RINNO PROJECT
Report

Transforming energy efficiency in European building stock through technology-enabled deep energy renovation

Deliverable 6.8: Replicability Analysis Report
Work Package 6: Integration, Demonstration, Evaluation & Replication Potential

CIRCE
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Executive Summary

The Replication Feasibility Analysis commenced with a kickoff meeting on May 7, 2023. During this session, the project team presented an initial draft of the methodology, an illustrative example of the planned analysis, a Gantt chart, and an outline of the expected contributions from each participating partner.

At the M42 General Assembly in Paris, the task was officially introduced to the consortium. A dedicated workshop was held to engage the involved partners and facilitate deeper discussion on the task's objectives and approach.

Over the following months data collection was carried out from various open-source geographic portals [1–5]. The team also requested specific datasets from each demonstration leader (EGC, Bouygues, LMH, Nape, and HPHI) and held meetings with technology partners (Ekolab, K-FLEX, PINK, GREENSTRUCT).

In parallel, the initial methodology was progressively refined to accommodate the different data available from the different demos ensuring consistent applicability across different local contexts and technological. A unified calculation tool was developed as a common framework, allowing results to be generated under the same methodological approach.

The calculation phase utilized publicly available data and involved iterative calibration of the tool. After several cycles of refinement, the final results were achieved. The findings indicate substantial opportunities for improving energy efficiency and reducing emissions through replication across similar building stocks. These results offer an evidence-based foundation for policymakers and stakeholders to prioritize investment and design effective policy frameworks to support large-scale adoption of energy-saving measures.

The analysis identified 9.620 replicable buildings, showing strong potential for large- scale adoption of RINNO technologies. Results demonstrate that Primary Energy Savings (PES) and GHG emission reductions substantially exceed project targets under both Conservative and Optimistic scenarios. Even in the most conservative case, PES surpass the target by 85%, while GHG reductions reach 100.000 tCO_2e/year against a target of 39.206 tCO_2e/year. These findings confirm a high replicability potential, provide actionable insights for policymakers and stakeholders, and represent a significant step toward scaling up energy efficient renovation strategies across Europe.

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CS	Conservative Scenario
GHG	Greenhouse Gas
GIS	Geographic Information Systems
KPI	Key Project Indicators
OS	Optimistic Scenario
PES	Primary Energy Savings
TDPE	Total Delivered Primary Energy

1. Introduction

The present report is a confidential deliverable (Deliverable D6.8 "Replicability Analysis Report") of the RINNO H2020 funded European project (GA 892071).

1.1 Objectives of Deliverable 6.8

The aim of this deliverable is to present the work developed under Task 6.5, in order to evaluate the replication potential of RINNO technology solutions through an assessment based on applications of Geographical Information Systems (GIS).

This evaluation is performed by identifying other buildings similar to the four RINNO demonstrators, located within their respective urban or suburban areas. The replicability is expressed in their impact on Primary Energy Savings (PES) and Greenhouse Gas (GHG) emission reductions. Therefore, this analysis contributes to the evaluation of the following two KPIs:

KPI 1.2: PES triggered by the project after entering markets – full development.

KPI 7.1: Reduction of GHG emissions after entering markets – full development.

Each KPI has their own target. For KPI 1.2, it is expected that the PES triggered by the project after entering markets exceeds 157,6 GWh/year. On the other hand, KPI 7.1 has a target of reducing 39.206t CO2e/year. Thus, it is considered that the project is replicable if such targets are meet or exceeded.

2. Scope

This study focuses on buildings with similar characteristics to those in the demonstration projects, while taking into account that such projects are considerably different between one another in the following ways:

1. Each demonstration site is located in a different country. Therefore, the analysis was carried out within its local national context (Figure 1).
2. Different sets of technologies are being applied in each demonstration project. (Table 1).

Therefore, the aim is not to conduct a direct comparison, but rather to estimate the potential impact of replicating these technologies within the respective urban or suburban areas of each demo site.

At project level, the contribution of each demo to the overall KPIs is calculated as an overall project result. This, however, should not be understood as a comparative analysis.

Beyond the country-specific focus, additional criteria were used to define the study's scope, including building typology, construction period, and urban or suburban location.

The specific construction periods considered, where determined based on significant shifts in building energy efficiency. Through TABULA database, buildings constructed during periods when energy efficiency improved significantly were excluded, as they were considered less relevant for RINNO's solutions [6]. The selected construction period limits are as follows:

- Denmark and France: Up to 1979
- Poland: Up to 1989
- Greece: Up to 2010

GIS were utilized to map and identify potential replication sites, ensuring a data-driven approach to assessing the feasibility of implementing RINNO solutions.

The analysis specifically targets building segments exhibiting notably poor energy efficiency, given that these structures present the greatest opportunities for improvement. This focused approach naturally results in higher estimated energy savings per building compared to national averages. However, it can also introduce selection bias and limits straightforward comparisons between countries, since each nation's building stock is unique. Although building typologies were standardized and the tool developed by VTT as part of Deliverable 3.4 (from now on VTT tool), was employed to incorporate national climate data, it is important to recognize that the findings represent careful, context-dependent estimates rather than universally applicable averages [7].

The analysis was not conducted on a national scale; rather, it concentrated on the specific urban or suburban areas (from now on to be referred as regions) within each respective country, determined by the locations of the RINNO demonstration sites. These regions included: Lille Urban Area (France), Slagelse Urban Area (Denmark), Moschato, Tavros and Kallithea (Greece), and Jablonna (Poland). These areas defined the spatial boundaries for identifying comparable buildings using GIS tools, thereby constraining the set of buildings examined for replication potential.

Figure 1 provides a four-panel map overview, illustrating the geographic extent of each region (pink) considered in the study, as well as the location of each demo site (black pin).

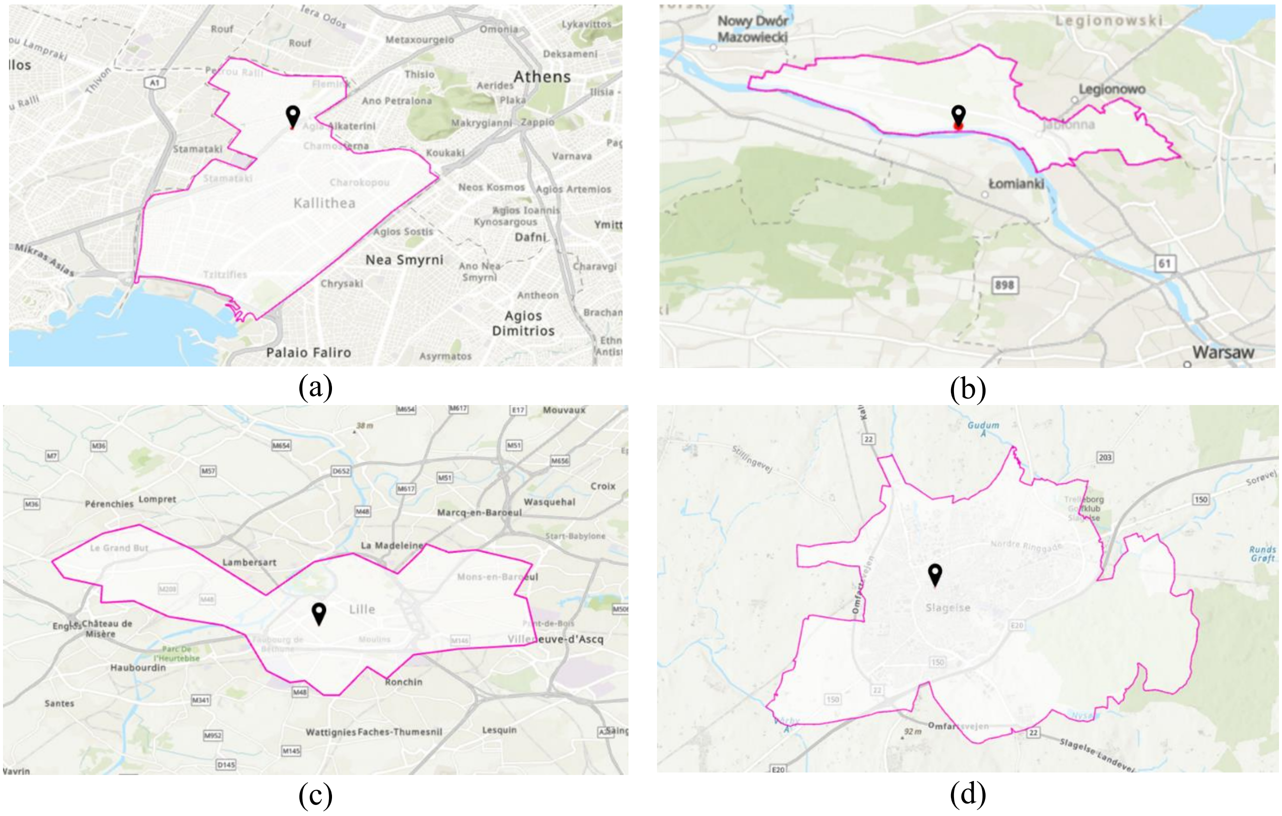

Figure 1. Geographic boundaries of the analysis in each demonstration country. Panel a: Moschato, Tavros y Kallithea (Greece); Panel b: Jablonna (Poland); Panel c: Lille Urban Area (France); Panel d: Slagelse Urban Area (Denmark)

Table 1 presents the technologies applied in each demo building, according to the "Summary of RINNO technology demonstration in all demo-sites" presented in Deliverable 1.5.

Table 1. Renovation Technologies Implemented in Each Demonstration Site

Technologies	Greece	Poland	France	Denmark
Bio-based double layer panels (K- FLEX)	X	X		X
Bio-based pipes and sheets (K- FLEX)		X	X	X
Isocell Cellulose Insulation (EKOLAB)		X		X
Thermochromic glass (GREENSTRUCT)	X			
Building integrated Photovoltaic glass (GREENSTRUCT)	X			
Zappa PV -Roof and -Facade solutions (EKOLAB)		X		X
MicroVent sustainable Ventilation system (EKOLAB)			X	X
K-BOX bio-based insulating system for parts of energy systems (KFLEX)			X	X
De-centralized domestic hot water solution (PINK)*				X

The scope of the analysis is defined through the distinction between an ex-ante and ex-post stage. The ex-ante stage corresponds to the current condition of the building stock, prior to the implementation of any technological solutions. The ex-post stage, on the other hand, represents a hypothetical condition in which the RINNO technological solutions have been deployed (after entering the market). At this stage, the number of replicable buildings is identified. This refers to those sharing similar characteristics with the demonstration sites, as well as building segments showing poor energy performance, since these offer the highest potential for improvement.

Within the ex-post stage, two scenarios have been assessed:

- Optimistic Scenario (OS): All replicable buildings within the demonstration cities are assumed to undergo a complete renovation, thus applying the full package of RINNO technologies implemented in their respective demo cases.
- Conservative Scenario (CS): All replicable buildings within the demonstration cities are assumed to apply only the least effective RINNO technology, reflecting a more modest yet plausible outcome.

The least effective RINNO technology is the one demonstrating the lowest theoretical PES at each demo case. Interestingly, even this minimal intervention results in an improvement over the original state of the buildings (ex-ante).

The CS serves as a lower boundary, a cautious benchmark intended to complement the OS and to define the spectrum of potential energy savings outcomes. In practical terms, the actual impact of RINNO interventions is expected to fall somewhere between these two extremes.

This methodology ensures that all projected impacts are grounded in cautious, realistic assumptions rather than optimistic estimates. Table 2 summarizes the technologies used for assessing the CS.

In some cases, two technologies appear for a single country. This is because both were assigned identical PES contributions within the VTT tool, resulting in the same calculated energy savings [7]. As such, both are considered equally representative of the lower bound of performance for that demonstration case.

Table 2. Lowest-Performing Technologies Used for Conservative Energy Savings Estimation

	Worst Technologies	
France	Bio-based pipes and sheets (K- FLEX)	K-BOX bio-based insulating system for parts of energy systems (KFLEX)
Greece	Building integrated Photovoltaic glass (GREENSTRUCT)	
Poland	Zappa PV -Roof and -façade solutions (EKOLAB)	
Denmark	Bio-based pipes and sheets (K- FLEX)	K-BOX bio-based insulating system for parts of energy systems (KFLEX)

Clarification on the Polish Demonstrator:

Regarding the Polish demonstrator, the renovation works unfortunately did not reach completion within the project's timeframe. Multiple attempts were made, including several tender procedures, but all bids received were way over budget, making it impossible to proceed with awarding a contract.

Despite this, the replicability analysis for the demonstrator was still conducted and is included in this deliverable. The analysis offers meaningful insights regarding the potential for transferring the demonstrator's concept and solutions to its local context, even though the renovation itself was not finalized. Given both the significance of these findings and the effort invested, it was considered appropriate to retain this analysis as part of the overall study.

3. Methodology

The methodology underpinning this work is centred on the creation of a GIS-enabled, Excel-based tool, designed to identify buildings with characteristics similar to those of the RINNO demonstration projects. The intent was to estimate their potential for PES and associated reductions of GHG emissions following the application of RINNO renovation solutions.

In accordance with the task outline, the approach initially drew upon two primary sources of geospatial information:

1. Demo-level data: For each demonstration site, a standardized template was developed to capture essential building attributes, such as year of construction, number of floors, building use type, and geolocation, in a structured, georeferenced format.
2. Urban-level data: In addition to the demo-level information, partners at each demonstration site were tasked with gathering shapefiles and other relevant urban-scale geographic datasets.

While the demo-level template (see Annex 1) was successfully designed and disseminated, subsequent discussions with RINNO solution providers highlighted that many of the attributes specified in the demo-level template were not readily accessible at the urban scale across all four participating countries. The availability, quality, and consistency of urban data varied considerably by region, constraining the broader applicability of the template.

Moreover, it became apparent that several attributes collected through the template had limited or negligible impact on the performance or suitability of the renovation technologies. Consequently, despite its methodological rigor, the detailed demo-level template ultimately offered limited practical value for urban large-scale estimation of energy savings or emissions reductions.

In response to these challenges, the methodology was refined and adapted in the following key ways:

- Only those attributes directly influencing energy performance and technology applicability were retained.
- A flexible data model was adopted, enabling accommodation of variation in urban datasets while preserving the same methodology structure across all countries.
- The final methodology emphasized data that could be systematically extracted from available shapefiles and national databases, supplementing with assumptions or estimation rules as necessary.

The diagram below provides an overview of the overall process, illustrating the main phases and data sources involved in developing and applying the tool.

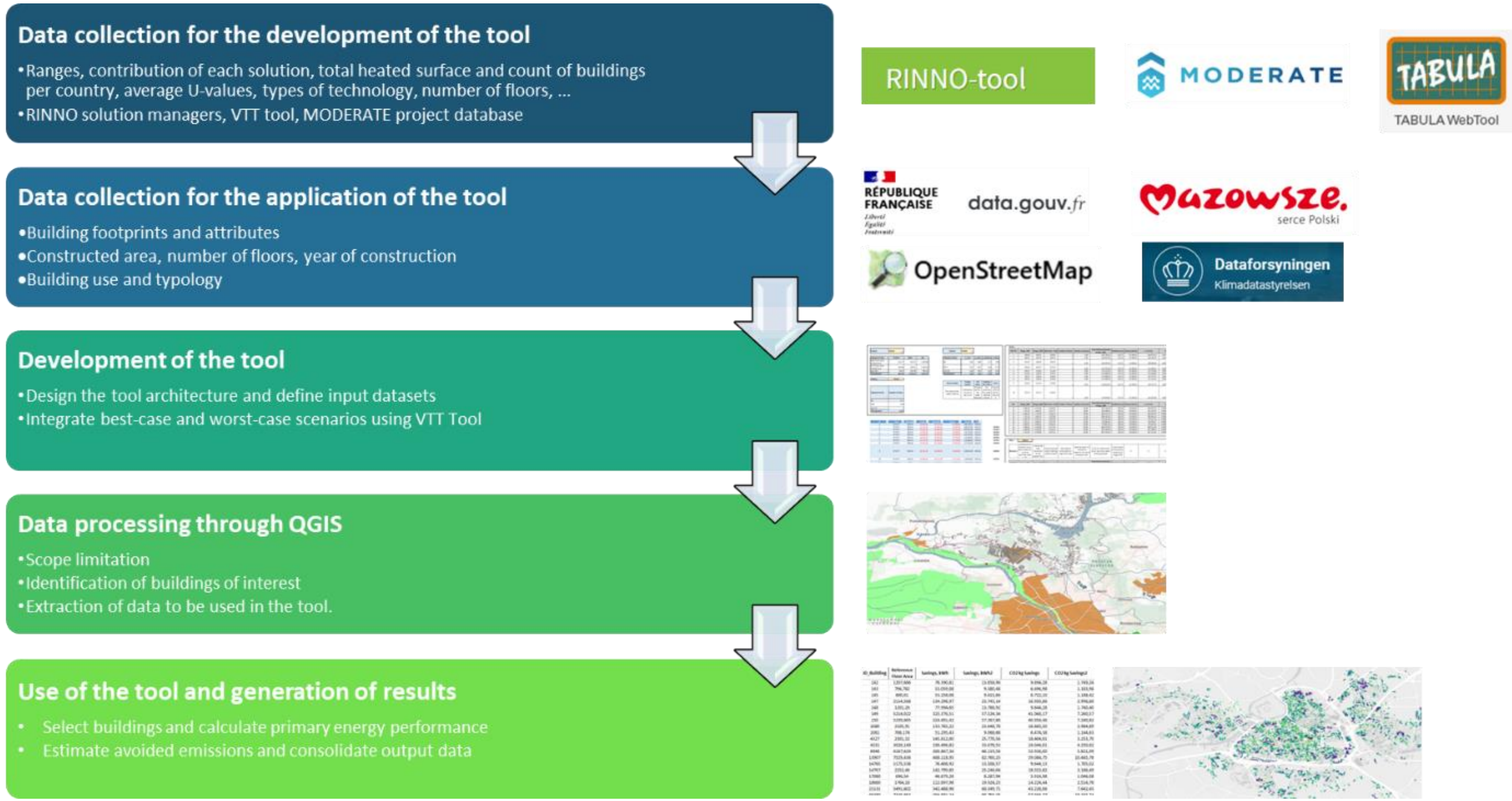

Figure 2. Methodology diagram

3.1. Data collection

As mentioned above, two types of data collection were carried out, one for the development of the tool and the other to feed the tool and obtain the results.

3.1.1. Data collection for the development of the tool

The first step involved gathering information through dedicated meetings with each of the RINNO solution partners to align the contribution of each technology, with the measures listed in the VTT tool [7]. The complete table compiled during these meetings is provided in Annex 2. A summary of the key findings is presented below.

- Bio-based double layer panels (K- FLEX)
  - Insulation of outside walls U-value (W/m2K) after 0,46
  - Insulation of outside walls, best reduction U-value (W/m2K) after 0,25
  - Adding layers of insulation material on top of the base floor
  - Improving heat insulation of the upper floor
- Bio-based pipes and sheets (K- FLEX)
  - Insulating hot water heating system pipes
- Isocell Cellulose Insulation (EKOLAB)
  - Insulation of outside walls U-value (W/m2K) after 0,46
  - Insulation of outside walls, best reduction U-value (W/m2K) after 0,25
  - Adding layers of insulation material on top of the base floor
  - Improving heat insulation of the upper floor
- Thermochromic glass (GREENSTRUCT)
  - Replacement of windows with improved thermal performance (U-value)
  - Replacement of windows with a new type (G-value) (Thermochromic_glass)
- Building integrated Photovoltaic glass (GREENSTRUCT)
  - Installation of pv panels, production target 25%
  - Installation of pv panels, production target 50%
  - Installation of pv panels, production target 75%
  - Installation of pv panels, production target 100%
- Zappa PV -Roof and -Facade solutions (EKOLAB)
  - Installation of pv panels, production target 25%
  - Installation of pv panels, production target 50%
  - Installation of pv panels, production target 75%
  - Installation of pv panels, production target 100%
- MicroVent sustainable Ventilation system (EKOLAB)
  - Heat recovery for the ventilation system
- K-BOX bio-based insulating system for parts of energy systems (KFLEX)
  - Insulating hot water heating system pipes
- De-centralized domestic hot water solution (PINK)
  - Solar collector as an auxiliary hot water system, share target low
  - Solar collector as an auxiliary hot water system, share target high

In preparation for using the VTT tool, additional data were collected from the MODERATE project database, which provided [8]:

Data on total heated surface area and building count were gathered and categorized by building type, single-family houses, multi-family houses, and apartment blocks, as well as by construction period. These datasets were then analysed to determine the minimum, maximum, and average surface areas for each country across different timeframes. The resulting figures provided the foundation for selecting representative reference buildings used in the subsequent analysis.

Table 3. Minimum and maximum surface areas calculated per country and type of building [8]

Area Type	Country	Apartment Blocks	Multi Family House	Single Family House
Min	Denmark	1.010,19	1.091,95	94,00
Max	Denmark	1.949,32	1.553,37	195,61
Min	France	664,33	568,11	114,32
Max	France	1.177,30	885,60	233,65
Min	Greece	294,85	427,11	126,09
Max	Greece	365,72	697,02	136,30
Min	Poland	1.490,33	293,91	194,66
Max	Poland	2.339,89	537,37	231,17

To accurately represent the thermal characteristics of typical buildings, average U-values ($W/m^2 \cdot K$) were collected for primary envelope components, namely roofs, walls, windows, and floors, on a country-by-country basis. These metrics, which fluctuate depending on building typology, directly reflect the prevailing construction standards within each national context. Incorporating this data enables the tool to simulate baseline energy performance with a high degree of realism, establishing a credible reference point prior to any renovation interventions.

Table 4.U-values per country and building element

Country	Building Type	Roof	Walls	Windows	Floor
France	SFH/TH	0,90	0,89	3,05	0,79
France	MFH	0,74	0,69	2,53	0,67
France	AB	1,53	1,28	2,58	0,95
Denmark	SFH/TH	0,40	0,61	2,36	0,45
Denmark	MFH	0,32	0,48	2,23	0,47
Denmark	AB	0,61	0,94	2,46	0,56

Greece	SFH/TH	1,77	1,84	4,51	1,97
Greece	MFH	1,90	1,73	3,88	1,86
Greece	AB	1,33	1,02	3,38	1,75
Poland	SFH/TH	0,66	0,94	2,50	0,94
Poland	MFH	0,52	0,67	1,98	0,73
Poland	AB	0,63	0,86	2,73	1,00

To achieve a more accurate representation of existing buildings, the methodology incorporated a typological breakdown of the primary technologies used in essential systems, such as space heating, cooling, and hot water provision. This approach allows for a more precise reflection of each country's typical energy infrastructure, which is crucial when estimating energy consumption prior to any renovations.

Table 5. Predominant System Types per Country and Building Type

Country	Building Type	Space heating	Cooling system	Hot water	Auxiliary hot water
France	SFH/TH	Old gas boiler, space heating	Old electric chiller or split unit	Old direct electricity	No auxiliary hot water heating system
France	MFH	Old gas boiler, space heating	Old electric chiller or split unit	Old direct electricity	No auxiliary hot water heating system
France	AB	Old gas boiler, space heating	Old electric chiller or split unit	Old direct electricity	No auxiliary hot water heating system
Denmark	SFH/TH	Old gas boiler, space heating	Old electric chiller or split unit	Old district heating, hot water heating	No auxiliary hot water heating system
Denmark	MFH	Old gas boiler, space heating	Old electric chiller or split unit	Old district heating, hot water heating	No auxiliary hot water heating system
Denmark	AB	Old gas boiler, space heating	Old electric chiller or split unit	Old district heating, hot water heating	No auxiliary hot water heating system
Greece	SFH/TH	Old oil boiler, space heating	Old electric chiller or split unit	Old oil boiler, hot water heating	No auxiliary hot water heating system

Greece	MFH	Old oil boiler, space heating	Old electric chiller or split unit	Old oil boiler, hot water heating	No auxiliary hot water heating system
Greece	AB	Old oil boiler, space heating	Old electric chiller or split unit	Old oil boiler, hot water heating	No auxiliary hot water heating system
Poland	SFH/TH	Old coal boiler, space heating	Old electric chiller or split unit	Old gas boiler, hot water heating	No auxiliary hot water heating system
Poland	MFH	Old coal boiler, space heating	Old electric chiller or split unit	Old gas boiler, hot water heating	No auxiliary hot water heating system
Poland	AB	Old coal boiler, space heating	Old electric chiller or split unit	Old gas boiler, hot water heating	No auxiliary hot water heating system

Additionally, to approximate occupancy levels and internal gains, the average number of floors per building was gathered by country and building typology. This information was then used to approximate the total number of dwelling units, which allowed for the scaling of individual energy performance results to represent the broader building stock.

Table 6. Average Number of Floors per Building by Country and Typology

Country	Building Type	Floors
France	SFH/TH	1,60
France	MFH	4,00
France	AB	4,30
Denmark	SFH/TH	1,16
Denmark	MFH	5,25
Denmark	AB	4,26
Greece	SFH/TH	1,00
Greece	MFH	3,20
Greece	AB	4,43
Poland	SFH/TH	2,00
Poland	MFH	5,08
Poland	AB	4,17

Additional data sources included:

- ENTRANZE project: Provided average floor area per capita and estimated the number of flats per building per country.

- Eurostat: Provided fuel consumption breakdowns for heating and hot water, as well as electricity and heat production data by fuel type.
- Emission factors for each fuel type were used to estimate CO_2 emission reductions per kWh saved.

The VTT tool was employed to extract primary energy consumption and savings values for 10 buildings per country. The buildings were selected to ensure a balanced range between the minimum and maximum area values for each typology.

Although data were collected to enable the application of the tool across various building typologies, SFH/TH, MFH and AB. In practice, however, the results focused primarily on AB buildings, as this typology closely matched most of the RINNO demonstration sites and was anticipated to benefit most from the implemented solutions. The only exception was Poland, where the demonstration involved a SFH (according to the local GIS databases). In this case, results were collected and analysed for both AB and SFH typologies, with the latter being not only representative of the demo but also the most common building type in the surrounding area.

3.1.2. Data collection to feed the tool

The tool was populated with data from Shapefile layers, which included:

- Building footprints and attributes
- Constructed area, number of floors, year of construction
- Building use and typology

In cases where only polygon data was available without additional attributes, external sources and estimations were used to infer missing details. These included:

- Using land-use layers to exclude non-residential buildings.
- Determining building type and construction year based on polygon area.

3.2. Development of the tool

The tool is an Excel file with three sheets:

1. Comprehensive Data Sheet: Contains all relevant data.
2. Country-Specific Analysis Sheet: Displays data for a selected country through drop-down menus and three tables. These tables present primary energy consumption for each building in three scenarios:
    a. Before renovation (ex-ante)
    b. After renovation incorporating all RINNO solutions (OS)
    c. After renovation with only the least effective RINNO solution (CS)
3. Shapefile Data Sheet: This sheet is used to export building data and join it with the building geographic layers, for further special analysis and representation.

3.2.1. PES calculation methodology

To estimate delivered energy values, ten intervals were defined between the minimum and maximum building area values. These area values, along with the Total Delivered Primary Energy (kWh) data from the VTT tool, were used to derive the parameters of a linear equation:

$$y = m * x + b$$

Table 7. Linear Regression Parameters for Delivered Energy Estimation

Min Range (m²)	Max Range (m²)	Ref. Floor Area (m²)	Floors	People	Primary energy, kWh	Pendiente (m)	Intersección (b)	y =m*x+b
664,33	715,63	689,98	4	13	171.988	218,17	19.536,29	170.066,96
715,63	766,93	741,28	4	13	180.418	218,17	19.536,29	181.258,06
766,93	818,22	792,57	4	14	191.757	218,17	19.536,29	192.449,16
818,22	869,52	843,87	4	15	203.102	218,17	19.536,29	203.640,25
869,52	920,82	895,17	4	16	214.451	218,17	19.536,29	214.831,35
920,82	972,11	946,46	4	17	225.800	218,17	19.536,29	226.022,45
972,11	1.023,41	997,76	4	18	237.153	218,17	19.536,29	237.213,55
1.023,41	1.074,70	1.049,06	4	19	248.509	218,17	19.536,29	248.404,64
1.074,70	1.126,00	1.100,35	4	20	259.866	218,17	19.536,29	259.595,74
1.126,00	1.177,30	1.151,65	4	21	271.225	218,17	19.536,29	270.786,84

The regression models performed exceptionally well across all examined countries and building types, with R^2 values consistently exceeding 0.99, both pre- and post-renovation. In other words, building floor area accounted for more than 99% of the variation in primary energy consumption within the linear models applied.

3.2.2. GHG Emissions Savings Calculation Methodology

To evaluate the greenhouse gas (GHG) emissions reductions resulting from energy efficiency measures implemented in the RINNO demonstration projects, a systematic multi-stage methodology was established. This methodology incorporates national energy consumption patterns, fuel composition, and CO_2 emission factors, enabling the calculation of country-specific emission intensities, which are then applied to the measured PES.

1. National Energy End-Use Distribution

   For each of the four countries involved—Greece, Poland, France, and Denmark—data regarding the allocation of final energy consumption across various end uses was collected. The categories analyzed include:

   - Space heating
   - Space cooling

- Water heating
- Cooking
- Lighting and electrical appliances
- Other end uses

These data, sourced from Eurostat [9], represent residential sector national averages. The segmentation facilitates the identification of dominant energy services within each national context, thereby supporting more accurate emissions assessments.

2. Fuel Mix for Space and Water Heating

A focused analysis was conducted for space and water heating, as these end uses typically represent the largest shares of residential energy consumption. For both, the distribution of energy consumption by fuel type was determined, again leveraging Eurostat data [9,10]. The fuels examined comprised:

- Solid fossil fuels (including peat, peat products, oil shale, and oil sands)
- Oil and petroleum products
- Natural gas
- Electricity
- Renewables and biofuels
- Heat (e.g., district heating)

The percentage contribution of each fuel to the overall energy demand enabled the derivation of weighted-average emission factors for each country.

3. Emission Factors and Unit Conversion

Standardized emission factors, expressed in grams of CO_2 per gigajoule (g CO_2/GJ), were gathered from the IPCC covering the principal fuels utilized [11]:

- Natural gas
- Oil and petroleum products (e.g., gasoil)
- Electricity
- Other bituminous coal
- Lignite

To ensure compatibility with energy consumption data and inter-metric comparability, all emission factors were converted to kilograms of CO_2 per kilowatt-hour (kg CO_2/kWh) using established energy unit conversions.

National electricity emission intensities were determined using country-specific grid averages, ensuring that reported values accurately represent each nation's predominant energy sources. These figures were sourced from Eurostat's "Production of electricity and derived heat by type of fuel" database[10], which details the fuel mix underlying national electricity and heat generation. As a result, emission factors for electricity vary considerably between countries. For instance, France, which relies heavily on nuclear power, reports a relatively low emission factor. In contrast, Poland's dependence on coal results in a much higher value.

This method, which relies on annual averages, ensures consistency and facilitates meaningful comparisons across countries. Still, it doesn't account for short-term fluctuations in grid intensity, think seasonal swings or hourly ups and downs. As a result, the avoided emissions reported here should be viewed as long-term average figures, not as precise reflections of moment to moment changes.

4. Calculation of Avoided Emissions

Applying the country-specific fuel mix percentages and corresponding emission factors, a weighted-average emission factor was computed for both space and water heating. These averages were then used to estimate the CO_2 emissions reductions attributable to the RINNO interventions. The final estimation followed this formula:

Avoided CO_2 (kg) = Average Emission Factor (kg CO_2/kWh) × Primary Energy Saved (kWh)

This process was conducted individually for each country, ensuring that results reflect both the specific national energy context and the actual performance of the renovation interventions. The emission factors ultimately used in the GHG reduction estimations are as follows:

- Denmark: 0,14 kg CO_2/kWh
- France: 0,13 kg CO_2/kWh
- Greece: 0,27 kg CO_2/kWh
- Poland: 0,50 kg CO_2/kWh.

3.3. Classification of Energy and Emissions Ranges

To facilitate interpretation of the PES and GHG emission reductions outputs, both indicators were segmented into seven classification ranges. These ranges allow for clear scale comparison and visual analysis of buildings' ex-post performance across the four demo regions. Again, since these regions have such different local contexts, the idea is not to compare the results from one another but rather to have a visual understanding of the different scale of PES and GHG reductions within the context of the project.

The classification system was designed to streamline the representation of energy and emissions data by transforming continuous values into structured, categories. This approach enhances the tool's usability, making it easier to identify performance patterns across different countries. It also supports visual analysis and data-driven decision-making by enabling clear differentiation between buildings with higher and lower energy and emissions levels. This is a step forward from the building scale units used mostly in technical environments (kWh/m2.y), to a more city scale useful decision making units (kWh/building).

The classification thresholds were based on a single dataset encompassing all four case studies (Denmark, France, Greece, and Poland), containing over 7.700 data points in total. This dataset was analysed to extract key descriptive statistics including minimum, maximum, mean, standard deviation, and variance for both energy (kWh) and CO_2 emissions.

Given that both datasets exhibit right-skewed distributions (with long upper tails), a logarithmic scaling approach was adopted to define the range thresholds. The following steps summarize the process used to generate the classification thresholds:

1. Review of Descriptive Statistics:

   Maximum and minimum values, alongside the average and standard deviation, were used as reference points.

2. Definition of Base Units

   Starting points (e.g., 100 kWh and 10 kg CO_2) were selected to ensure that the minimum values fell within the first interval.

3. Logarithmic Scaling

   Ranges were incremented based on multiplicative factors (approx. ×5 to ×10) to create increasing intervals that accommodate data dispersion.

4. Alignment Across Variables:

   Both kWh and CO_2 ranges were defined using parallel structures to simplify joint interpretation.

5. Validation

   Final ranges were verified to ensure they captured the complete span of values observed in the tool and provided meaningful differentiation between building performance levels.

The final classification ranges are presented in Table 8, showing the specific thresholds for both energy (kWh) and CO_2 emissions (kg) at each level. These thresholds are project-specific and were derived directly from the distribution of more than 7,700 data points across the four case-study countries. They are not benchmarked against EU or ISO standards; instead, they provide a data-driven framework designed to enable consistent comparison of building performance across scenarios within the RINNO project.

Table 8. Classification Thresholds for Energy and CO_2 Emissions

Level	Energy (kWh)	Emissions (CO2, kg)
1	100	10
2	10.000	1.000
3	50.000	10.000
4	100.000	50.000
5	500.000	100.000
6	1.000.000	500.000
7	2.000.000	1.000.000

These thresholds have been applied to the maps presented in the Results section of this deliverable.

4. Results analysis and discussion

This section presents the replication potential assessment of the RINNO technology solutions in both, the optimistic and conservative scenarios, at the ex-post hypothetical stage. The results are shown for the 4 demo regions: Lille Urban Area (France), Slagelse Urban Area (Denmark), Moschato, Tavros and Kallithea (Greece), and Jablonna (Poland).

As a result, Table 9 shows there are 9.620 replicable buildings between all 4 demo regions which correspond to more than 9 million square meters of replicable floor area. The region of Jablonna in Poland represents the highest contribution of replicable buildings, with 36% of the total, followed by Moschato, Tavros and Kallithea, in Greece, Lille in France and Slagelse, Denmark, with 30, 24 and 9,7 percent, respectively.

Table 9. Replicable buildings and floor area

Demo region	No. of replicable buildings	Replicable floor area (m2)	Contribution to the project in No. of buildings
Lille - France	2.288	6.847.891,12	24%
Moschato, Tavros and Kallithea - Greece	2.921	446.444,10	30%
Slagelse - Denmark	934	734.979,00	9,7%
Jablonna - Poland	3.477	1.025.524,03	36%
TOTAL	**9.620**	**9.054.838**	**100%**

The difference between the highest and lowest percentages of contribution between the different demo regions, reflects just how divers the demo regions are. The Polish region of Jablonna is a low density (almost rural) but very wide area where most buildings have the same typology as the demo. In contrast, the Danish region is a much smaller area, were mostly the city centre buildings resemble the project demonstrator. Instead, the French and Greek regions show more urban concentrated areas.

4.1. Primary Energy Savings

In order to analyse the replicability analysis, it is necessary to take into account the European directive on the energy performance of buildings (EU-2024/1275), which sets targets for all Member States. About the residential building stock in particular, the directive sets the goal to reduce the primary energy use (kWh/m2.y) by at least 16 % compared to 2020 by 2030 [12]. Even though reaching this target is out of the scope of the project, it does constitute a useful point of reference for understanding the obtained results.

4.1.1. Optimistic scenario PES results

The following table shows the ex-ante Total Delivered Primary Energy (TDPE), as well as the hypothetical TDPE under the ex-post optimistic scenario, which assumes that all replicable buildings would undergo a complete renovation, thus applying the full package of RINNO technologies as applied in their respective demonstrator. It also shows the PES by square meters.

Table 10. OS. PES reductions by sqm

City	Total Delivered Primary Energy		PES/m2	
	Ex-ante kWh/(m2.y)	Ex-post kWh/(m2.y)	kWh/(m2.y)	% Savings
Lille. France	532.647	384.844	147.803	**28%**
Moschato-Tavros Greece	1.165.774	583.538	582.236	**50%**
Slagelse. Denmark	274.803	79.100	195.702	**71%**
Jablonna. Poland	1.755.134	715.465	1.039.668	**59%**

Since all 4 demo regions are considerably different between one another, the analysis is not based on PES/m² values, which would imply a direct comparison between regions. Instead, it focuses on the percentage of savings relative to each region's own ex-ante starting point. In this sense, although Jablonna shows the highest PES per square meter, Slagelse achieves the best results under the optimistic scenario, as it shows the greatest improvement compared to its ex-ante situation.

The percentage of savings go from 28 to 71 percent, coming from the French and Danish regions, respectively. In the case of Slagelse, this could be the result of applying 7 out of the 9 available RINNO technologies (Table 1) to all 934 replicable buildings. Still, under this scenario, all 4 demo regions show excellent results which would make it very easy for them to overcome the 16% target set by the EU directive. The timing to reach such achievements, however, would depend on a great variety of economic, social, political and implementation factors, which are unique for the local context of each region and out of the scope of the study.

Regarding the primary energy savings KPI (Table 11), this scenario results show that the project's impact after entering the market would significantly exceed its 157,6 GWh/year goal. In fact, 2 out of the 4 demo regions could exceed the target by themselves (Lille and Jablonna). The contributions to the total 935,9 GWh of PES per year vary from the 46% of Lille and the 9% of Moschato-Tavros.

Table 11. OS. PES reductions by region

City	Total PES per demo región [GWh/y]
Lille. France	431,2
Moschato-Tavros Greece	88,2
Slagelse. Denmark	115,0
Jablonna. Poland	301,6
Total	**935,9**

Nevertheless, this overachievement is the result of a very ambitious scenario, which is possible from a technical point of view, but unlikely in reality when considering the real-life challenges typically observed in renovation projects. From finding the means to carry out the works (investors, subsidies, owners, tenants, payments, etc), to the continuous decision making processes within the community.

4.1.2. Conservative scenario PES results

The following table shows the ex-ante Total Delivered Primary Energy (TDPE), as well as the hypothetical TDPE under the ex-post conservative scenario, which assumes that all replicable buildings would only apply only the least effective RINNO technology from their respective demonstrator. It also shows the PES by square meters triggered by this renovation.

Table 12. CS. PES reductions by sqm

City	Total Delivered Primary Energy		PES/m2	
	Ex-ante kWh/(m2.y)	Ex-post kWh/(m2.y)	kWh/(m2.y)	% Savings
Lille. France	532.647	506.517	26.130	**5%**
Moschato-Tavros Greece	1.165.774	973.000	192.775	**17%**
Slagelse. Denmark	274.803	271.867	2.936	**1%**
Jablonna. Poland	1.755.134	1.141.729	613.404	**35%**

Since all 4 demo regions are considerably different between one another, the analysis is not based on PES/m² values, which would imply a direct comparison between regions. Instead, it focuses on the percentage of savings relative to each region's own ex-ante starting point. In this case though, Jablonna shows both, the highest PES per square meter, as well as the greatest improvement compared to its own ex-ante situation with a 35% savings. Moschato-Tavros in Greece, follows with 17%, and Lille and Slagelse result in a 5 and 1% respectively.

Under this scenario, only Jablonna and Moschato-Tavros would reach and overcome the 16% target set by the EU directive. Lille and Slagelse on the other hand, would contribute to the goal but significant additional efforts should be done still, to achieve such target, thus intervening more buildings or implementing more technology solutions.

For the purpose of this study, both the most optimistic and the most conservative scenarios were considered. As mentioned in the Scope section, this approach allows to establish upper and lower boundaries of impact. In practical terms, the actual effect of RINNO interventions is expected to fall between these two extremes. However, if only one technology were to be implemented, a prior feasibility study is recommended. This would help identify the most impactful technology solution and ensure that efforts are directed in the most efficient way.

Regarding the primary energy savings KPI (Table 13), this scenario results also show that the project's impact after entering the market would exceed its 157,6 GWh/year goal. Jablonna alone contributes to more than 60% of the goal, while the other 3 regions combined contribute to around 40% of the 285 GWh/y of PES per year.

Table 13. CS. PES reductions by region

City	Total PES per demo región [GWh/y]
Lille. France	76
Moschato-Tavros Greece	29
Slagelse. Denmark	2
Jablonna. Poland	178
Total	**285**

It is important to note that even under the most conservative scenario, the project KPI 1.2. is exceeded. Since this represents a more realistic scenario, a map of each replication region is provided, showing the potential PES, while applying the classification of energy presented in section 3.3. Each map includes a region-wide view along with a zoom into the surroundings of the project's demonstrator building, which is marked with a black pin and circle.

Even though these 4 replicable areas have mayor structural differences between each other, using the same scale and symbology for all of theme, allows for a comprehensive understanding of the potential of PES in all the regions. Also, these maps deliver information on the local context, like the density of urban fabric and their distribution within the region of analysis, as well as the surrounding areas and replicable buildings near the demonstrator building of the project.

The maps show the distribution of Primary Energy Savings (PES) ranges within each replicable area. In the French, Greek, and Polish areas, most buildings fall within similar PES intervals, ranging from approximately 101 GWh/year to 1.000.000 GWh/year. In contrast, the Danish replicable area shows PES values concentrated in the lowest range, between 0 and 100.000 GWh/year. This difference reflects the smaller building stock and lower overall energy savings potential in Denmark compared to the other locations.

This visualization is a step forward from the building scale units used mostly in technical environments (kWh/m2.y), to a more city scale useful decision making units (kWh/building).

To estimate renovation investment costs under both scenarios, project leaders were asked to provide implementation costs for each RINNO technology, expressed in euros per square meter. This approach differs from Deliverable D7.3, where costs appear in various units depending on the specific technology or measure. For this analysis, a standardized cost per square meter was necessary to apply calculations across the total area of replicable buildings.

Based on the collected data, deploying the Optimistic Scenario (OS) across all suitable buildings would entail a total investment of at least €2.5 billion, assuming the full suite of RINNO technologies is implemented in each demonstration site. The more restrained Conservative Scenario (CS) carries an estimated cost of approximately €800 million. Both estimates encompass roughly 90% of the replicable building stock, which amounts to 8.686 buildings.

Is worth mentioning that these figures are indicative estimates. The costs cover both the technologies themselves and their implementation, but installation expenses can vary substantially across countries, particularly with respect to labor costs. Furthermore, the actual timeline for implementation remains highly uncertain, influenced by economic, social, political, and logistical factors unique to each local

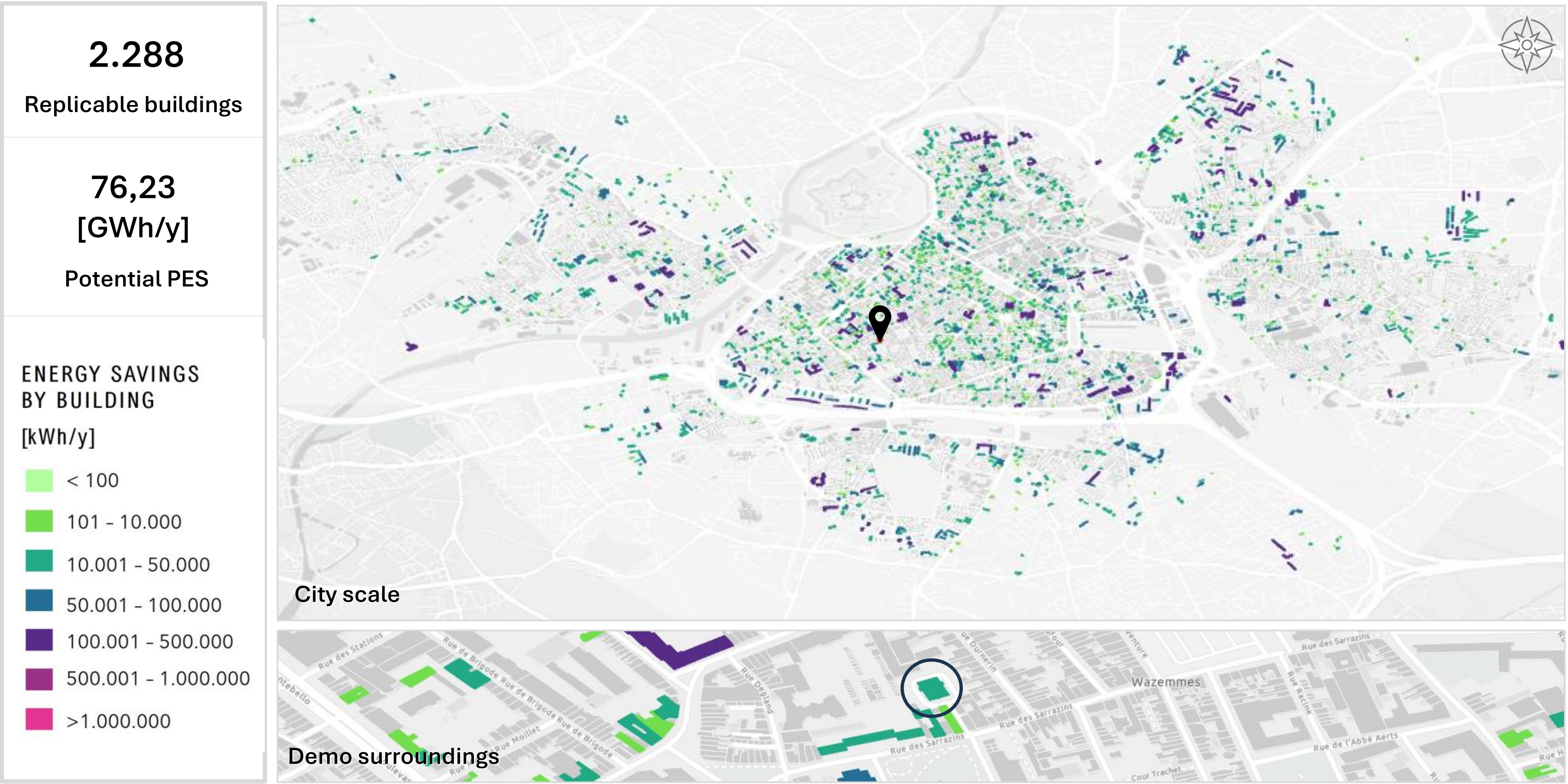

Figure 3. Lille-France PES under CS

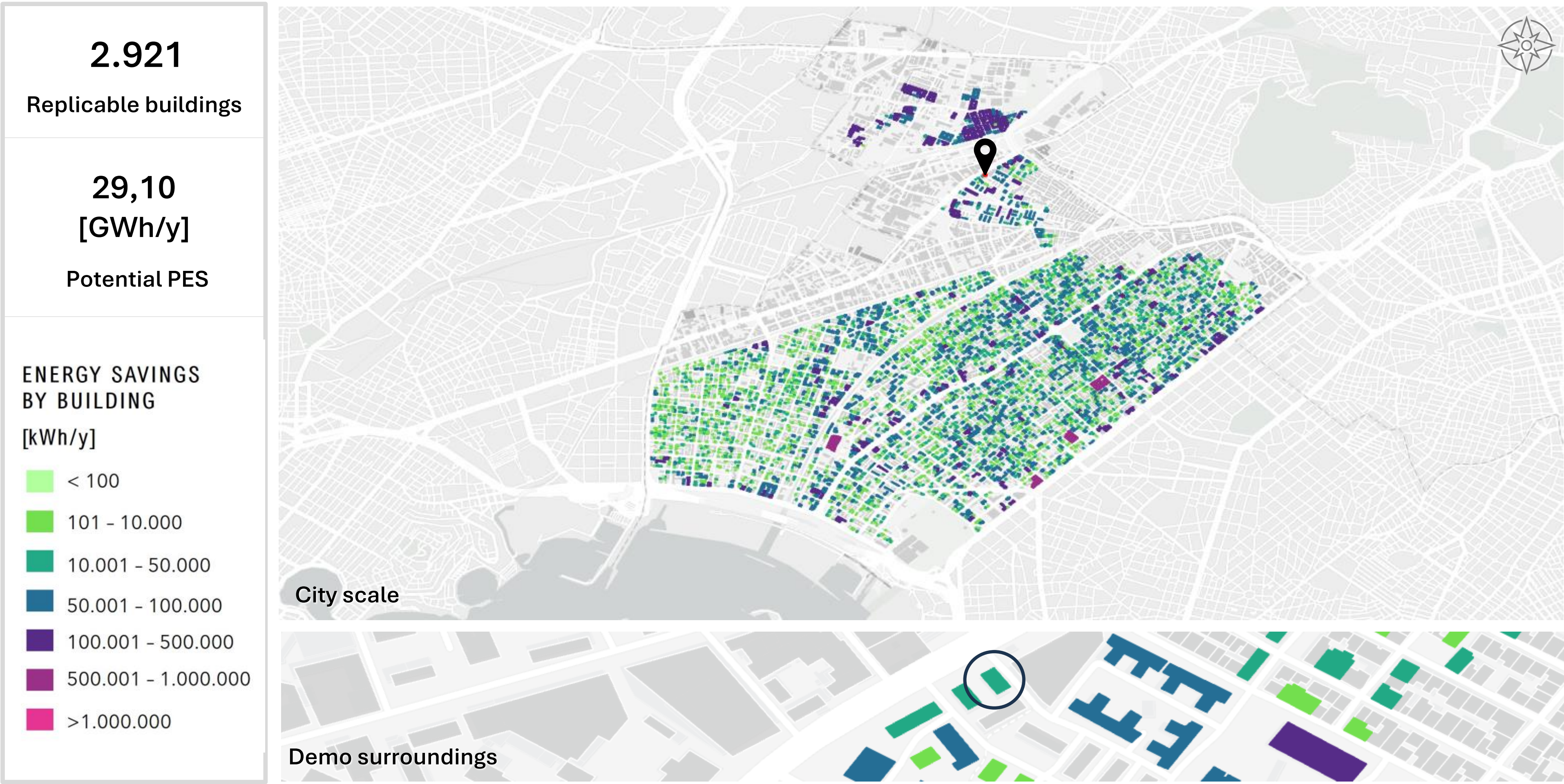

Figure 4. Moschato Tavros-Greece PES under CS

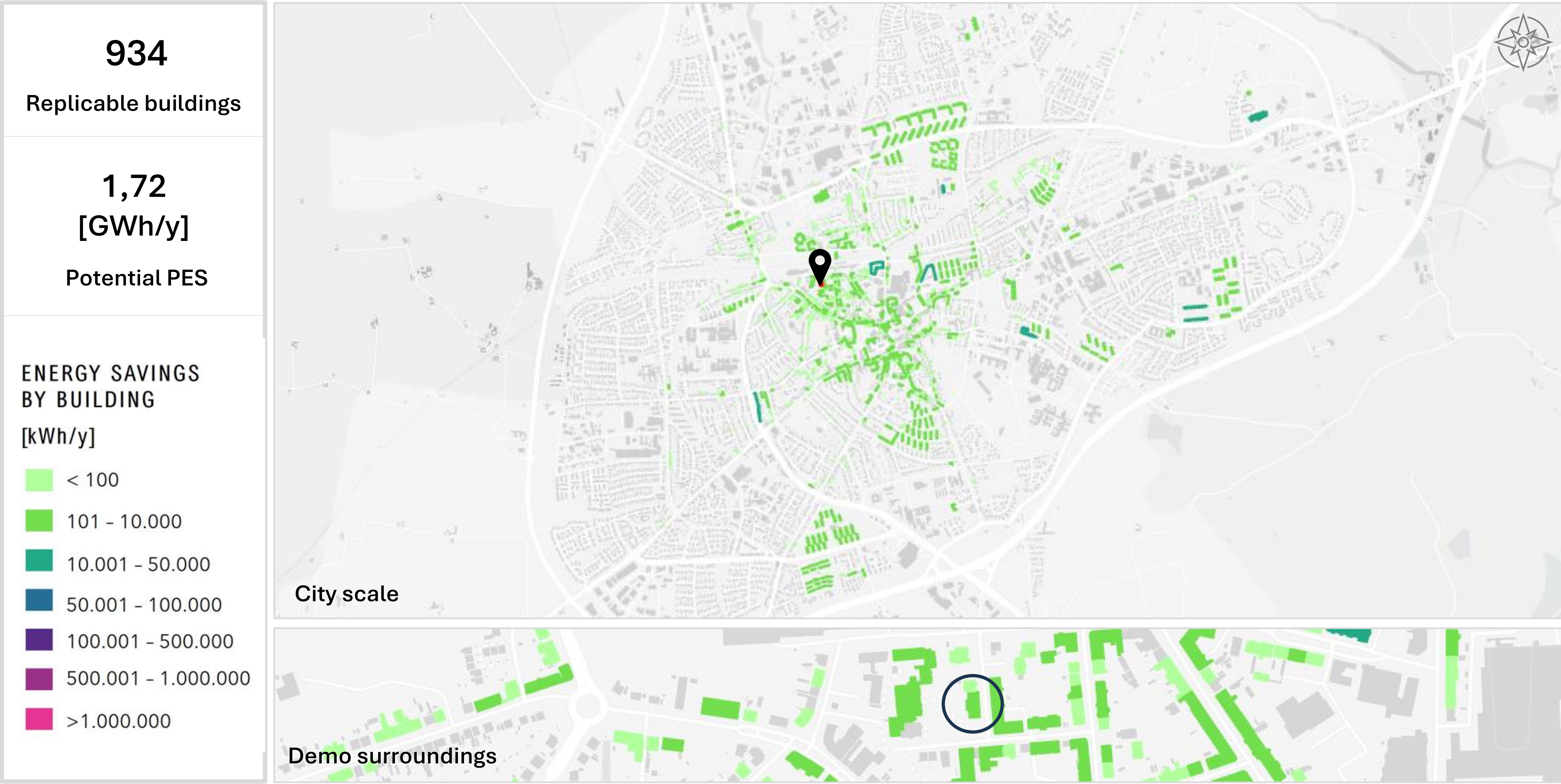

Figure 5. Slagelse-Denmark PES under CS

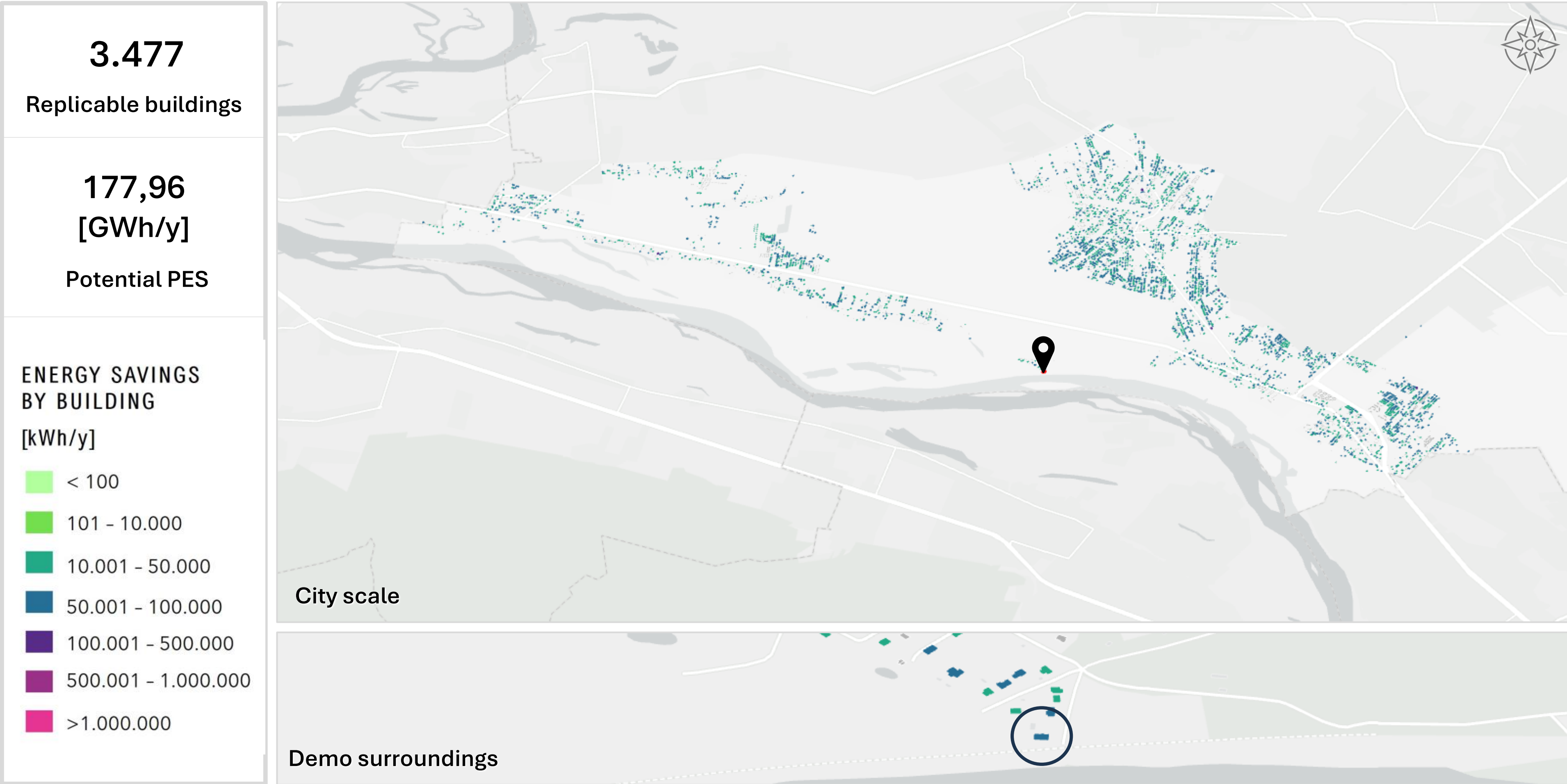

Figure 6. Jablonna-Poland PES under CS

1.1. GHG emissions reductions

When it comes to GHG emission reductions, both analyzed scenarios not only meet but substantially surpass the established KPI target of 39.206 tCO_2e/year for greenhouse gas (GHG) emission reductions (Table 14). In the OS scenario, total emissions reductions reach 244.827,56 tCO_2e/year, a figure that dramatically exceeds the minimum requirement. Jablonna-Poland, emerges as the principal contributor here, accounting for 62% of the overall emissions savings. This significant proportion immediately highlights the site's outsized role in the overall performance.

Turning to the CS scenario, the positive trend continues. Again, the KPI target is achieved and surpassed by a considerable margin, with reductions over 100.000 tCO_2e/year. What's particularly noteworthy in this case is Jablonna's contribution: more than 80% of the total reductions originate from this single site. Such dominance by one region is remarkable and warrants closer analysis.

Despite the different technologies employed across scenarios, the relative contributions of each site remain consistent. Jablonna holds the leading position by a substantial margin, followed by Lille, Moschato-Tavros, and Slagelse. This recurring pattern suggests that certain underlying factors may be driving the observed distribution of emission reductions.

Diving into the reasons behind Jablonna's overwhelming contribution, two main elements stand out. Firstly, the average EF adopted in the calculations (as detailed in Section 3.2.2) is significantly higher in Poland compared to the other locations. This means that each additional square meter of replicable intervention in Poland has a much larger impact on emissions reduction. Secondly, Jablonna possesses the highest number of replicable buildings among all demonstrator sites. The combination of these two factors, a high EF and a large base of replicable buildings, creates a situation where Poland's share of total reductions far exceeds that of the other regions.

On the other hand, the Danish demonstration region finds itself at a disadvantage. Not only does it have the lowest number of replicable buildings, but it also has the second-lowest EF among the analysed locations. As a result, its contribution to the overall emissions reduction target is the smallest of all demo regions.

In summary, while both scenarios demonstrate strong overall performance in GHG emissions reduction, the distribution of these reductions is highly uneven. Jablonna's exceptional output is primarily a function of both a hight EF and a large replicable building stock, showing how site-specific variables can dramatically influence aggregate outcomes. This analysis reinforces the importance of considering both technological and contextual factors when evaluating emissions reduction strategies across diverse geographic locations.

Table 14. GHG emission reductions

City	OS		CS	
	TOTAL city demo [tCO2e/y]	% of contribution to KPI target	TOTAL city demo [tCO2e/y]	% of contribution to KPI target
Lille. France	54.422	22%	9.621	9%
Moschato-Tavros Greece	23.780	10%	7.847	7%
Slagelse. Denmark	15.726	6%	236	0,2%
Jablonna. Poland	150.900	62%	89.031	83%
Total	**244.828**	**100%**	**106.735**	**100%**

Since the CS represents a more realistic scenario, a map of each replication area is provided, showing the potential GHG emissions reductions while applying the “Classification of Emissions Ranges” presented in presented in section 3.3. Each map includes a city-wide view along with a detailed zoom into the surroundings of the project’s demonstrator building, which is marked with a black pin and circle.

The maps present the distribution of GHG emission reduction ranges across each replicable region. In the French and Greek regions, the majority of buildings are clustered within similar intervals, roughly 11 to 100.000 t CO_2/y, and with some occasional buildings reaching up to 500.000 t CO_2/y. The Danish replicable area, in contrast, displays reductions mainly concentrated in the lowest range, specifically between 0 and 10.000 t CO_2/y. The Polish area stands out for its consistent distribution, with most values falling between 10.001 and 100.000 t CO_2/y. These observed patterns primarily reflect differences in building stock characteristics and the emission factor associated with each country’s specific energy mix.

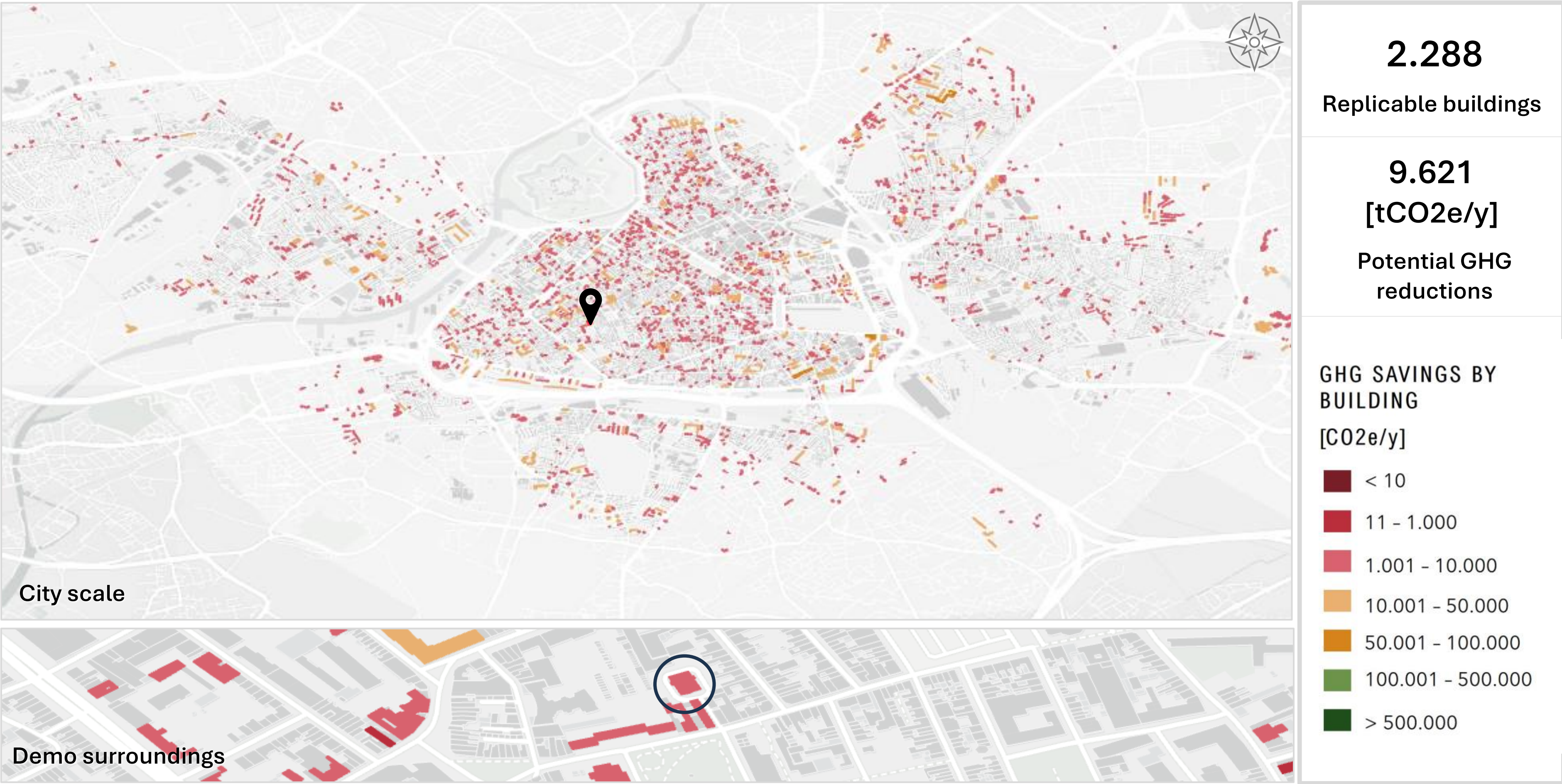

Figure 7. Lille-France GHG emission reductions under CS

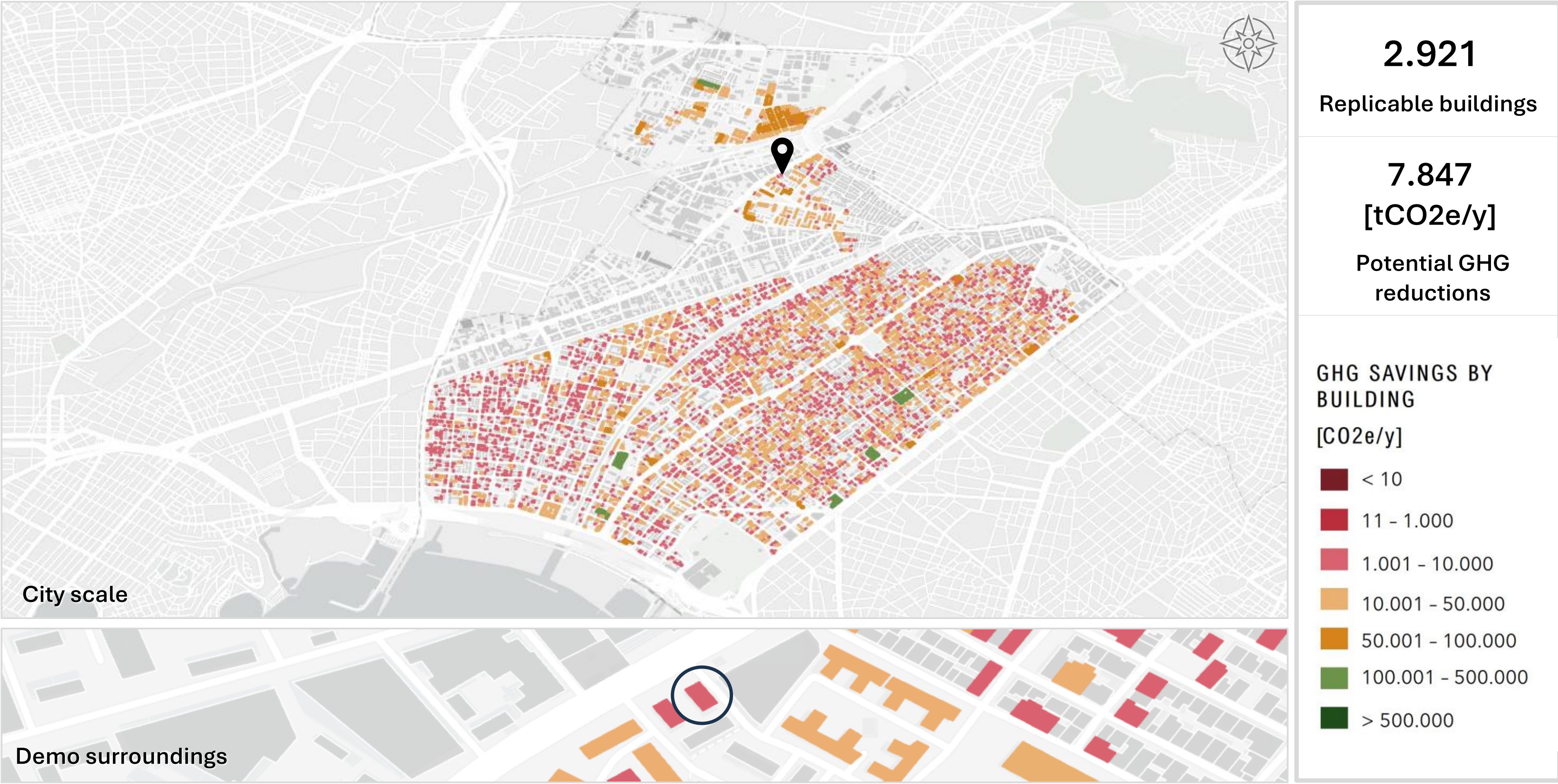

Figure 8.. Moschato Tavros-Greece GHG emission reductions under CS

Figure 9. Slagelse-Denmark GHG emission reductions under CS

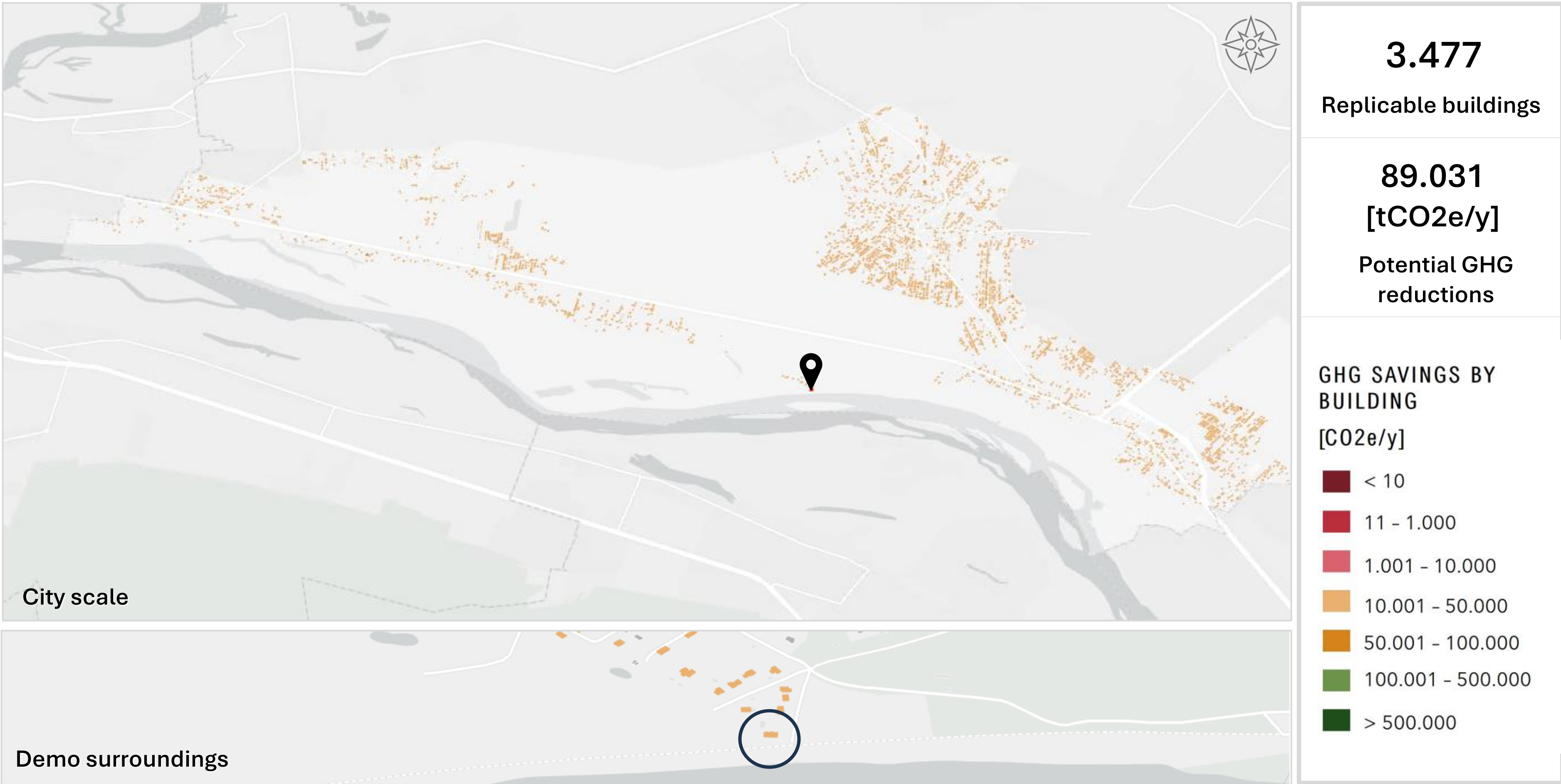

Figure 10. Jablonna-Poland GHG emission reductions under CS

2. Limitations

The methodology offers a consistent and transparent structure for evaluating the replicability of RINNO technologies, but it's important to keep its limitations in mind.

Scope and Selection Bias

The analysis specifically targeted building segments demonstrating subpar energy efficiency, intentionally omitting periods of construction already recognized for notable advancements in efficiency. This selective focus was intended to identify buildings with the highest potential for renovation, yet it also introduces a degree of selection bias. Consequently, the findings are context-dependent and should not be interpreted as nationally representative. The research was explicitly designed to concentrate on structures comparable to the RINNO demonstration projects, with similarity primarily assessed via energy demand metrics. As a result, newer and more efficient buildings were excluded from the study's scope.

Simplified Regression Modelling

While this approach produced remarkably high R^2 values (over 0.99 across various countries and building typologies), it does not fully account for the complex, non-linear factors that influence actual energy consumption in buildings. The strong statistical fit is largely attributable to the dataset's structure, which is shaped by the VTT tool parameters and national typology classifications. Consequently, these results should be considered indicative rather than strictly predictive, especially when generalized beyond the specific contexts examined in this study.

The choice of linear regression was motivated by its transparency, reproducibility, and straightforward application within an Excel-based framework, which is advantageous for replication and comparative studies. It is important to note that the analysis was also limited by data availability: across all four demonstration sites, the only consistently available variables were building floor area and the Primary Energy Demand values generated by the VTT tool.

Electricity Emission Factors and Variability

Electricity emission factors were sourced from Eurostat's country-specific grid averages, reflecting each nation's unique energy profile—think France's heavy nuclear presence versus Poland's reliance on coal. Still, it's important to note that this approach doesn't capture short-term fluctuations, like seasonal swings or even hour-by-hour changes in grid carbon intensity. So, these figures represent broad, long-term averages rather than precise, real-time data. Unfortunately, more granular, temporally specific emission factors just weren't available at this larger scale of analysis, which meant country-level detail couldn't be further refined. Despite these limitations, this method does maintain consistency across the dataset.

Operational Focus in Emissions Accounting

The analysis specifically focused on operational CO_2 emissions arising from energy consumption for heating and hot water, deliberately excluding embodied emissions and other life-cycle stages. Admittedly, this exclusion represents a notable limitation, particularly in light of the growing emphasis on life-cycle carbon assessments in current regulatory frameworks, such as the EPBD. The principal obstacle lies in the absence of reliable, building-level life-cycle data, for all buildings within the regions analysed, which makes it impractical to incorporate embodied emissions at this stage. As a result, the scope of the analysis remains restricted to operational impacts to maintain methodological consistency and feasibility.

Scenario Framework

The study focused exclusively on two extremes, the OS and the CS, while omitting any intermediate or policy-driven scenarios. It also did not include sensitivity analyses for variables such as U-values, energy prices, or emission factors. As a result, the findings should be interpreted as indicative boundaries rather than precise predictions of real-world outcomes.

This two-scenario framework was chosen primarily to ensure clear upper and lower limits for potential impacts, allowing for straightforward comparison across the various sites included in the project scope.

Project-Specific Classification Thresholds

The classification ranges for energy use and CO_2 emissions presented in Table 8 were developed specifically for the purposes of this project, drawing on a dataset of more than 7.700 entries collected from the case-study countries. While this approach supports consistent internal comparison, these ranges are not aligned with external EU or ISO benchmarks and should not be regarded as regulatory standards. The project team established these ranges to enable a coherent, data-driven categorization across all four countries within a unified analytical framework tailored to the study's objectives.

3. Conclusions

The replicability analysis demonstrates very positive outcomes regarding both Primary Energy Savings (PES) and greenhouse gas (GHG) emission reductions, across both Conservative (CS) and Optimistic (OS) scenarios.

A total of 9.620 buildings were identified as replicable across the four demonstration regions, which is particularly significant considering the analysis was conducted at a granular geographical level, focusing exclusively on specific urban or suburban pilot areas.

The two scenarios offer a clear spectrum for expected outcomes: the CS scenario serves as a lower boundary, while the OS scenario represents a more ambitious upper limit. In practice, the actual impacts of RINNO interventions are likely to fall between these two margins.

Regarding PES, the results are highly encouraging. Under the CS, total savings reach 285 GWh/year. Under the OS, they rise to 935,9 GWh/year. Even in the most conservative case, the project target is exceeded by 85%.

The most interesting results in terms of PES is the comparison between the ex-ante and ex-post situation of each demo region. In the CS, savings range from 1% in Slagelse to 35% in Jablonna. Under the OS, savings range from 28% in Lille to 71% in Slagelse. For context, the EU Directive on the Energy Performance of Buildings requires a 16% reduction in residential building stock by 2030 (relative to 2020 levels). All demonstration regions surpass this benchmark under the OS scenario. In the CS scenario, only the Greek and Polish regions exceed this target (with savings of 17% and 35%, respectively), while Lille and Slagelse remain below (at 5% and 1%).

For GHG emissions, both scenarios substantially exceed the KPI threshold of 39.206 tCO_2e/year. Under the OS scenario, reductions approach 244.827,56 tCO_2e/year while under the CS scenario, reductions still exceed 100.000 tCO_2e/year, both far above the established target.

While some limitations exist, particularly the lack of harmonized datasets across countries, the analysis effectively establishes lower and upper boundaries for the expected results. Within these parameters, the outcomes remain consistently positive. Comparisons between pre-renovation and post-renovation conditions further underscore the scalability of RINNO technologies across the demonstration regions.

Additionally, the integration of geographic analysis adds significant value. By identifying and mapping replicable buildings at the city scale, the analysis provides actionable insights for decision makers seeking to prioritize intervention candidates. This transition from building level metrics (kWh/m^2·year) to city scale metrics (kWh/building) represents a meaningful advancement in aligning technical assessments with practical urban planning.

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Annexes

Annex 1. Table of building attributes.

Category	Field description	Attribute name	Country	*Further notes*	
			Data	Stage	
Identification	Pilot internal identification	ID		ok	
	Local cadastral code (BFE-nr.)	CAD_CODE		ok	
Location	Country	Country		ok	
	City	City		ok	
	Streat name and number	Address		ok	
	Postal code	Post_Code		ok	
	X coordinate WGS84	X		ok	
	Y coordinate WGS84	Y		ok	
Characteristics	Type of building use	UseType		ok	
	Year of construction	Year_Const		ok	
	Number of households within the building	Houshold_N		ok	
	Approximate number of residents in the building	Residents_Aprox		ok	
	Number of floors above the street level	Floors		ok	
	Total height of the building in meters	Height (m)		ok	
	Total facade area of the building in meters	Facade_A (m2)		ok	
	Total roof area in meters	Roof_Area (m2)		ok	
	Gross Surface Area (Total habitable)	GSA_Area (m2)		ok	
	Additional characteristics				
	…				

Annex 2.

Link between RINNO technologies and their measures

ID	Measures in VTT tool / RINNO Technologies	Multi-selection yes/no	Bio-based double layer panels (K- FLEX)	Bio-based pipes and sheets (K- FLEX)	Isocell Cellulose Insulation (EKOLAB)	Thermo chromic glass (GREEN STRUCT)	Building integrated Photovoltaic glass (GREEN STRUCT)	Zappa PV - Roof and - Facade solutions (EKOLAB)	MicroVent sustainable Ventilation system (EKOLAB)	K-BOX bio-based insulating system for parts of energy systems (KFLEX)	De-centralized domestic hot water solution (PINK)*
1.	**Improvement of the air tightness of building envelope**										
1.1	Replacing windows and installing ventilations system (Air change rate)	Y									
1.2	Sealing the envelope (Air tightness n50)	Y			x						

ID	Measures in VTT tool / RINNO Technologies	Multi-selection yes/no	Bio-based double layer panels (K- FLEX)	Bio-based pipes and sheets (K- FLEX)	Isocell Cellulose Insulation (EKOLAB)	Thermo chromic glass (GREEN STRUCT)	Building integrated Photovoltaic glass (GREEN STRUCT)	Zappa PV - Roof and - Facade solutions (EKOLAB)	MicroVent sustainable Ventilation system (EKOLAB)	K-BOX bio-based insulating system for parts of energy systems (KFLEX)	De-centralized domestic hot water solution (PINK)*
2	**Improvement of the thermal performance of windows.**										
2.1	Replacement of windows with improved thermal performance (U-value)	Y									
2.2	Replacement of windows with a new type (G-value) (Selective quadruple)	Y				x					

2.3	Replacement of windows with improved thermal performance (U-value)	Y									
2.4	Replacement of windows with a new type (G-value) (Thermochromic_glass)	Y				x					

3	**Retrofit of the thermal insulation in outside walls**										
	None	N									
3.1	Insulation of outside walls U-value (W/m2K) after 0,46	N					x				
3.2	Insulation of outside walls, best reduction U-value (W/m2K) after 0,25	N	X		x						

4	**Improved heat insulation of the base floor**										
	None	N									
4.1	Adding layers of insulation material on top of the base floor	N			X						

5	**Improved heat insulation of the upper floor**										
	None	N									
5.1	Improving heat insulation of the upper floor	N	X		X						

6	**Passive cooling with solar shading**										

	None	N									
6.1	Passive solar shading with curtains when solar radiation more than 300 W/m²	N									
7	**Improvement of the mechanical ventilation**										
7.1	Heat recovery for the ventilation system	Y							X		
8	**Improvement of the hot water system**										
8.1	Solar collector as an auxiliary hot water system, share target low	N									x
8.2	Solar collector as an auxiliary hot water system, share target high	N									
8.3	Centralized extraction with heat recovery, share target 20 %	N									
8.4	Centralized extraction with heat recovery, share target 80 %	N									
9	**Improved or changed heating system**										
	None	N									
9.1	Space and hot water heating, connection to the district heating system	N									
9.2	Space and hot water heating, ground source heat pump	N			X			X	X		
9.3	Space and hot water heating, air to water heat pump	N									

9.4	Space and hot water heating, change of boiler to enable the use of wood pellets	N									
9.5	Space and hot water heating, change of boiler to enable the use of gas	N									
10	**Auxiliary space heating systems**										
	None	N									
10.1	Air-to-air heat pump as an auxiliary space heating system	N			X			X	X		
11	**Improved or changed cooling system**										
	None	N									
11.1	New cooling device (Air-to-Air unit)	N									
11.2	Bore hole cooling from the ground	N									
12	**Improved or changed household (appliances and lighting) electricity system**										
	None	N									
12.1	Installation of pv panels, production target 25%	N					X	X			
12.2	Installation of pv panels, production target 50%	N					X	X			
12.3	Installation of pv panels, production target 75%	N									

12.4	Installation of pv panels, production target 100%	N									
12.5	Improvement of the lighting, reduce power (like led)	N									
12.6	Improvement of the appliances, reduce power	N				X			X		
13	**Improved pipe insulation for hot water heating system (whole building)**										
	None										
13.1	Insulating hot water heating system pipes	N		X						X	

ABOUT RINNO

RINNO is a four-year EU-funded research project that aspires to deliver greener, bio-based, less energy- intensive from a life cycle perspective and easily applicable building renovation elements and energy systems that will reduce the time and cost required for deep energy renovation, while improving the building energy performance. Its ultimate goal is to develop, validate and demonstrate an operational interface with augmented intelligence and an occupant-centered approach that will streamline and facilitate the whole lifecycle of building renovation.

For more information, please visit **https://rinno-h2020.eu/**

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