.
- **Frontend**: built in JavaScript using OpenLayers for map rendering and Chart.js for visualizations. UI interactions are handled via popups and DOM events.
- **Integration**: Frontend and backend exchange data using API endpoints, primarily in GeoJSON format.

3. Backend data pipeline

- **Building Data**: downloaded via scripts or API, cleaned and validated, then enriched using data from the iNSPiRe project (e.g., year of construction, S/V ratios).
- **Energy and CO_2 estimations**: based on building geometry and iNSPiRe-based baseline values.
- **Clustering**: buildings are grouped by year of construction and S/V ratio to recommend retrofit packages.
- **Retrofit selection**: once a building is selected, users can choose among four retrofit options; the system displays data tables comparing energy and environmental performance.

4. Vulnerability algorithm

- Developed for the showcased pilots, using ISTAT and ONB data.
- Indicators are computed using predefined formulae and thresholds.
- Vulnerability levels (L1, L2) are assigned based on a set of logic rules.
- Final Global Vulnerability Index is calculated using a "traffic light" model (critical, medium, mild, none).

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- The algorithm includes robust handling of missing or incomplete data, ensuring consistent area classification.

5. Technologies used

- **Python**: for data acquisition, cleaning, transformation, clustering, and indicator computation.
- **JavaScript**: for frontend logic, UI components, interactive maps, and event handling.
- **OpenLayers**: for advanced GIS-based mapping and visualizations.
- **Flask:** for backend server logic and API handling.

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E. Tool's release and exploitation

The EP-0 tool, developed and led by R2M Solution, is released as a web-based, open-source visualization platform designed to support large-scale, data-driven energy renovations in urban areas. It specifically targets residential districts facing energy poverty and social vulnerability, aiming to advance both environmental sustainability and social equity. As detailed in the previous sections, the tool integrates building, energy, environmental, and socio-economic data through four main modules: a building data module that visualizes energy use and clusters similar buildings; a vulnerability module that maps at-risk areas; a solutions catalogue offering prefabricated retrofit options and installation guidance; and a financial module enabling preliminary cost-effectiveness assessments.

This multi-dimensional functionality enables municipalities, public institutions, housing organizations, and funding bodies to develop informed strategies for improving housing quality, energy efficiency, and overall living conditions, particularly in vulnerable neighbourhoods.

The EP-0 tool holds particular value for a wide range of stakeholders.

Municipalities and public authorities can use it to prioritize interventions based on energy performance and social risk, thereby accelerating retrofitting programs and enhancing the quality of public housing. Funding bodies, energy help desks, and aid organizations benefit from the tool's analytical capabilities, which guide targeted investment decisions to ensure maximum social and environmental return. National Energy Poverty Observatories can utilize the tool to identify high-need urban zones, facilitating alignment of public funds and policies with national and EU priorities. Researchers, observatories, and nonprofit actors also gain access to validated methodologies for assessing energy and social vulnerability, creating opportunities for scalable solutions across regions and future projects.

R2M has released the tool under the open-source Apache 2.0 license and continues to host it on its server, with all relevant access links and documentation freely available to users. The tool's source code is also published on Zenodo. While no further updates or maintenance are currently foreseen, R2M expresses interest in reusing the tool and its underlying methodology as a foundation for future EU projects and services supporting municipalities, particularly in Italy, where early collaborations with the Municipality of Milan and Banco dell'Energia have already taken place.

In the final phase of the EP-0 project, significant efforts were made to engage key stakeholders (as narrated in the *Annex C of D2.1*) and promote the exploitation of the EP-0 tool, particularly in Italy. A major workshop on energy poverty was held in Milan in December 2024, organized by the Municipality of Milan in collaboration with AMAT, Banco dell'Energia, OIPE, and other partners. The event brought together experts, policymakers, and institutions to discuss integrated strategies for addressing energy poverty. The EP-0 team contributed by presenting the tool and its methodology for mapping energy and social vulnerability, which aligned with Milan's broader goals of promoting climate resilience, equity, and energy access.

Figure 21. Representatives of R2M Solution during the Energy Poverty workshop in Milan, aligned with EP-0 WP2 activities and broader commitments for tackling energy poverty.

Figure 22. Press conference by OIPE during the Energy Poverty workshop in Milan, featuring main actors and stakeholders.

Following the workshop, two focused bilateral meetings took place in early 2025 with the Municipality of Milan and Banco dell'Energia. In the meeting with the Municipality, R2M Solution showcased the full functionality of the EP-0 tool, which was well received, particularly for its ability to support large-scale energy and social vulnerability analysis. The Municipality expressed interest in using the tool's methodology within its developing plan on energy poverty and efforts to enhance Energy Help Desks into one-stop shops for citizens. They also valued the vulnerability index and catalogues of retrofit solutions, noting the need for more accurate city-level data and follow-up feasibility studies.

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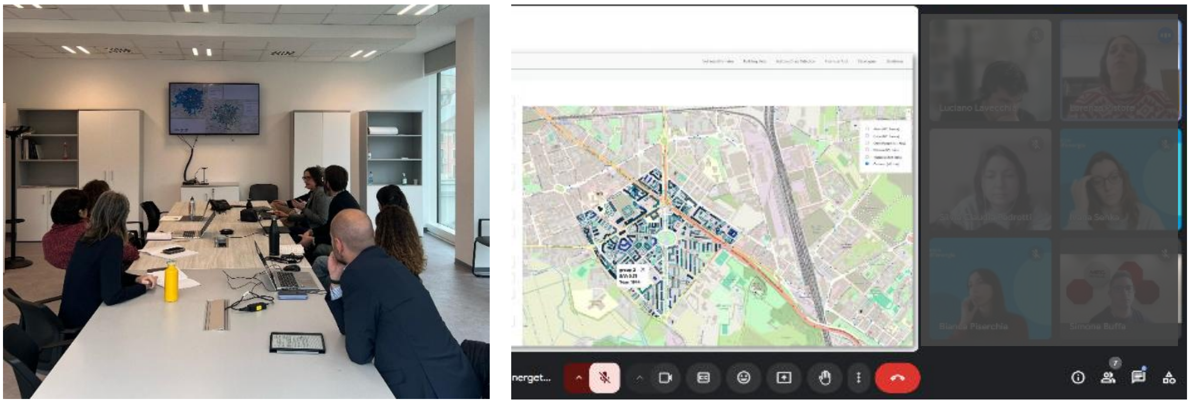

Figure 23. Pictures from the meeting with the Municipality of Milan and with banco dell'Energia.

The meeting with Banco dell'Energia focused on the vulnerability mapping capabilities of the EP-0 tool. Banco dell'Energia is a philanthropic foundation based in Milan, Italy, established in 2016 by A2A and its associated foundations to fight energy poverty. Its mission is to support individuals and families facing economic and social hardships by implementing initiatives aimed at alleviating energy poverty. They expressed strong interest in applying the methodology in cities beyond Milan, such as Rome, and integrating the tool into their broader national initiatives. Banco dell'Energia also invited R2M to endorse its manifesto, "Together to Fight Energy Poverty," reinforcing their collaboration and shared commitment. The insights generated by the EP-0 tool have established a strong foundation for future initiatives aligned with their mission.

Meetings with scientific institutions like GEODIP in France and observatories such as ONPE and OIPE have laid the groundwork for further development and integration into national-level initiatives.

Overall, these engagements confirmed the EP-0 tool's value as a practical, scalable solution for mapping and addressing energy poverty. Both the Municipality of Milan and Banco dell'Energia acknowledged its role in advancing fair, data-driven urban planning and energy transition efforts. The meetings laid the groundwork for future collaborations, the tool's replication in other urban contexts, and long-term exploitation of its methodologies beyond the project's end. All project partners are committed to sustaining and promoting the tool's usage beyond the project lifecycle. Dissemination activities include sharing the tool through institutional websites, social media, public events, and the creation of a leaflet to boost the dissemination of this tool. Key deliverables, including methodological documents, will be publicly available through the LIFE library and partner websites. These actions aim to embed the EP-0 tool or its underlying methodologies into existing urban planning ecosystems, ensuring that it remains a practical and scalable resource for combating energy poverty and supporting a just transition in European cities.

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F. Conclusions: towards scalable and equitable retrofit actions

The release of the deployed EP-0 tool marks a significant step forward in enabling municipalities, social housing providers, and policymakers to tackle energy poverty through data-driven and district-scale renovation planning. By integrating building performance data, social vulnerability indicators, financial evaluation, and a repository of prefabricated retrofit solutions, the tool provides a holistic platform for prioritizing and designing interventions that are technically feasible, economically viable, and socially just. As a freely available, open-source tool, EP-0 lays a foundation for ongoing innovation in urban sustainability and equity, supporting a just transition in line with EU climate and social objectives. Continued dissemination and collaboration will be key to embedding the tool's methodology into future work, research and innovation.

🔗 Access the EP-0 tool and resources

📌 EP-0 tool

🌐 Launch the tool

A web-based platform for mapping and analysing energy and social vulnerability in urban areas.

📂 Zenodo repository

📥 Open-access release

Includes source code, methodology, and documentation under an Apache 2.0 open-source license.

📰 Learn more

📄 Read the article

An overview of how the EP-0 tool supports fair, data-driven energy transition strategies.

How to cite

Pistore, L., Dhiman, J., Fuccaro, M., Alonso, R., & Buffa, S. (2025). EP-0 tool: an open-source web-based platform for analysing and mapping energy and social vulnerability, and guiding district-scale retrofit strategies. Zenodo. https://doi.org/10.5281/zenodo.15910447

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III. Annexes

- **Annex A.** User Instructions for the EP-0 tool.
- **Annex B.** Guideline for georeferenced data collection.
- **Annex C.** Guideline for uploading GeoJSON files into the tool.
- **Annex D.** Methodological document for calculating energy and social vulnerability based on the methodology integrated in the EP-0 tool.

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CONTACTS

WWW.ENERGIESPRONG.FR

Energy Poverty Zero

Annexes

2022
2025

energy
poverty 0
by energie
sprong

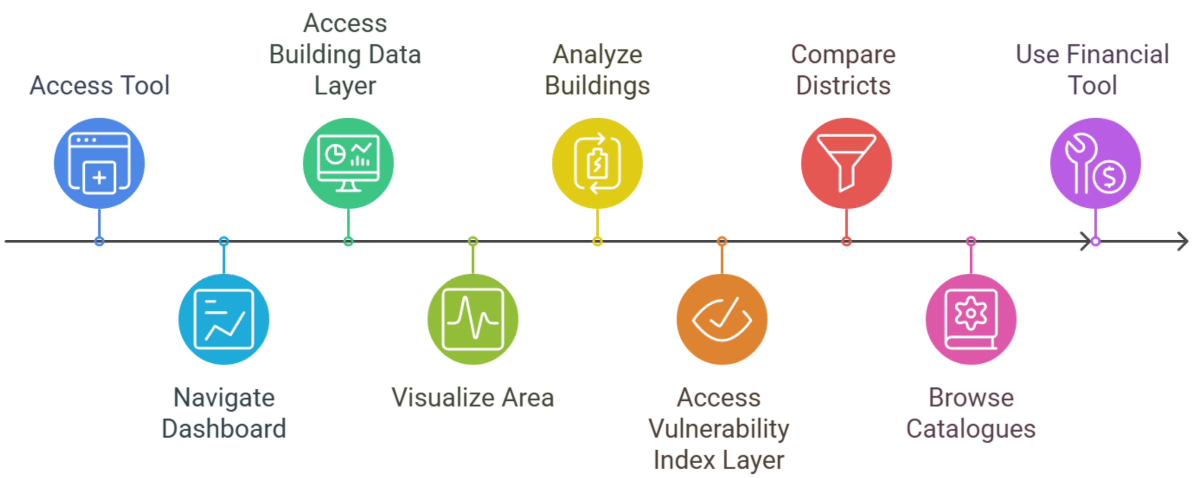
User Instructions for the EP-0 ICT Tool

1. Introduction

The **EP-0 ICT Tool** is a digital web-based platform designed to visualize and analyze data at a district level, supporting municipalities and housing authorities in tackling energy poverty. The tool helps analyze cities at large scale district level, and identify areas with inefficient buildings and energy and social vulnerability. The goal is to provide mainly municipalities and social housing organizations with a tool for fast and efficient large scale comprehensive assessments, facilitating policy-making, energy efficiency programs, and resource allocation.

The tool consists of various multiple layers and functionalities, including:

- **Building Data layer**: visualization of energy consumption and emissions data.
- **Vulnerability Index layer**: identification of socially and energetically vulnerable districts.
- **Catalogues**: suggested retrofit solutions.
- **Financial Tool**: cost analysis and financial assessment of renovation projects.



2. Using the EP-0 ICT Tool

a. Accessing the Tool

1. Open the EP-0 ICT Tool in your web browser: https://energypoverty0tool.r2m.cloud/.
2. Navigate the dashboard to access different analysis layers from the main tab.

b. Building Data Layer

1. Select the **Building Data layer** from the dashboard.
2. Select the layer you want to visualize by checking the corresponding box in the list of pilots.

3. Once buildings appear, select the specific building you want to assess.

4. View geometric information, including: area (m^2), perimeter (m), year of construction, height (m), surface area (m^2), volume (m^3), S/V ratio (m^{-1}) and building type.

5. Analyze baseline energy-related information: heating and cooling energy consumption (kWh/m^2y and kWh/y) and CO_2 emissions (kg/m^2y).

6. Click on one option in the Retrofit Scenarios box to access pre-simulated indoor, energetic and economic results, along with suggested retrofit solutions.

Pre-simulated data. When you click on a building, the tool's back-end groups buildings based on their year of construction and S/V ratio. This allows each building to be assigned to a group with a reference archetype. Baseline and retrofit data are then provided based on the climate-specific pre-simulated archetype. The data were generated as part of the iNSPiRe project. Reference: Dipasquale C., et al. *Database of energy, environmental and economic indicators of renovation packages for European residential buildings*. Energy and Buildings (2019), DOI: 10.1016/j.enbuild.2019.109427.

7. If you would like to visualize your own pilot case, go to the Guidelines section to understand how to generate and upload the correct file.

c. Building Draw selection

1. Select the **Building Draw Selection** from the tab.

2. On the right, select the geometry type you want to use to select buildings (polygon or circle).

3. Visualize buildings in the area grouped based on **year of construction** and **S/V ratio** based on common archetypes.

4. Visualize the number of buildings for each cluster and average energy consumption (kWh/m^2y).

d. Vulnerability Index Layer

1. Navigate to the **Vulnerability Index Layer**.

2. Select the layer you want to visualize by checking the corresponding box in the list.

3. Select the social & energy vulnerability indicator you would like to display among the available ones.

4. When clicking on Global Vulnerability Index, view vulnerability classifications based on three levels:
   - **Red:** critical vulnerability.
   - **Orange:** moderate vulnerability.
   - **Yellow:** mild vulnerability.

5. Use filters to compare different districts/indicators and focus on priority areas for intervention.

6. To know more about how to analyze energy & social vulnerability, consult the methodological document.
7. If you would like to map the vulnerability of your area, contact us.

e. Catalogues

1. Access the **Catalogues** section from the main tab.
2. Browse suggested retrofit solutions categorized by Installation Categories: thermal envelope, energy solutions, improving building and living comfort.
3. Click on each solution to obtain MORE INFO on technical aspects, compatibility, installation, and benefits.
4. If you are a solution provider and would like to feature your product in the tool, download the template and contact us.

f. Financial Tool

1. Go to the **Financial Tool** section in the main tab.
2. Switch on the pilot you are interested in. If you would like to map a new case in the Building Data layer, go to the Guidelines section.
3. Select a specific building from the ones appeared.
4. Choose among the Technical data box the Type of Intervention you are interested in evaluating.
5. Select a level of retrofit: high, medium high, medium, low.
6. Check the provided inputs among the Economic Data section. Change them for a more tailored assessment.
7. If you are unsure which subsidies or incentives apply in your country, check the relevant proposed country web pages.
8. The tool will calculate:
    - Amortization plan (€/month).
    - Balance between savings and financing (€).
    - Incentive optimization (€)
    - Internal Rate of Return (€).
    - Net Present Value (€).
    - Net renovation costs (€).
    - Net economic contribution of incentives (€).
    - Payback period (years).
9. Click on the ⓘ symbol to know what these outputs are.
10. You can download the summary in pdf.

3. Guidelines

To ensure effective use and replicability of the tool, structured data collection is required. This involves:

- **Essential building data for the Building Data Layer**, including:
  - Building type (optional)
  - Country
  - Year of construction
  - Height
- **Georeferencing requirements**: data should be linked to an **OpenStreetMap ID** for proper mapping, or included in a shapefile or GeoJSON file with geometry information.
- **Essential building data for the Vulnerability Layer:** this assessment is based on publicly available data from national statistical databases. For more information consult the methodological document in the *read me* section.

To know more about the data formats supported by the tool, the available processes and how to upload a new pilot, consult the section in the tool.

4. Contact Information

For further inquiries, please contact: info@r2msolution.com

Guideline for georeferenced data collection

Geo-referenced data is information that is tied to specific locations on the Earth's surface. Think of it like having a map where every place, building, or region has its own specific spot, just like your home address tells exactly where your house is.

Imagine you have a map of your city, and you want to show where a particular building is. Geo-referenced data helps you pinpoint the exact location of that building on the map and the shape of how it looks in 2D from a top view. But it does not stop there; it can also tell you more about the building, like its name, height, the year it was built, etc.

How do you want to collect data of your district?

1. I have a geometry file

2. I have an Excel file

3. I have an IES iCD simulation model

1. I have a geometry file

Let us say we want to store buildings' information in a unique file together with their geometries. There are special types of files for this, like .shp (shapefile) or GeoJSON. These files can hold:

- Geometry information: i.e., the shape and location of the building. For example, the outline of the building on the map.
- Properties information: i.e., information about the building, such as its name, height, typology, etc.

An example is shown in Figure 1.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          0.0
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  ]
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  "name": "112_a",
  "/mp/v0/core/width": 1.0,
  "/mp/v0/core/rotation": 0.0,
  "/mp/v0/core/inclination": 0.0,
  "/mp/v0/core/pv-conversion-factor": 0.0,
  "type": "/mp/v0/core/object-types/building",
  "bldgGeom": "/mp/v0/scamp/building-geometry/storey-textured",
  "nonBldgGeom": "/mp/v0/scamp/building-geometry/shell-nb",
  "constructionDate": "1919-1945",
  "numStoreys": 1,
  "storeyHeight": 4,
  "nonBldgHeight": 1.0,
  "maxHeight": 4.0,
  "/mp/v0/core/derivedglazing": 0.0,
  "bldgtype": "/mp/v0/core/lists/bldgtype/office",
  "zAxisOffset": 0,
  "roofType": "/mp/v0/core/lists/rooftype/flat",
  "roofAngle": 30,
  "roofOverlap": 0,
  "roofGlazing": "0",
  "extWallArea": 80.9989564205629,
  "footprintArea": 24.21971,
  "totalFloorArea": 24.21971004804275,
```


(a) (b)

Figure 1. Example of geometry file including geometry and properties of a building.

In this example, the geometry part (a) specifies the shape and exact location of a building by means of specific coordinates, the properties part (b) includes attribute details e.g., height and year of construction.

If you have a shapefile or GeoJSON file, you can use this template and provide it to us as a unique mean to collect data of your buildings, or upload it directly in the tool.

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2. I have an Excel file

If your data is stored in an Excel spreadsheet, it is crucial to geo-reference data to specific buildings on the map by using its ID from Open Street Map (OSM). The process to do this is explained hereafter.

- To get to the **Open Street map** webpage, click on the link below: https://www.openstreetmap.org/#map=20/44.40863/8.96796&layers=H
- The webpage allows you to visualize the buildings in an area by either selecting it on the map or using the search bar (Figure 2).
- Just type the address of the building in the search bar, highlighted by the red box ((Figure 2), or just select the building of interest by clicking on the map if you can identify it in the area.

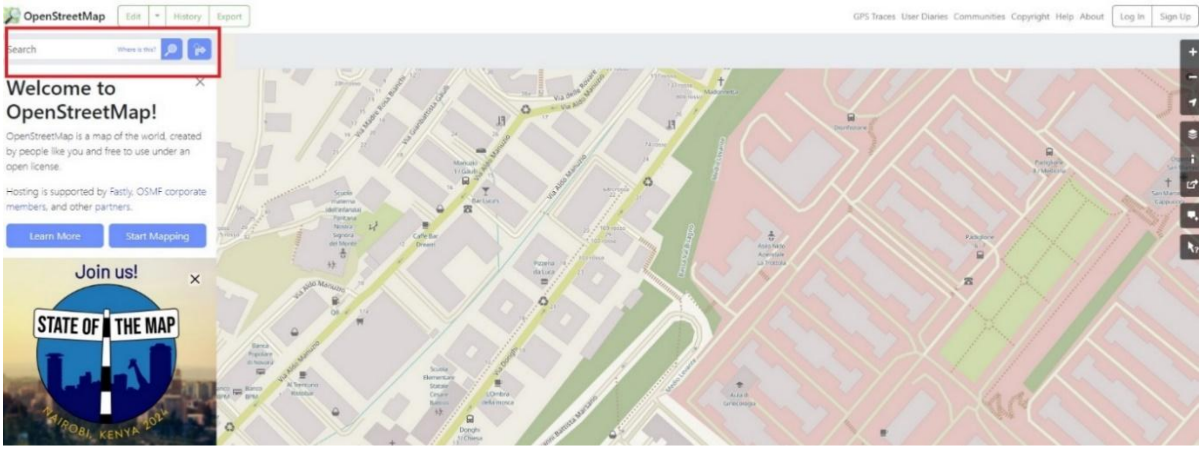

Figure 2. OSM visual interface.

- You can also directly point the cursor on the map at a particular location or building and then right click on it. In both cases when you have a building of interest or area of interest, right click on the location and a popup window appears. You can select the option "Query features" from the list (Figure 3).

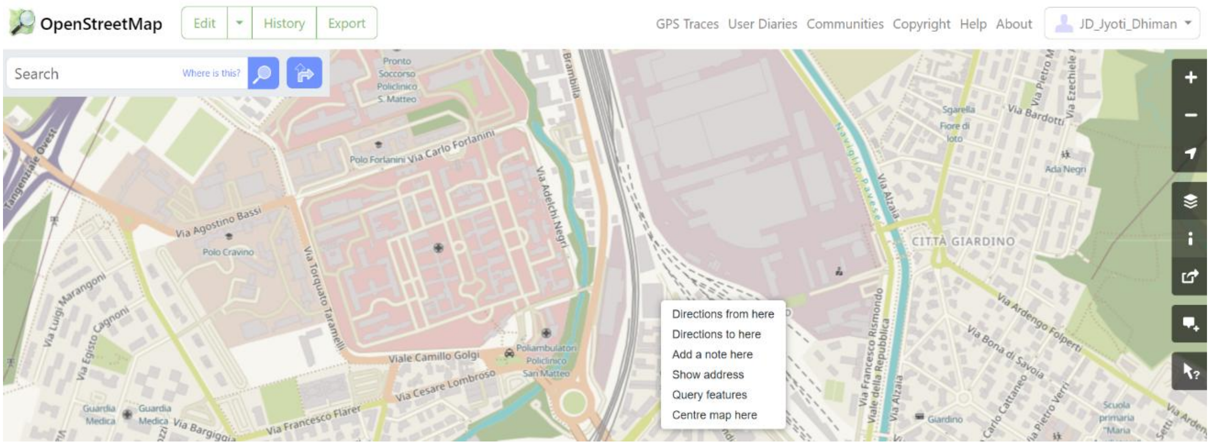

Figure 3. OSM right-click popup window.

- Once you select "Query features", on the left side you get the list of all the features available near the point where you right clicked on the map (Figure 4). When you hover with the cursor over the items of this list, it highlights the feature which it represents. You can just click on the feature whose information you want. In our case it is Building "Polo Tecnologico di Pavia".

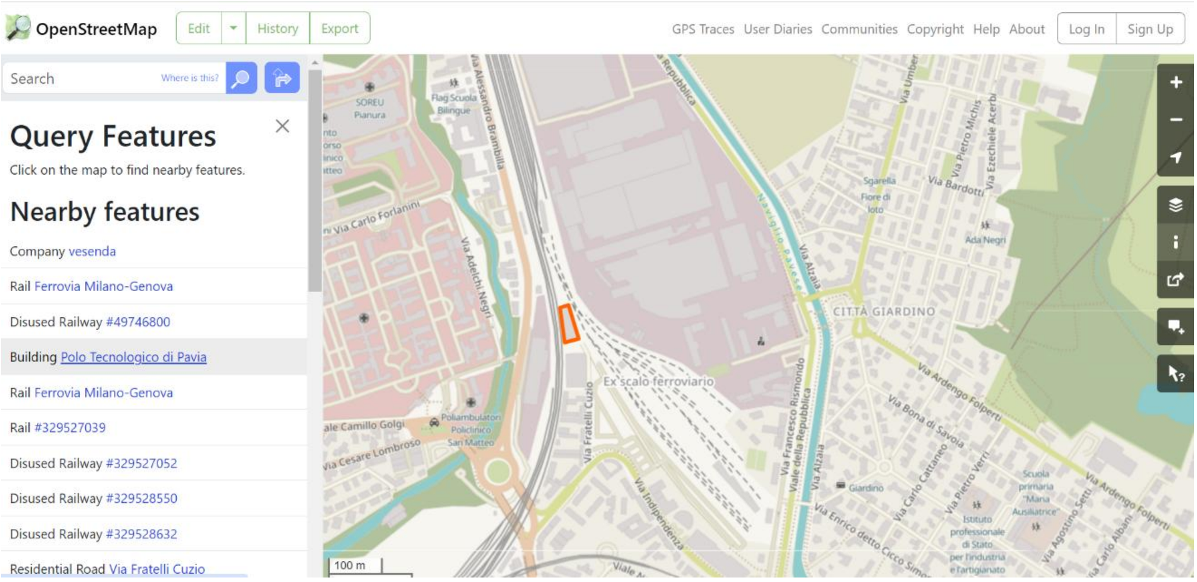

Figure 4. OSM Building features box.

- Once you have done that, information related to the building like its ID, address, postal code, etc., can be found (Figure 5).

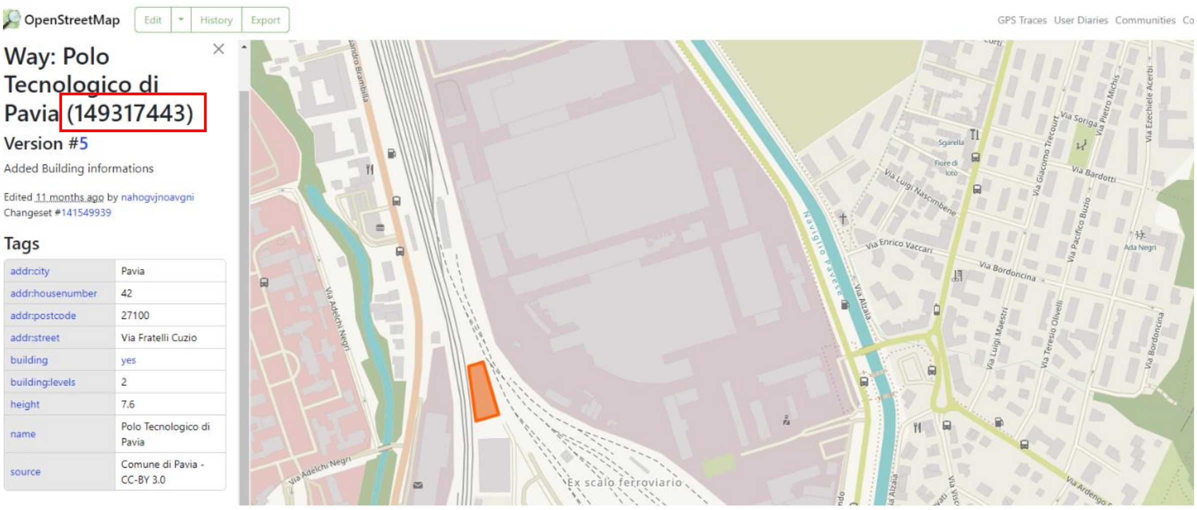

Figure 5. OSM Building information with ID.

The Building ID is the “149317443” (in the red square in Figure 5) that you can copy from here and add it in the “Building ID (From OSM)” column in this template file. This ID will help to link the building geometry with the building properties information in the Excel file (Figure 6).

Minimum - mandatory						
#	Country	Building ID (From OSM)	Building's type	Year of construction	Height	Number of floors
			Residential/offices/healthcare/others...	year	m	number
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Figure 6. Excel file template for buildings' data collection.

To verify the ID on OSM, go to this link Way: Polo Tecnologico di Pavia (149317443) | OpenStreetMap, and replace in the URL that ID within the () with the ID you want to test and press enter. This should take you to the corresponding building.

Once you have identified the IDs for all your buildings, you can use this template and provide it to us as a unique mean to collect data for your buildings.

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Technical note. In Open Layers, if you do not explicitly set one, your map is going to use our default which is the Web Mercator projection (EPSG:3857). It is converted into this format in data preprocessing step.

3. I have an IES iCD simulation model

If you have a simulation model created with IES iCD suite, you can directly export the GeoJSON file.

- Open your simulation model with SketchUp Pro software (Figure 7). In the upper toolbar, select Extensions > Import/Export > Export GeoJSON. Before saving, make sure to select from the dropdown menu the .geojson file extension.

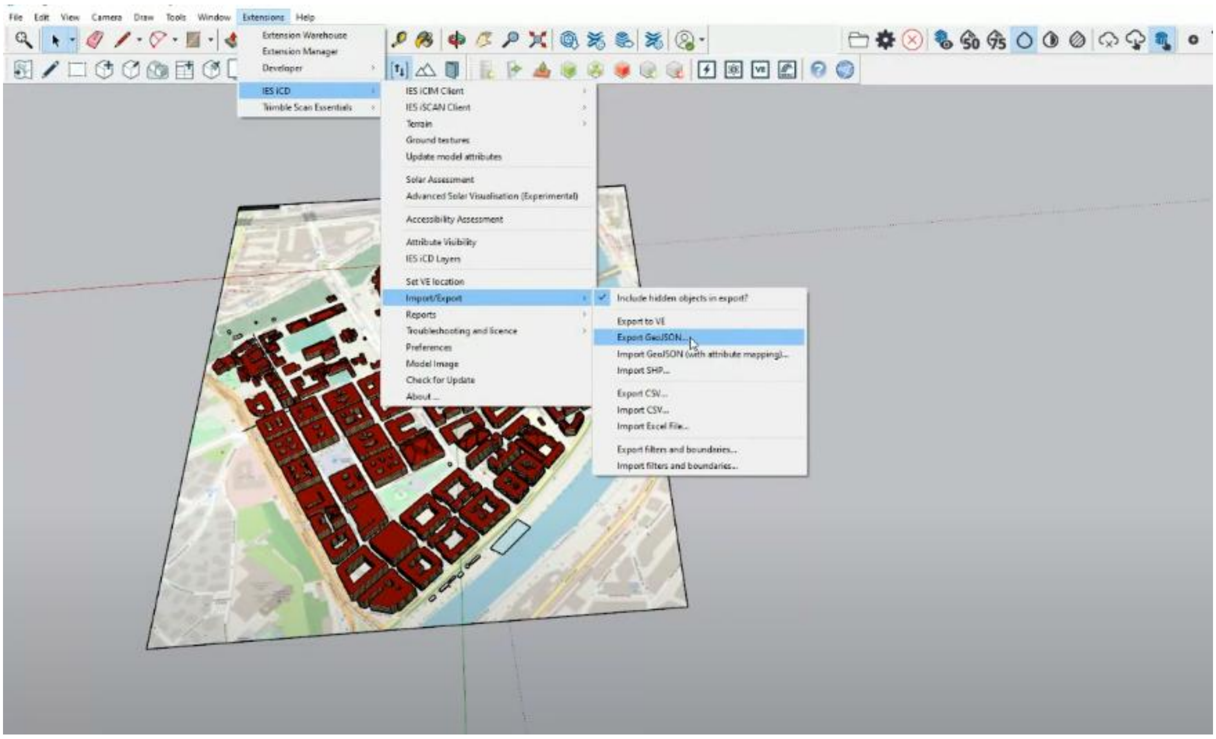

Figure 7. Data export from IES simulation model.

Once you have saved it, you can go to section *1. I have a geometry file*.

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Technical note. In Open Layers, if you do not explicitly set one, your map is going to use our default which is the Web Mercator projection (EPSG:3857). It is converted into this format in data preprocessing step.

Guideline for uploading GeoJSON files into the tool

File Source: IES software

1. The tool supports GeoJSON files exported from the **IES** model. To upload a GeoJSON file, simply click the "**Upload File**" button.
2. Upon clicking the upload button, you'll be prompted to browse your local device and select the appropriate file.
3. Once uploaded, the tool **automatically** processes the data, performs calculations, and creates a new layer on top of the existing layers.
4. Depending on the file size, processing may take a few seconds. During this time, a loading indicator will be displayed, and once the process is complete, the new layer will appear in the layer switcher.
5. You can toggle between the uploaded layer and predefined layers or switch them on or off as needed.

File Source: OpenStreetMap

1. The tool also supports GeoJSON files exported from **OpenStreetMap** using the overpass turbo API.
2. To download the data, follow the provided link to the Overpass page, navigate to the location you want to extract data from, or search for an address. Zoom in until the desired buildings are visible.
3. Once you've pinpointed the area, click the "**Run**" button at the top left corner of the map.
4. After the query runs, click on the "**Export**" button.
5. When prompted to choose a file format, select "GeoJSON" for download.
6. To upload the exported GeoJSON file, click the "**Upload File**" button in the tool.
7. You'll be prompted to browse your local device to select the file for upload.
8. Once uploaded, the tool **automatically** handles data preprocessing and performs all necessary calculations, then adds the new layer on top of the existing layers.
9. Processing may take a few seconds based on the file size. During this time, a loading indicator will be shown, and the layer will appear in the layer switcher once complete.
10. You can easily toggle between the uploaded layer and predefined layers or switch them on and off as required.

Methodological document for calculating energy and social vulnerability based on the methodology integrated in the EP-0 tool.

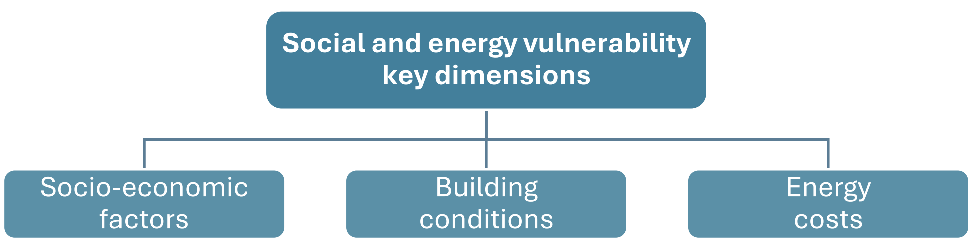
The tool is built on a **methodology based on scientific literature**[1], developed to **map social and energy vulnerability at the census section level**. This assessment utilizes and combines various indicators based on the guidelines of the Energy Poverty Advisory Hub (EPAH), **focusing on the three key dimensions of vulnerability**. Vulnerability is mapped at the census section level, using **public data**, along with potential statistical assumptions and additional contributions from the involved entities.

This approach seeks to establish a scalable and replicable methodology, minimizing the need for case-by-case surveys, which are time-consuming, resource-intensive, and raise significant concerns regarding sensitive data collection and the psychological impact on residents. Instead, it leverages large statistical databases to support district-scale assessments.

Step 1: data collection and calculation of single indicators

The first step is to gather and calculate relevant indicators for each census or chosen unit. The indicators are divided into three main dimensions of vulnerability:

1. **socio-economic factors**
2. **building conditions**
3. **energy costs**.



1.1 Collect data for each selected indicator

- Use publicly available datasets, such as **census data from statistical national institutes, income tax reports data, national household energy consumption data**, or other public

[1] *Terés-Zubiaga, J., González-Pino, I., Álvarez-González, I., Campos-Celador, Á., 2023. Multidimensional procedure for mapping and monitoring urban energy vulnerability at regional level using public data: Proposal and implementation into a case study in Spain. Sustainable Cities and Society (89). https://doi.org/10.1016/j.scs.2022.104301

sources you might find accessible in your country. For Italy, ISTAT census data and IRPEF reports have been used.
- Ensure data is available at the **census section** level (or at the available administrative unit that you consider appropriate for statistical purposes in your country).
- If direct data is unavailable, you might consider using **statistical estimates** based on regional trends or data enrichment based on municipal sources.

1.2 Calculate the following indicators for each census section

The selected indicators are the followings, however, you might consider adapting this selection to the data available in our country or most suitable for your specific context.

DIMENSION	PARAMETER	INDICATOR	DESCRIPTION
SOCIO-ECONOMIC FACTORS	**Income**	Average household income	Income per household in the census section
	Vulnerable population by age	% of people aged >65 or <5	Percentage of elderly and young children in the population
	Unemployment rate	% unemployed (aged 15-64)	Share of unemployed residents aged 15-64
	Rented households	% of rented households	Proportion of households living in rented accommodations
	Education level	% without high school diploma	Share of residents without a secondary education diploma
	Foreign population	% foreign-born and stateless population	Proportion of residents who are foreign nationals
BUILDING CONDITIONS	**State of conservation**	% of buildings in poor condition	Share of buildings classified as "in poor conservation state"
	Building age	% of buildings built before selected year	Proportion of buildings constructed before national energy efficiency regulations
ENERGY COSTS	**Energy expenditure**	Energy cost-to-income ratio	Ratio of household energy spending to income

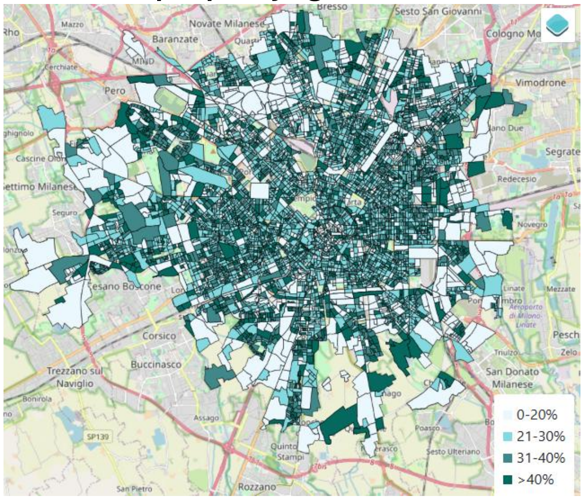
Step 2: mapping single indicators using GIS files

Once the single indicators are calculated for each census section/unit:

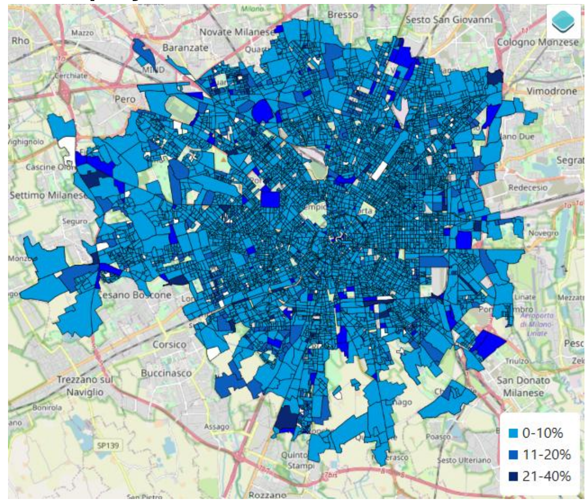
1. **Create a spatial database** with census section/units boundaries using **shapefiles (.shp) or GeoJSON files**.
2. **Overlay the indicators result** onto the map using GIS software (e.g., QGIS, ArcGIS).
3. Each indicator is linked to the corresponding census section, allowing visualization of **spatial patterns of vulnerability**.

The pictures below showcase an example performed on some indicators for the City of Milan (Italy).

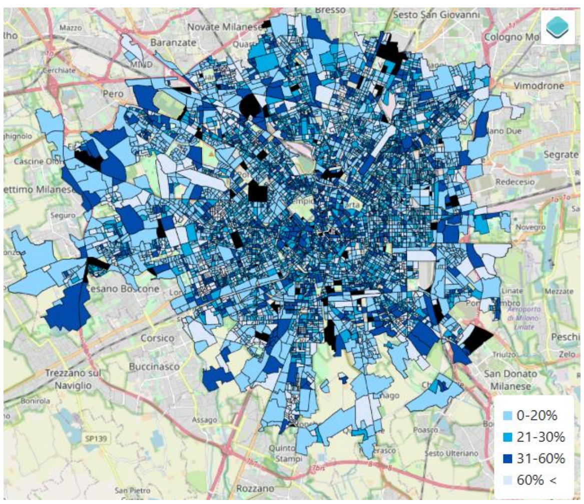
Vulnerable people by age



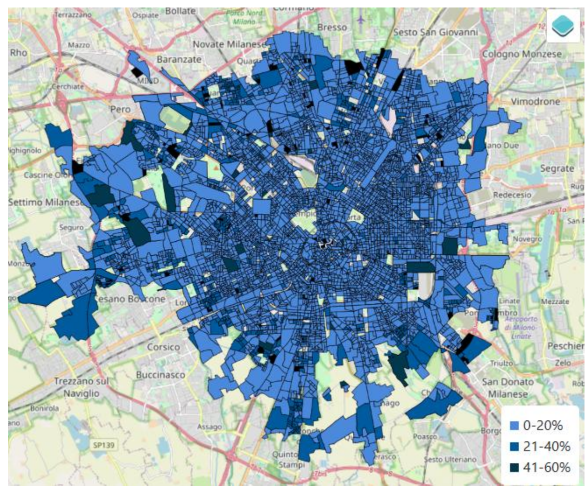
Unemployment rate



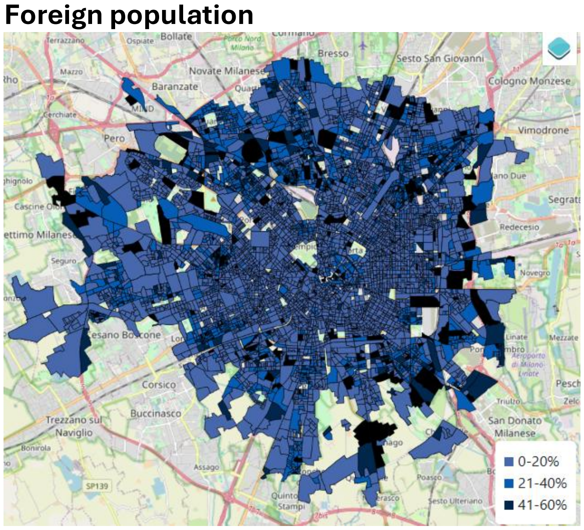
Rented households



Education level



Foreign population



Step 3: define vulnerability thresholds

To classify census sections into different levels of vulnerability, set **threshold values** for each indicator based on the **regional average**. The proposed thresholds are the followings, but you can consider adapting them with context-specific evaluations.

INDICATOR	VULNERABILITY THRESHOLD
INCOME	≤ **0.5** of the regional average household income
VULNERABLE POPULATION BY AGE	≥ **1.5** of the regional average
UNEMPLOYMENT RATE	≥ **1.5** of the regional average
RENTED HOUSEHOLDS	≥ **1.5** of the regional average
EDUCATION LEVEL	≥ **1.5** of the regional average
FOREIGN POPULATION	≥ **1.5** of the regional average
STATE OF CONSERVATION	≥ **1.5** of the regional average
BUILDING AGE	≥ **1.5** of the regional average
ENERGY EXPENDITURE	≥ **10%**

Why define thresholds based on the regional average?

- Different regions (e.g., Northern vs. Southern Italy) have different socio-economic conditions.
- The approach ensures **contextual relevance** rather than using a fixed national standard.

Step 4: assign preliminary vulnerability levels for each dimension

For each census section, assign **preliminary vulnerability levels (L1 or L2)** based on indicator thresholds. You might consider changing the logics behind these levels with specific contextual-based insights. The following ones were used for the City of Milan.

1. **Socio-economic factors**
    - **L1 (Moderate)**: if income is below the threshold **OR** the percentage of vulnerable individuals is above the threshold.
    - **L2 (High)**: if both income is below the threshold **AND** the percentage of vulnerable individuals is above the threshold.
    - **Else**: No vulnerability assigned.
2. **Building conditions**
    - **L1 (Moderate)**: if the percentage of old buildings exceeds the threshold.
    - **L2 (High)**: if the percentage of buildings in poor condition exceeds the threshold.
    - **L2 (High)**: if both the percentage of old buildings **AND** poor-condition buildings exceed the threshold.
    - **Else**: No vulnerability assigned.
3. **Energy cost**
    - **L2 (High)**: if the household energy cost burden exceeds **10% of income**.
    - **Else**: No vulnerability assigned.

In summary:

CATEGORY	CONDITION	VULNERABILITY LEVEL	COLOR CODE
SOCIO-ECONOMIC FACTORS	**If** Income ≤ Threshold ≥ Threshold	**L1 (Moderate Vulnerability)**	**Orange**
	If Vulnerable population by age ≥ Threshold	**L1 (Moderate Vulnerability)**	**Orange**
	If Income ≤ Threshold **AND** Vulnerable population by age ≥ Threshold	**L2 (High Vulnerability)**	**Red**
	Else: L1	**L1 (Moderate Vulnerability)**	**Orange**
BUILDING CONDITIONS	**If** Building age ≥ Threshold	**L1 (Moderate Vulnerability)**	**Orange**
	If State of conservation ≥ Threshold	**L2 (High Vulnerability)**	**Red**
	If State of conservation ≥ Threshold **AND** Building age > Threshold	**L2 (High Vulnerability)**	**Red**
	Else: No condition met	**No Vulnerability Assigned**	**None**
ENERGY COSTS	**If** Energy expenditure ≥ Threshold	**L2 (High Vulnerability)**	**Red**
	Else: Energy expenditure ≤ Threshold	**No Vulnerability Assigned**	**None**

Step 5: compute the Global Vulnerability Index (GVI)

Once preliminary vulnerability levels (**L1 and L2**) are assigned for each dimension, **combine them** to determine the **overall vulnerability classification** for each census section by means of Global Vulnerability Index.

FINAL VULNERABILITY LEVEL	CRITERIA
CRITICAL (RED – SEVERE VULNERABILITY)	If mostly L2 across two or three dimensions
MEDIUM (ORANGE – MODERATE VULNERABILITY)	If a mix of L1 and L2 across one, two or three dimensions
LOW (YELLOW – MILD VULNERABILITY)	If mostly L1 levels across one, two or three dimensions

For example, for the City of Milan the following logics were used:

CRITICAL	L2	L2	L2
	L1	L2	L2
		L2	L2
MEDIUM	L1	L1	L2
		L1	L2
LOW		L1	L1
			L1
			L2

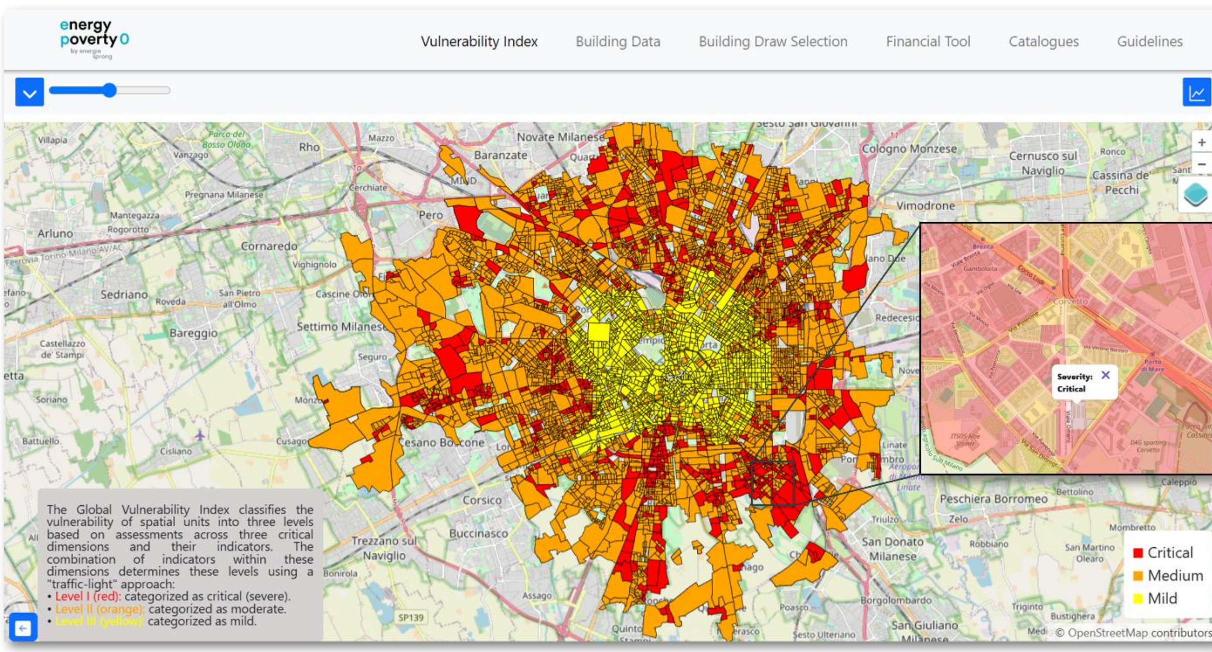
The final classification is visualized on a map using a **traffic light system**:

- **Red (Critical Vulnerability)**
- **Orange (Medium Vulnerability)**
- **Yellow (Low Vulnerability)**

Step 6: map and interpret results

1. **Visualize the final vulnerability index** using GIS applications to produce **spatial maps**.
2. **Identify high-risk areas** (critical/red zones) where intervention is needed.
3. **Compare vulnerability patterns** across census sections to support policy decisions.

The picture below shows the final result in the City of Milan.



Summary of calculation steps

1. **Collect and calculate indicators** from public data sources.
2. **Map indicators** using GIS tools with shapefiles or GeoJSON.
3. **Define vulnerability thresholds** based on the regional average.
4. **Assign preliminary vulnerability levels** for each dimension.
5. **Compute the global vulnerability index** by combining results.
6. **Map and analyze results** to identify priority areas for intervention.

This methodology ensures a **scalable and data-driven approach** to assessing social and energy vulnerability across different regions.

For further inquiries, please contact: info@r2msolution.com