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ZEB4ZEN

ZEB4ZEN

Zero energy buildings for zero Energy neighborhoods

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D.2.4.3 TRANSNATIONAL METODOLOGY FOR MRV OF ENERGY SAVINGS

A. INTRODUCTION

The ZEB4ZEN project aims to support the transition towards zero-emission neighbourhoods by combining analytical methodologies with real-life pilot investments in historic urban areas. Within this framework, Deliverable D1.5.1 provided a comprehensive assessment of energy flows at the neighbourhood level, together with the implementation and documentation of pilot actions in Karlovac, Palmanova and Zamość.

The Energy Flow analysis established a detailed baseline of energy consumption, production and associated emissions across buildings, public lighting and transport systems, using a harmonised bottom-up modelling approach based on multi-source data and calibrated against real consumption where available.

Building on this baseline, pilot investments tested concrete energy efficiency and renewable energy solutions under real operating conditions, generating measurable impacts in terms of energy savings, CO_2 emission reductions and financial performance.

In this context, Deliverable D2.4.3 develops a transnational methodology for the monitoring, reporting and verification (MRV) of energy savings achieved by the implemented measures. The methodology is directly linked to the calculation framework applied in the project, operationalised through the pilot-specific datasets and Excel-based tools used for quantifying final energy savings, primary energy impacts and emission reductions. It ensures consistency between baseline assessment, ex-post evaluation and cumulative savings estimation, thereby enabling comparability across pilot sites and supporting the replication of results in other historic neighbourhoods. The methodology was developed jointly by EIHP, PL, APE FVG and HSMD; EIHP prepared the methodology and calculations, while the pilot partners provided project data and reviewed the results.

B. METHODOLOGY

The methodology for monitoring, reporting and verification (MRV) of energy savings is based on the implementation of the Croatian national methodology for calculating and verifying energy savings for EE measures and RES. This approach ensures alignment with established regulatory frameworks and enables consistent and transparent quantification of energy efficiency impacts across the analysed pilot measures. The calculation of energy savings is performed using standardised procedures and formulas defined within the national framework, with a focus on determining final energy savings (FES), primary energy savings and associated CO_2 emission reductions. To ensure accuracy and comparability of results, national conversion factors are systematically applied. This includes the use of country-specific primary energy factors and CO_2 emission factors for different energy carriers, reflecting the characteristics of national energy systems. By applying these factors, the methodology ensures that calculated impacts are consistent with national reporting practices and suitable for aggregation and benchmarking at both national and transnational levels. The MRV framework is operationalised through a structured calculation approach implemented in dedicated Excel-based tools, allowing for transparent tracking of input parameters, assumptions and results for each pilot measure. This enables reproducibility of calculations, facilitates verification procedures, and supports the comparability of results across different pilot locations within the ZEB4ZEN project.

1.1. Determination and verification of savings

The energy savings are estimated with engineering calculation models, i.e. standardised mathematical formulas applied to verified project-specific input data (installed capacities, U-values and renovated areas, vehicle consumption and mileage) and, where project-specific data are not available, to reference values. Savings are verified as prescribed by the Croatian national framework, the Energy Efficiency Act and the Ordinance on the system for monitoring, measuring and verification of energy savings. Under that framework, verification consists of checking the documented evidence of implementation (expert supervision reports, technical documentation, invoices, fuel and mileage records), checking the input data and reference values used, and recalculating the savings with the prescribed formulas. This bottom-up approach based on deemed and engineering estimates is consistent with the methods for calculating energy savings set out in Annex V of the Energy Efficiency Directive (EU) 2023/1791. Consequently, all results presented in Chapter C are calculated estimates, not measured results.

1.2. Determination of savings and metering-based verification

The project foresees that the MRV of energy savings will be also based on metered data and evaluation findings 12 months after the pilot investments are implemented. The project duration was extended until 30 September 2026. Even so, the 12-month period of operation needed for a representative metering-based verification had not elapsed for any of the pilot measures before the end of the project.

Karlovac: the PV plant was handed over on 3 June 2026, and the electric vehicle was delivered on 24 February 2026. By the end of the project, the PV plant had operated for about four months and the electric vehicle for about seven months. Neither period covers the seasonal variation in solar irradiation, building load and vehicle use over a full year.

Palmanova: the Renewable Energy Community, through which the electricity produced by the PV plants is shared among its members, was officially established on 12 January 2026. A full year of operation of the community, with production and shared energy data for all seasons, had not been completed by the end of the project.

Zamość: the thermal insulation works were completed and accepted on 7 October 2025. The first heating season after renovation (2025/2026) is not representative for verification. In the same period, the heating installation was modified (replacement of radiators, changes to the distribution system) and air-conditioning units were installed, so changes in metered district heating consumption cannot be attributed to the attic insulation alone. In addition, the heating system and building operation were still being adjusted after the works. Verification will therefore be based on the 2026/2027 heating season, the first full season of stable operation, compared with pre-renovation consumption and normalised to heating degree-days.

Until metered data are available, annual savings are determined with the engineering calculation methods described in Chapter B.1.1, in line with the Croatian Ordinance on the system for monitoring, measuring and verification of energy savings. This approach corresponds to the deemed savings and scaled savings methods (engineering estimates) set out in Annex V, point 1(a) and 1(c), of the Energy Efficiency Directive (EU) 2023/1791. Under Annex V, scaled savings may be used where establishing robust measured data for a specific installation is difficult or disproportionately expensive, which was the case for the pilot measures within the project period. Metering-based verification (metered savings, Annex V, point 1(b)) will follow, as shown in Table 1. It will be carried out by the partners owning and operating the pilot investments, using the methodology and calculation tool developed in this deliverable.

Table 1: Completion of pilot measures, determination of savings and planned verification by metering

Pilot	Measure	Completion / start of operation	Operation by project end (30 Sep 2026)	Determination of savings (Chapter C)	Verification of savings by metering
Karlovac (HR)	Rooftop PV plant, City Hall (11,7 kWp)	3 Jun 2026 (handover); permanent operation from 26 Jun 2026	approx. 4 months	Calculated estimate according to the MRV methodology (EED Annex V, 1(a)/(c))	**June 2027**, after 12 months of operation; SenzoriKA platform and DSO meter; City of Karlovac
Karlovac (HR)	Electric vehicle with V2G (replacing a petrol vehicle)	24 Feb 2026 (vehicle handover); bidirectional charger 19 Dec 2025	approx. 7 months	Calculated estimate according to the MRV methodology (EED Annex V, 1(a)/(c))	**March 2027**, after 12 months of operation; mileage records and charging data (SenzoriKA); City of Karlovac
Palmanova (IT)	PV plants STELLA and SOLE (108,40 kWp), Renewable Energy Community	12 Jan 2026 (REC officially established)	approx. 8 months	Calculated estimate according to the MRV methodology (EED Annex V, 1(a)/(c))	**February 2027**, after 12 months of REC operation; inverter, meter and shared energy data (GSE); Municipality of Palmanova / REC
Zamość (PL)	Thermal insulation of the attic, Ormiańska 11	7 Oct 2025 (final acceptance and commissioning)	approx. 12 months; one non-representative heating season (2025/2026)	Calculated estimate according to the MRV methodology (EED Annex V, 1(a)/(c))	**June 2027**, after the end of the 2026/2027 heating season (May 2027); metered district heating consumption, normalised to heating degree-days; City of Zamość

1.3. Conversion factors, measure lifetimes and discounting factors

Wherever applicable, national primary energy factors and CO_2 emission factors of the country in which each pilot is located have been used. This ensures that the calculated impacts reflect the characteristics of each national energy system and are consistent with national reporting practice. For the calculation of cumulative energy savings, the measure lifetimes and discounting factors prescribed by the Croatian regulation on monitoring, measuring and verification of energy savings were applied uniformly to all pilots. Applying the same factors keeps cumulative results comparable across countries.

Table 2: Conversion factors, measure lifetimes and discounting factors applied

Country / energy carrier	CO_2 emission factor [kg CO_2/kWh]	Primary energy factor [-]	Source
Croatia - electricity	0,159	1,498	[National regulation]
Croatia - petrol	0,280	1,130	[National regulation]
Italy - electricity	0,260	2,420	[National regulation]
Poland - district heating (Zamość)	0,200	1,200	[National regulation]

Measure type	Lifetime [years]	Discounting factor f_d [-]
Photovoltaic systems	23	15,450
Electric vehicles	8	7,002
Thermal insulation of the building envelope	25	16,247

1.4. MRV procedure

The MRV framework applied to each pilot measure consists of four steps:

1. **Baseline establishment. The situation without the measure is defined for each measure type:**
   - photovoltaic systems: electricity supplied from the grid without on-site generation (Chapter B.1);
   - electric mobility: the energy consumption of the replaced or reference petrol vehicle (Chapter B.2);
   - building envelope renovation: the heat transfer coefficients of the building elements before renovation (Chapter B.3).

The neighbourhood-level baseline of energy consumption, production and emissions was established in Deliverable D.1.5.1.

2. **Monitoring. The following input parameters are collected and documented for each measure:**
   - installed capacity, performance ratio and share of energy fed into the grid;
   - vehicle consumption, mileage and number of vehicles;
   - U-values and areas of the renovated elements, heating system efficiency and heating degree-days.

Actual project-specific data are always given priority. Reference values are used only where actual data are not available.

3. **Reporting. For each measure, the following indicators are calculated with the Excel-based calculation tool and reported in a uniform tabular format (Chapter C):**

- annual final energy savings;
- annual primary energy savings;
- annual CO_2 emission reduction;
- cumulative lifetime energy savings;
- annual cost savings and simple payback period.

4. Verification. Verification consists of three checks:

- the documented evidence of implementation (expert supervision reports, technical documentation, invoices, fuel and mileage records);
- the plausibility of the input data and reference values;
- an independent recalculation of the savings with the prescribed formulas.

The transparent structure of the calculation tool allows a third party to verify every result.

5. Conservative approach and avoidance of double counting

A conservative approach is applied in all calculations:

- For photovoltaic systems, only the electricity that reduces final energy consumption is counted as savings. Electricity fed into the public grid is excluded.
- For electric mobility, the electricity consumed by the new vehicle is deducted from the energy consumption of the replaced petrol vehicle.
- For the building envelope, only the elements actually renovated are taken into account.

1.5. Transferability

The methodology can be transferred to other countries and historic neighbourhoods. The calculation formulas and the MRV procedure stay the same; only the country-specific primary energy and CO_2 emission factors and, where available, national reference values (for example solar irradiation and heating degree-days) need to be replaced. The metering-based verification described in Chapter B.1.2 can be applied in the same way at other sites.

2. PHOTOVOLTAIC SOLAR MODULES

This methodology provides a formula for assessing the unit annual energy savings resulting from the installation of photovoltaic (PV) solar modules in existing or new residential and service sector buildings, industrial or other facilities.

Total annual energy savings in direct consumption are obtained by multiplying the installed peak power of the PV system by the duration of sunlight at 1000 W/m2.

The part of the electricity that leads to a reduction in final energy consumption, i.e. self-supply, can be counted towards energy savings, and not the part that is delivered to the grid. The relevant installed power of the PV system for the energy savings of the facility is the DC power.

2.1. Method of determining savings

Estimated savings.

2.2. Calculation formula

Formula for calculating the energy savings achieved by installing the PV module:

$$FES = P_{PV} * h * PR * (1 - ee_{net})$$

where:

FES	[kWh/y]	Total annual energy savings in direct consumption
P_{PV}	[kW]	Installed peak power of the photovoltaic system
h	[h/y]	Duration of sunlight at 1000 W/m2 (constant load) on the site
ee_{net}	[-]	The share of electricity that is fed into the public grid and cannot be counted as a reduction in direct consumption
PR	[-]	Photovoltaic system performance ratio - defined as the ratio between the actual electricity generated by the photovoltaic system and the energy generated by the module

2.3. Required data and documentation

The data required to calculate the savings are the total installed peak power of the photovoltaic system, the duration of sunlight, the efficiency ratio of the photovoltaic power plant and the share of the generated electricity delivered to the grid.

Required project-specific data:

P_{PV}	Installed peak power of a photovoltaic system	[kW]	Actual value
h	Duration of sunlight at 1000 W/m2 (constant load) in the field	[h/year]	Actual / reference value
PR	Efficiency ratio of a photovoltaic system	[-]	Actual / reference value

ee_{net}	Share of electricity fed into the public grid	[-]	Actual value

The documentation that must be attached/possessed as evidence of the implementation of the measure and verification of the input data for the calculation of savings is as follows:

- final report of the expert supervision on the completion of the photovoltaic system installation project,

- technical data on the photovoltaic system,

- report on the share of electricity consumed at the location from which the share of electricity that is transmitted to the public grid and cannot be counted as a reduction in direct consumption is evident. The report is prepared by a certified electrical engineer or a person authorized to conduct energy audits and energy certification of buildings or large companies in the electrical part.

2.4. Reference values

In the absence of project-specific data, reference values should be used:

Symbol	**Unit of measure**	**Value**
h*	[h/y]	1.400 for continental Croatia 1.800 for coastal Croatia
h**	[h/y]	1.150 for North Italy 1.250 for Centre-North Italy 1.350 for Centre Italy 1.450 for South Italy 1.550 for Islands
PR	[-]	0,7

**Source (for Croatia): https://narodne-novine.nn.hr/clanci/sluzbeni/2021_09_98_1772.html*
***Source (for Italy): https://calcolo gratis.it/wiki/fotovoltaico/ore-equivalenti/*

2.5. Greenhouse gas emissions reduction

Annual reduction in greenhouse gas emissions:

$$E_{CO2} = FES \times e/1000$$

Where:

E_{CO2}	[tCO_2/y]	Reducing greenhouse gas emissions
e	[$kgCO_2/kWh$]	CO_2 emission factor for electricity**Pogreška! Izvor reference nije pronađen.**
FES	[kWh/y]	Total annual energy savings in direct consumption

2.6. Primary energy savings

Annual savings in primary energy:

$$E_{prim} = FES \times e_{prim}$$

Where:

E_{prim}	[kWh/y]	Primary energy savings
e	[-]	Primary energy factor for electricity**Pogreška! Izvor reference nije pronađen.**
FES	[kWh/y]	Total annual energy savings in direct consumption

e_{prim} (for electricity - Croatia)	1,498 [-]
e_{prim} (for electricity - Italy)	2,420 [-]

2.7. Lifetime of the measure and cumulative energy savings

Lifetime of the measure	23 years
Discounting factors for cumulative energy savings	15,450

E_{cum}	[kWh]	Cumulative energy savings
f_d	[-]	Discounting factors for cumulative energy savings **Pogreška! Izvor reference nije pronađen.**
FES	[kWh/y]	Total annual energy savings in direct consumption

$$E_{kum} = FES \times f_d$$

3. REPLACING EXISTING VEHICLES AND BUYING NEW, MORE EFFICIENT VEHICLES

This method provides a way to determine savings when replacing or purchasing new, more efficient vehicles, and two typical cases are distinguished:

a. Replacing old vehicles with new, more efficient vehicles. In this case, the calculation is based on the difference in fuel consumption of old and new vehicles, multiplied by the average annual mileage and the number of cars replaced. An example of this is the replacement of old petrol or diesel vehicles with new vehicles that use electricity. Savings resulting from the replacement of existing vehicles with internal combustion engines with new vehicles with internal combustion engines are not acceptable. If it is a vehicle conversion, the calculation is the same as in the case of vehicle replacement.

b. Purchase of new efficient vehicles. In this case, the savings are calculated based on the difference between the unit consumption of the reference vehicle and the new vehicle, which is multiplied by the average annual mileage and the number of newly purchased cars. An example of this case is the procurement of new efficient vehicles that use electricity. The purchase of new vehicles with internal combustion engines is not an acceptable measure for which savings can be reported.

3.1. Method of determining savings

Estimated savings.

3.2. Calculation formula

The formula for calculating the energy savings due to the replacement of existing vehicles and the purchase of new, more efficient vehicles applies to cases (a) and (b):

$$UFES = \left(FC_{init} \times f_{C_init} - FC_{new} \times f_{C_new}\right) \times D$$

$$FES = \sum_{i=1}^{N} UFES_i$$

Where:

UFES	[kWh/vehicle x year]	Unit energy savings in direct consumption
FCinit	[l/100 km or kg/100 km]	Fuel consumption of an old vehicle
FCnew x f_{C_new}	[kWh/100 km]	Electricity consumption of a new vehicle
fC_init	[kWh/l or kWh/kg]	Conversion factor in kWh/100km for old vehicles
D	[km/year]	Average mileage for a specific type of vehicle
FES	[kWh/year]	Total annual energy savings in direct consumption
N	[-]	Number of replaced or newly purchased cars covered by the measure

3.3. Required input data

Mandatory input data for the calculation of savings in the event of replacing an old vehicle with a new one are the average consumption of the old and new vehicle and the average annual mileage.

In the case of buying a new energy-efficient vehicle, it is necessary to know the average consumption of the new vehicle.

3.4. Required data specific to a particular project

Case			a.	b.
FCinit	Fuel consumption of an old vehicle	[l/100 km or kg/100 km]	Actual/Benchmark	Actual/Benchmark
fC_init	Conversion factor in kWh/100km for old vehicles	[kWh/l or kWh/kg]	Actual/Benchmark	Actual/Benchmark
FCnewxfC_new	Energy consumption of a new electric vehicle	[kWh/100 km]	Actual/Benchmark	Actual/Benchmark
D	Average mileage for a specific type of vehicle	[km/year]	Actual/Benchmark	Actual/Benchmark
N	Number of replaced or new vehicles	-	Actual value	Actual value

Savings can be calculated using data specific to each project or using benchmarks.

In the case of using reference values, the documentation that needs to be submitted/possessed as proof of the implementation of the measure and verification of the input data for the calculation of savings is the invoice for the delivered vehicles, which shows the number and type of vehicles.

In the case of using specific values, in addition to the invoice for the delivered vehicles, it is necessary to attach/possess a record of fuel consumption and mileage of the vehicle.

3.5. Reference values

In the absence of individual data, the following benchmarks may be used:

Average annual mileage[1]:

Type of vehicle	Average annual mileage D [km/year]
Automobile	12.650
Gasoline car	9.200
Diesel car	15.500
Light Delivery Vehicle	20.000
Bus M2	34.500
Bus M3	65.000
N2 Truck	21.000

[1] Source: Croatian Vehicle Center (CVH)

N3 Truck	52.000
Motorcycle	3.000

Average fuel consumption[2]:

		FC_{init}	fc_{init}	D
Type of vehicle	**Fuel**	**[l/100km]**	**[kWh/l]**	**[km/year]**
Automobile	Petrol	7,5	9,35	9.200
Automobile	Diesel	5,9	10,02	15.500
Automobile	LPG	8,7	7,16	16.000
Automobile	SPP	5,3	12,94	15.000
Light Delivery Vehicle	Petrol	8,1	9,35	20.000
Light Delivery Vehicle	Diesel	9,1	10,02	20.000
Light Delivery Vehicle	LPG	8,9	7,16	20.000
Light Delivery Vehicle	SPP	5,9	12,94	20.000
Bus M2	Diesel	14,9	10,02	34.500
Bus M2	SPP	17,5	12,94	34.500
Bus M3	Diesel	33,0	10,02	65.000
Bus M3	SPP	52,0	12,94	65.000
N2 Truck	Diesel	12,2	10,02	21.000
N2 Truck	LPG	15,1	7,16	21.000
N2 Truck	SPP	14,3	12,94	21.000
N3 Truck	Diesel	29,7	10,02	52.000
N3 Truck	SPP	34,8	12,94	52.000
N3 Truck	UPP	55,6	7,0	52.000
Motorcycle	Petrol	4,3	9,35	3.000

Conversion factors[3]:

Conversion factor			
Fuel	**Base Unit**	**[MJ]**	**[kWh]**
Petrol	1 l	33,67	9,35
Diesel	1 l	36,09	10,02
LPG	1 l	25,79	7,16
SPP	1 kg	46,58	12,94
UPP	1 kg	56,3	15,7

To calculate the savings in energy consumption data for new light-duty vehicles, the declared consumption of the vehicle determined according to the WLTP cycle is used.

When purchasing new electric vehicles, the reference data is the energy consumption of a petrol car for the situation before the implementation of the measure. To calculate the savings in this case, the energy consumption in kWh/100km for the new vehicle, which is equal to the product of FCnewxfcnew, must still

[2] Source: EIHP

[3] Source: Energy in Croatia, 2018

be known. The consumption of the reference new electric vehicle is 19.1 kWh/100 km, but the actual figure should be used whenever possible.

If it is a vehicle that is not in one of the above categories, but, for example, a special purpose vehicle (tourist and special vehicles for national parks), the reference assumption is that an equivalent gasoline vehicle would consume three times more energy than such an electric vehicle.

In case (b), when purchasing new energy-efficient vehicles (electric vehicles), the reference values for the energy consumption of a petrol car shall be taken as FCinitxfc_init, i.e.: FCinitxfc_init = 7,5 l/100 km x 9,35 kWh/l = 70,125 kWh/100 km.

To calculate the savings in this case, the data on energy consumption in kWh/100km for the new vehicle, which is equal to the product of the FCnewxfc_new in the above formula, must still be known.

3.6. Lifetime of the measure and cumulative energy savings

Lifetime of the measure	8 years
Discounting factors for cumulative energy savings	7,002

E_{cum}	[kWh]	Cumulative energy savings
f_d	[-]	Discounting factors for cumulative energy savings **Pogreška! Izvor reference nije pronađen.**
FES	[kWh/y]	Total annual energy savings in direct consumption

$$E_{kum} = FES \times f_d$$

4. RENOVATION OF THERMAL INSULATION OF INDIVIDUAL PARTS OF THE BUILDING ENVELOPE

Thermal insulation of individual parts of the building envelope includes walls, windows and ceilings (roofs) of buildings.

The unit energy savings in direct consumption are calculated based on the difference in the heat transfer coefficient of the building components 'before' and 'after' the application of the EnU measure. The situation 'before' is given by the parameters of each building or reference values can be used depending on the period of construction of the building and the requirements of the regulations of the time. The heat transfer coefficients of building components should be adjusted according to the degree of heating and, if possible, according to the efficiency and intermittent of the heating system.

The total annual energy savings in direct consumption for a building are determined by multiplying the unit energy savings by the area of the building envelope that has been renovated.

4.1. Method of determining savings

Estimated savings.

4.2. Calculation formula

Formulas for the calculation of energy savings resulting from the renovation of building envelope elements (wall, window, roof), without replacement of heating equipment:

$$UFES_{wall} = \frac{((U_{init_wall} - U_{new_wall}) \times HDD \times 24\text{h} \times a \times \frac{1}{b} \times c)}{1000} \times f_{trans} \times s_{elem}$$

$$UFES_{window} = \frac{((U_{init_window} - U_{new_window}) \times HDD \times 24\text{h} \times a \times \frac{1}{b} \times c)}{1000} \times f_{trans} \times s_{elem}$$

$$UFES_{roof} = \frac{((U_{init_roof} - U_{new_roof}) \times HDD \times 24\text{h} \times a \times \frac{1}{b} \times c)}{1000} \times f_{trans} \times s_{elem}$$

$$UFES_{wall,unheted} = \frac{((U_{init_wall,unheated} - U_{new_wall,unheated}) \times HDD \times 24\text{h} \times a \times \frac{1}{b} \times c)}{1000} \times f_{trans} \times s_{elem} x\ 0{,}5$$

$$UFES_{floor} = \frac{((U_{init_floor} - U_{new_floor}) \times HDD \times 24\text{h} \times a \times \frac{1}{b} \times c)}{1000} \times f_{trans} \times s_{elem} x\ 0{,}3$$

$$FES = \sum_{i=1}^{n} UFES\, i \times Ai$$

Where:

UFES	[kWh/m2/year]	Unit energy savings in direct consumption
Uinit	[W/m2K]	Heat transfer coefficient for a characteristic old element before reconstruction
Unew	[W/m2K]	Heat transfer coefficient for a characteristic element after reconstruction
HDD	[-]	Degree-day heating
24h	[h]	24 hours
a	[-]	Correction factor depending on the climatic zone in which the building is located
b	[-]	Efficiency of the heating system
c	[-]	Heating interruption coefficient
ftrans	[-]	Correction factor for the share of transmission losses in the total annual heat demand for heating
Selem	[-]	Share of an individual envelope element in the total annual heat losses through the building envelope
FES	[kWh/y]	Total annual energy savings in direct consumption
$A_i = \sum A_z + A_p + A_k$	[m2]	Area of the outer shell of the building

4.3. Required input data and documentation

To calculate the savings, it is necessary to know the area of the reconstructed structure of the outer shell of the building and the exact data for the degree-day of heating, i.e. the actual climatic zone in which the building is located.

It is desirable to know the heat transfer coefficient before and after the reconstruction and the efficiency of the heating system. If the distribution of the total heat losses of the building by individual heat transfer mechanisms (through the envelope, ventilation, infiltration) is known from the energy performance certificate for the calculation of the annual heat demand for heating the building, the correction factor ftr$_a$ns is determined as the proportion of annual heat loss through the envelope (Qtr$_a$ns) in the total annual heat demand for heating the building (Qh,nd): , f_trans=Q_trans/Q_(H,nd) where this factor shows how much of the heat required for heating is lost through the building envelope and is used to correct unit energy savings in envelope renovation measures. If data on Qtr$_a$ns and Qh,nd are not available, the reference values of the ftr$_a$ns factors determined according to the purpose and age of the building shall be used (Ordinance on the SMIV, Table 10, Annex B). The size s$_e$l$_e$m represents the proportion of an individual envelope element (e.g. walls, windows, roof, floor to ground or wall to unheated space) in the total annual heat loss through the building envelope (Q_trans). The sum of all shares must be 1.0. In case there are actual calculations from the energy performance certificate, these calculated proportions shall be used for s $_e$l$_e$m.

If such data are not available, the reference values given in the table (Ordinance on the SMIV, Table 11, Annex B) shall be used (breakdown by typical uses and construction periods).

4.4. Required data specific to a particular project:

A	Area of the outer shell of the building	[m2]	Actual value
Uinit	Heat transfer coefficient for a characteristic old element before reconstruction	[W/m2K]	Actual/Benchmark
Unew	Heat transfer coefficient for a characteristic element after reconstruction	[W/m2K]	Actual/Benchmark
HDD	Degree-day heating	[-]	Actual value
b	Efficiency of the heating system	[-]	Actual/Benchmark
c	Heating interruption coefficient	[-]	Benchmark

The documentation that needs to be submitted/possessed as proof of the implementation of the measure and verification of the input data for the calculation of savings is as follows:

- an invoice with the construction work carried out on the site with a clearly indicated amount of individual items for the calculation of savings.

4.5. Reference values

In the absence of project-specific data, reference values should be used:

Reference values:	**Continental Croatia**	**Littoral Croatia**
Uinit_wall [W/m²K]	1,26	
Unew_wall [W/m²K]	0,30	0,45
Uinit_window [W/m²K]	3,15	
Unew_window [W/m²K]	1,60	1,80
Uinit_roof [W/m²K]	1,75	
Unew_roof [W/m²K]	0,25	0,30
Uinit_wall,unheated [W/m²K]	1,65	
Unew_wall,unheated [W/m²K]	0,40	0,60
Uinit_floor,background [W/m²K]	1,51	
Unew_floor,background [W/m²K]	0,40	0,50
HDD[4]	2.965	1.691
a	1	
b=η	Depending on the product of the selected subsystems	
ftrans	Choose according to purpose and year of construction	
Selem	Select according to each part of the envelope	

c[5]

[4] Converted values from MGIPU Meteorological Data (https://mgipu.gov.hr/UserDocsImages/dokumenti/EnergetskaUcinkovitost/Meteo_parametri_po_postajama.pdf) (access date: 09.10.2020.)

[5] Algorithm for the calculation of the required energy for heating and cooling of the building space according to HRN EN ISO 13790

Family houses	1,00
Multi-apartment buildings	0,71
Offices	0,39
Education Buildings	0,42
Hotels & Restaurants	1,00
Hospitals	1,00
Sports halls	0,61
Shops	0,54
Other buildings	0,42

Reference unit energy savings:						
Purpose of the building	Climatic zone	**UFES_wall**	**UFES_window**	**UFES_roof**	**UFES_ unheated wall**	**UFES_floor**
		[kWh/m²/yr]				
Family houses	Littoral Croatia	53,9	89,8	96,5	34,9	20,2
	Continental Croatia	112,0	180,8	175,0	72,9	38,8
Multi-apartment buildings	Littoral Croatia	38,2	63,6	70,7	29,5	15,7
	Continental Croatia	79,3	128,1	123,9	51,6	27,5
Offices	Littoral Croatia	20,9	34,8	38,6	16,1	8,6
	Continental Croatia	43,3	70,0	67,7	28,2	15,0
Education Buildings	Littoral Croatia	22,5	37,4	41,6	17,3	9,2
	Continental Croatia	46,7	75,3	72,9	30,4	16,2
Hotels & Restaurants	Littoral Croatia	53,9	89,8	99,8	41,6	22,2
	Continental Croatia	112,0	180,8	175,0	72,9	38,8
Hospitals	Littoral Croatia	53,9	89,8	99,8	41,6	22,2
	Continental Croatia	112,0	180,8	175,0	72,9	38,8
Sports halls	Littoral Croatia	32,7	54,5	60,6	25,2	13,5
	Continental Croatia	68,0	109,8	106,2	44,3	23,6
Shops	Littoral Croatia	28,9	48,1	53,5	22,3	11,9
	Continental Croatia	60,0	96,9	93,7	39,1	20,8
Other buildings	Littoral Croatia	22,5	37,4	41,6	17,3	9,2
	Continental Croatia	46,7	75,3	72,9	30,4	16,2

4.6. Reducing greenhouse gas emissions

The annual reduction in CO2 emissions depends on the type of fuel/energy used in the heating system.

Formula for calculating the annual reduction of greenhouse gas emissions:

$$E_{CO2} = FES \times e/1000$$

Where:

E_{CO2}	[tCO2/year]	Total annual greenhouse gas emission reductions
e	[kgCO2/kWh]	Emission factor
FES	[kWh/y]	Total annual energy savings in direct consumption

If several energy sources are used for heating, it is necessary to determine the emission factor according to the share of each energy source in the production of thermal energy.

If the data on the fuel used is not known, it is necessary to use the emission factor for natural gas.

4.7. Lifetime of the measure and cumulative energy savings

Lifetime of the measure	25 years
Discounting factors for cumulative energy savings	16,247

E_{cum}	[kWh]	Cumulative energy savings
f_d	[-]	Discounting factors for cumulative energy savings **Pogreška! Izvor reference nije pronađen.**
FES	[kWh/y]	Total annual energy savings in direct consumption

$$E_{kum} = FES \times f_d$$

C. ENERGY SAVINGS AND CO_2 REDUCTION CALCULATIONS

1. KARLOVAC, CROATIA

1.1. Karlovac - Photovoltaic system

A rooftop photovoltaic system was installed on the City Hall building to generate renewable electricity for on-site consumption. The system reduces grid electricity demand, lowers operational costs and contributes to CO_2 emission reductions. It also forms part of an integrated energy system including digital monitoring and optimisation. The Karlovac pilot demonstrates a small-scale demand response concept through the integration of a **10 kW** photovoltaic system, a bidirectional EV charging station (V2G) and an electric vehicle acting as a mobile battery, enabling flexible energy use and load balancing within the building. Annual savings of the photovoltaic power plant are **11.466,00 kWh/y**.

Table 3: Energy savings and CO_2 reduction calculation for photovoltaic (Methodology calculation) - Karlovac pilot

PARAMETER	VALUE	UNIT OF MEASURE
Rated power:	10,00	[kW]
Peak power (Ppv):	11,70	[kW]
Module power:	450,00	[Wp]
Number of modules:	26,00	[-]
Performance ratio (PR):	0,70	[-]
Duration of sunlight at 1000 W/m2 (h):	1.400	[hours]
Share of electricity fed into the public grid (e_{enet}):	0,00	[-]
CO2 emission factor (Croatia):	0,159	kg CO2/kWh
Primary energy factor (Croatia):	1,498	[-]
Lifetime of the measure:	23	[years]
Discounting factors for cumulative savings:	15,45	[-]
Electricity unit cost (Croatia):	0,131	[€/kWh]
Investment:	12.409,16	[€]
FES - Final energy savings:	11.466,00	kWh/y
CO2 emissions savings:	1,82	t CO2/y
Primary energy savings:	17.176,07	kWh/y
Cumulative energy savings:	177.161,17	kWh
Cost savings:	1.502,05	[€/y]
Simple payback period:	8,26	[y]

1.2. Karlovac - Electric vehicle

An electric vehicle with bidirectional charging capability was introduced as a replacement for a conventional petrol vehicle. The measure reduces fuel consumption and enables additional flexibility through vehicle-to-grid (V2G) operation, supporting load balancing and improved energy management. It contributes to both direct energy savings in transport and indirect optimisation of electricity use.

Table 4: Energy savings and CO_2 reduction calculation for electric vehicle - Karlovac pilot

PARAMETER	VALUE	UNIT OF MEASURE
OLD VEHICLE		
Fuel type:	petrol	
Vehicle type:	personal vehicle	
Average annual consumpition - FCint:	7,5	[l/100km]
Conversion factor- fCint:	9,35	[kWh/l]
FCint*fcint:	0,70125	[kWh/km]
NEW VEHICLE		
Fuel type:	electricity	
Vehicle type:	personal vehicle	
Average annual consumpition - FCnew:		
Conversion factor- fcnew:		
FCnew*fcnew:	0,199	[kWh/km]
Average mileage for a specific type of vehicle D:	12.650	km
Number of replaced vehicles N:	1	[-]
Unit savings - UFES [kWh/vehicle/y]:	6.353	kWh/y
Total final energy savings - FES [kWh/y]:	**6.353**	**kWh/y**
Lifetime of the measure:	8	years
Discounting factors for cumulative savings:	7,002	[-]
Cumulative energy savings:	44.487	kWh
Petrol conversion factor:	9,35	kWh/l
Petrol savings:	680	l
CO2 emission factor for electricity (Croatia):	0,159	kg CO2/kWh
CO2 emission factor for petrol (Croatia):	0,280	kg CO2/kWh
Primary energy factor for electricity (Croatia):	1,498	[-]
Primary energy factor for petrol (Croatia):	1,130	[-]
Primary energy savings:	7.179,41	kWh/y
CO2 emissions reduction:	2,08	t/y
Petrol unit cost:	1,64	[€/l]
Cost savings:	1.114,40	[€/y]
Investment:	33.500,00	[€]
Simple payback period:	30,06	[y]

2. PALMANOVA, ITALY

2.1. Palmanova - Photovoltaic system and Renewable Energy Community (REC)

The pilot includes the development of a photovoltaic system located outside the historic city walls, combined with the establishment of a Renewable Energy Community. This setup enables collective use of renewable electricity by residents and local stakeholders without impacting protected heritage structures. The measure reduces grid consumption, energy costs and CO_2 emissions at community level. Regarding documentation the 2 photovoltaic power plants have a power of **60,51 kW - STELLA** and **47,89 kW - SOLE**, resulting in a total installed photovoltaic system capacity of **108,40 kW.** Using the methodology from chapter 1. that governs the verification system, energy savings are **113.569,51 kWh/y**.

Table 5: Energy savings and CO_2 reduction calculation for photovoltaic - CER Palmanova pilot

PARAMETER	VALUE	UNIT OF MEASURE
Rated power:	108,40	[kW]
Peak power (Ppv):	108,40	[kW]
Performance ratio (PR):	0,84	[-]
Duration of sunlight at 1000 W/m2 (h):	1.247,25	[hours]
Share of electricity fed into the public grid (e_{enet}):	0,00	[-]
CO2 emission factor (Italy):	0,260	kg CO2/kWh
Primary energy factor (Italy):	2,420	[-]
Lifetime of the measure:	23	[years]
Discounting factors for cumulative savings:	15,45	[-]
Electricity unit cost (Italy - Palmanova):	0,297	[€/kWh]
Investment:	79.172,59	[€]
FES - Final energy savings:	113.569,51	kWh/y
CO2 emissions savings:	29,53	t CO2/y
Primary energy savings:	274.838,22	kWh/y
Cumulative energy savings:	1.754.762,53	[kWh]
Cost savings:	33.730,15	[€/y]
Simple payback period:	2,35	[y]

3. ZAMOSC, POLAND

3.1. Zamość – Thermal insulation of historic building - model

The pilot in Zamość concerns the energy renovation (thermal insulation) of only a part of the building – the attic of the historic building at Ormiańska 11, Zamosc. The measure included the insulation of the external and internal walls of the attic, roof slopes and ceiling, with the replacement or improvement of individual elements such as windows. The insulation was carried out mainly from the inside, using mineral boards (Multipor) and natural materials such as sheep wool. The works were carried out on the entire attic area.

3.2. Zamość – Thermal insulation of historic building – building

The results presented in this chapter and in Table 4 are the output of a computer simulation of the entire building. They are given as an illustrative example of the savings potential of a comprehensive energy renovation of the building and do not represent the savings achieved by the pilot measure implemented on site. The savings of the implemented pilot measure (thermal insulation of the attic) are presented in Chapter 3.3.

The simulation was carried out with an analytical building energy model created in the specialised software Audytor OZC 7.0 Pro (Sankom). The whole heated building (useful area 620,30 m²) was modelled in two states: the reference state before renovation and a target state after renovation. In the target state, improved thermal properties were assumed not only for the attic envelope, but also for the external walls of the ground and first floor and for the basement walls (insulated wall area of approximately 1.500 m²). For both states, the annual heat demand for heating and ventilation (QH,nd) and the specific heat demand per m² of useful area were calculated.

According to the simulation, the annual heat demand of the building decreases from 131.342 kWh/y (211,70 kWh/m²) to 74.228 kWh/y (119,70 kWh/m²), i.e. by 57.114 kWh/y or approximately 43 %. Because the computer simulation calculated the reduction of energy consumption for the building as a whole, this value cannot be attributed to the attic renovation. It is used in this deliverable only as an example of the whole-building potential and as a reference for allocating savings to the attic intervention (Chapter 3.3).

The investment shown in Table 6 (1.071.315 €) is an indicative estimate based on a unit price of 714,21 €/m² of insulated wall area, not an actual cost; the resulting payback period should therefore also be read as indicative. All values in Table 6 are calculated estimates, not measured results.

Table 6: Energy savings and CO_2 reduction calculation for thermal insulation of building – Zamosc pilot

PARAMETER	VALUE	UNIT OF MEASURE
Usefull area of the building	620,30	[m²]
Specific heat demand - before	211,70	[kWh/m²]
Heat demand - before	131.342,00	[kWh/y]
U values (walls) - before	0,401 - 1,404	[W/m²K]
U values (windows, doors) - before	1,8; 2,2	[W/m²K]
Specific heat demand - after	119,70	[kWh/m²]
Heat demand - after	74.228,00	[kWh/y]
U values (walls) - after	0,142 - 0,504	[W/m²K]
U values (windows, doors) - after	0,9; 1,3	[W/m²K]
CO_2 factor for District heating (Poland, Zamosc):	0,200	[kg CO2/kWh]

Primary energy factor for District heating (Poland, Zamosc):	1,200	[-]
Unit cost for District heating (Poland, Zamosc):	0,089	[€/kWh]
Lifetime of the measure:	25	[years]
Discounting factors for cumulative savings:	16,247	[-]
Area of the thermally insulated wall (whole building simulation):	1.500,00	[m²]
Investment:	1.071.315,00	[€]
FES - Final energy savings:	57.114,00	kWh/y
CO_2 emissions savings:	11,42	t CO2/y
Primary energy savings:	68.536,80	kWh/y
Cumulative energy savings:	927.931,16	[kWh]
Cost savings:	5.083,15	[€/y]
Simple payback period:	210,76	[y]

3.3. Zamość – Thermal insulation of historic building - attic

The measure actually implemented on site within the Zamość pilot is the thermal insulation of the attic of the historic building at Ormiańska 11 (useful area of the attic 133,12 m²). The savings reported for the Zamość pilot are therefore the savings of the attic intervention presented in Table 8.

Since the computer simulation (Chapter 3.2) calculated the reduction of energy consumption for the whole building, its results were scaled down to the attic. For this purpose, the energy savings were calculated according to the methodology in Chapter B.3 (Renovation of thermal insulation of individual parts of the building envelope), taking into account only the attic envelope elements that were renovated: attic slopes (SKOS 2.2 – 158,68 m² and SKOS 2.1 – 58,49 m²), internal attic walls (SZ 1.1 – 54,41 m² and SZ 1.2 – 24,09 m²), attic windows (48,05 m²) and external doors (8,43 m²), with a total renovated envelope area of 352,16 m². The heat transfer coefficients (U-values) before and after renovation and the element areas were taken from the project documentation and the building energy model; the heating system efficiency (η = 0,70965) and the heating interruption coefficient (c = 0,42 – other buildings) were applied as shown in Table 7.

Other attic-related elements of the model (the ceiling under the unheated attic, the dormer ceilings and the internal attic walls to unheated spaces) were not included in the calculation, so the result is a conservative estimate.

The calculated final energy savings of the attic intervention amount to 11.635,02 kWh/y, which corresponds to approximately 20 % of the savings simulated for the whole building (57.114 kWh/y). This proportion serves as a plausibility check between the methodology-based calculation and the building simulation.

In line with the methodology, the attic savings are a calculated estimate based on verified input data (project documentation, U-values and areas of the renovated elements), not a measured result. They will be verified ex post (see Chapter B.1.2) by comparing the metered district heating consumption of the building before and after the renovation, normalised to heating degree-days.

Table 7: Input data for calculating savings according to the methodology

DATA	VALUE
Wall heat transfer coefficient - Old [W/m2 K]:	0,393; 0,401; 1,404; 1,364; 1,8; 2,2
Wall heat transfer coefficient - New [W/m2 K]:	0,142; 0,196; 0,311; 0,504; 0,9; 1,3
Heating system efficiency - η:	0,709650 - η average
Heating cut-off coefficient:	0,420000 - Other buildings
External building envelope area [m2]:	352,16

Table 8: Energy savings and CO2 reduction calculation for thermal insulation of the attic – Zamosc pilot

PARAMETER	VALUE	UNIT OF MEASURE
Useful area of the attic:	133,12	[m²]
U values (walls) - before:	0,393 - 1,404	[W/m²K]
U values (windows, doors) - before:	1,8; 2,2	[W/m²K]
U values (walls) - after:	0,142 - 0,504	[W/m²K]
U values (windows, doors) - after:	0,9; 1,3	[W/m²K]
CO2 factor for District heating (Poland, Zamosc):	0,200	[kg CO2/kWh]
Primary energy factor for District heating (Poland, Zamosc):	1,200	[-]
Unit cost for District heating (Poland, Zamosc):	0,089	[€/kWh]
Lifetime of the measure:	25	[years]
Discounting factors for cumulative savings:	16,247	[-]
Walls area that is insulated (attic):	352,16	[m²]
Investment:	251.516,19	[€]
FES - Final energy savings:	11.635,02	kWh/y
CO2 emissions savings:	2,33	t CO2/y
Primary energy savings:	13.962,02	kWh/y
Cumulative energy savings:	189.034,17	[kWh]
Cost savings:	1.035,52	[€/y]
Simple payback period:	242,89	[y]

D. SUMMARY OF ENERGY SAVINGS AND CO_2 EMISSION REDUCTION

The pilot investments implemented within the ZEB4ZEN project in Karlovac (Croatia), Palmanova (Italy) and Zamość (Poland) show how the transition towards zero-emission neighbourhoods can be advanced in heritage-sensitive urban environments through targeted, replicable energy efficiency and renewable energy measures. Applying the common MRV methodology described in Chapter B to all pilots gives results that are quantified consistently, transparently and comparably across the participating countries, despite differences in national energy systems, climate conditions and the type of measures. Table 9 summarises the results calculated in Chapter C for the four measures implemented on site: two photovoltaic systems, one electric vehicle with vehicle-to-grid (V2G) functionality and one thermal renovation of a historic building envelope. Together they achieve annual final energy savings of approximately 143.024 kWh/y and annual primary energy savings of approximately 313.156 kWh/y. Over the lifetime of the measures, the cumulative energy savings amount to approximately 2.165.445 kWh (2,17 GWh). The annual CO_2 emission reduction is approximately 35,76 t CO_2/y.

The Palmanova photovoltaic systems, operated within a Renewable Energy Community, account for the largest share of the results: about 79 % of final energy savings and 83 % of CO_2 emission reductions. This shows the strong potential of community-based renewable energy models that leave protected heritage structures untouched. The Karlovac pilot combines rooftop PV generation, bidirectional charging and an electric vehicle acting as a mobile battery. It shows how small-scale, integrated solutions can deliver savings in both the building and the transport sector while adding flexibility to local energy use. The Zamość pilot shows that the thermal renovation of a historic building is technically feasible with heritage-compatible materials and methods, such as interior insulation with mineral boards and natural sheep wool. In heritage contexts, the value of such measures lies not only in the energy saved but also in demonstrating solutions that preserve the cultural and architectural value of the building. Overall, the results confirm that the methodology can be applied to different types of measures and national contexts. They provide a sound, evidence-based basis for reporting the project's contribution to energy and climate targets and for replicating the tested solutions in other historic neighbourhoods across Central Europe.

Table 9: Summary of energy savings and CO_2 emission reductions of the ZEB4ZEN pilot investments

PILOT	IMPLEMENTED MEASURE	FINAL ENERGY SAVINGS [kWh/y]	PRIMARY ENERGY SAVINGS [kWh/y]	CUMULATIVE ENERGY SAVINGS [kWh]	CO_2 EMISSION REDUCTION [t CO_2/y]
Karlovac (HR)	Rooftop PV system, City Hall (11,70 kWp)	11.466,00	17.176,07	177.161,17	1,82
Karlovac (HR)	Electric vehicle with V2G (replacing a petrol car)	6.353,46	7.179,41	44.486,94	2,08
Palmanova (IT)	PV systems STELLA and SOLE, Renewable Energy Community (108,40 kWp)	113.569,51	274.838,22	1.754.762,53	29,53
Zamość (PL)	Thermal insulation of the attic, Ormiańska 11	11.635,02	13.962,02	189.034,17	2,33
TOTAL	**All pilot measures**	**143.023,99**	**313.155,72**	**2.165.444,81**	**35,76**

***Note**: Savings are calculated estimates obtained with the methodology described in Chapter B, not measured results. Lifetimes of the measures: 23 years for PV systems, 8 years for the electric vehicle and 25 years for the building envelope renovation. For Zamość, only the attic insulation implemented on site is included. The whole-building simulation (Chapter 3.2) is not counted.*

E. CONCLUSION

This deliverable establishes a robust and transparent transnational methodology for the monitoring, reporting and verification (MRV) of energy savings within the ZEB4ZEN project. By building on a harmonised baseline of energy flows and aligning with national calculation frameworks, the methodology ensures consistency between ex-ante assessments, ex-post evaluations and the estimation of cumulative impacts across pilot sites. The developed approach demonstrates that reliable quantification of energy savings, primary energy impacts and CO_2 emission reductions can be achieved through standardised formulas, clearly defined input data requirements and the systematic application of national conversion factors. The use of structured, Excel-based calculation tools further enhances transparency, reproducibility and verifiability, enabling stakeholders to trace assumptions and validate results across different measures and locations.

Application of the methodology to pilot actions in Karlovac, Palmanova and Zamość confirms its practical relevance and flexibility. It successfully captures the impacts of diverse measures, including photovoltaic systems, electric vehicle deployment and building envelope renovation, while accommodating differences in local conditions, energy systems and data availability. At the same time, the use of reference values ensures that the methodology remains applicable even in cases where project-specific data are limited. Importantly, the MRV framework supports comparability of results across countries by integrating country-specific emission and primary energy factors within a common methodological structure. This enables aggregation of results at project level and facilitates benchmarking, policy reporting and replication in other historic neighbourhoods. The consistent treatment of measure lifetimes and cumulative savings further strengthens the long-term evaluation of energy efficiency interventions.

For the Karlovac and Palmanova pilots, the calculated savings come almost entirely from photovoltaic generation, which is highly predictable. Annual PV production depends mainly on installed capacity, solar irradiation and system performance, all of which are well documented. Calculated and measured production of well-designed PV plants typically differ only slightly. This is confirmed by the first operating data from Karlovac: between June and October 2026 the PV plant produced 6.196 kWh, in line with the expected seasonal distribution. Over the same period, practically no electricity (5,44 kWh) was exported to the grid, which confirms the full self-consumption assumed in the calculation (D.2.3.3). On this basis, the consortium considers the calculated savings for these two pilots sufficiently reliable for reporting the project results.

For the Zamość pilot, no full heating season of measured consumption was available for the evaluation, so the reported savings are based on the calculation and on the building energy simulation. The consortium considers this approach acceptable. The simulation was carried out with a detailed building energy model based on the actual geometry and construction of the building. In addition, the improvement of the renovated building elements was confirmed by in-situ measurements of thermal transmittance and by thermographic surveys before and after the renovation (D.2.2.3). The calculated savings for the attic are also conservative, as only the renovated envelope elements are taken into account.

For all pilots, the metering-based verification described in Chapter B.1.2 will serve as a final confirmation of the calculated savings once a full year of operating data is available.

Overall, the methodology provides a solid foundation for evidence-based decision-making and for scaling up energy efficiency and renewable energy measures in heritage-sensitive urban contexts. By combining methodological rigor with practical applicability, it contributes to the broader ZEB4ZEN objective of supporting the transition towards zero-emission neighbourhoods through measurable, verifiable and comparable energy savings outcomes.