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EASI ZERo

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Deliverable

ENVELOPE MATERIAL SYSTEM WITH LOW IMPACT FOR ZERO ENERGY RENOVATION AND CONSTRUCTION

Deliverable ID	**D5.3**
Deliverable name	**Numerical code for simulations**
Deliverable description	Associated to the guidelines disclosed in delivered report D5.2, D5.3 proposes the procedure and numerical methodology based on simulation tools and environment known and used in the sector. Project solutions and use cases are covered. More specifically, this deliverable describes the numerical simulations performed in Task 5.2, with its assumptions and input data. The newly developed EASI ZERo renovation components and materials were modelled in the simulation software IDA ICE and EnergyPlus under aligned boundary conditions and weather data. The models replicated the test conditions carried out in Task 5.3. The inputs include the geometry of the test facilities, building envelope layer compositions and material properties, airtightness values, internal conditions, and operational schedules. The results prove to be consistent with the measurements. Supporting materials for the simulation codes from Task 5.2, including weather files and test facilities' geometry, have been uploaded to Zenodo under the 'EASI ZERo project' community.

WP	5	Performance evaluation in test environments
Task	5.2	Modelling and performance assessments

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ACRONYM

ACH – Air Changes per Hour
Ψ – Linear thermal transmittance (W/m·K)
U – Thermal transmittance (W/m²·K)
Ug – Glazing thermal transmittance
Uf – Frame thermal transmittance
Uw – Window thermal transmittance
PUR – Polyurethane
Bio-PUR – bio-based PUR
EPS – Expanded Polystyrene
OSB – Oriented Strand Board
PE – Polyethylene
PVC – Polyvinyl Chloride

1. Executive summary

1.1 Description of the Deliverable content and objectives

Deliverable D5.3 “Numerical code for simulations” is one of the outputs of Task 5.2 of the EASIZERo project. As a DATA deliverable, the simulation codes have been uploaded to Zenodo, while this report describes the main assumptions and input parameters used in the models.
Task 5.2 focused on conducting dynamic simulations to assess the thermal and energy performance of the components and assemblies developed in WP4. Such components were implemented in two of the EASI ZERo experimental facilities, namely the SINTEF test cells in Trondheim, Norway, and the CEA PASSYS test cells in Chambéry, France. The modelling framework was defined by specifying geometry, material properties, and environmental conditions. Simulations were carried out based on the thermal and optical characteristics of the materials and components, using two established simulation tools, namely IDA ICE and EnergyPlus.
The developed models were validated against experimental data obtained in Task 5.3.

1.2Deviation from objectives, corrective action

No deviations from the planned objectives were identified. The activities were carried out according to the project plan.

1.3 Technical progress

Numerical simulation models of the SINTEF and CEA test facilities were developed and validated using the available experimental data. The models incorporate input data concerning the building envelope, internal boundary conditions, and climatic inputs.
Simulations were performed to compare the thermal and energy performance of the renovated EASI ZERo wall configuration with that of the reference (non-renovated) configuration under consistent modelling conditions.

1.4 Impact of the results

The simulation results provide quantitative insights into the energy performance improvements associated with the EASI ZERo renovation solutions. In particular, the models enable the estimation of energy savings and thermal performance improvements under realistic operating conditions.
The developed simulation framework also supports future analyses of renovation strategies and contributes to the optimization of building envelope solutions for zero-energy renovation scenarios.

1.5 Dissemination activities carried out

Two scientific publications have been prepared within the project:

1. Conference paper:

Presentation at *CESBP 2025 (6th Central European Symposium on Building Physics)*, Budapest, Hungary, 11–13 September 2025.
Title: *Simulation and Validation of Building Renovation Components – A Case Study Using IDA ICE and EnergyPlus.*
The work has been published in the indexed conference proceedings, Lecture Notes in Civil Engineering, vol 796. Springer. DOI: https://doi.org/10.1007/978-3-032-14019-7_24

2. Journal paper:

Submission to the journal *Energy and Buildings*.
Title: *Experimental–simulation framework for assessing novel insulation performance: A case study on bio-PUR combining measurements with IDA ICE and EnergyPlus modelling.*
The work has been published in the journal of Energy and Buildings. DOI: 10.1016/j.enbuild.2026.117832.

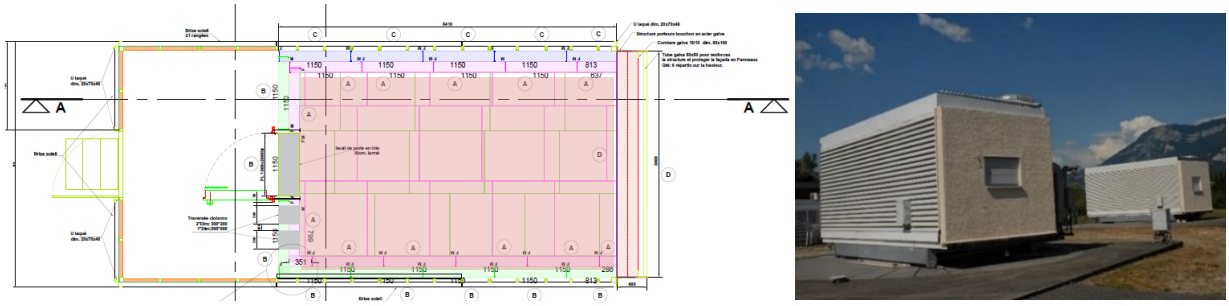
2 Technical content

The following sub-sections describe the two laboratory facilities that serve as full-scale experimental setups within the EASI ZERo project. These facilities are designed to evaluate the thermal and energy performance of retrofitting solutions under real outdoor conditions.

2.1 CEA Passys Cells

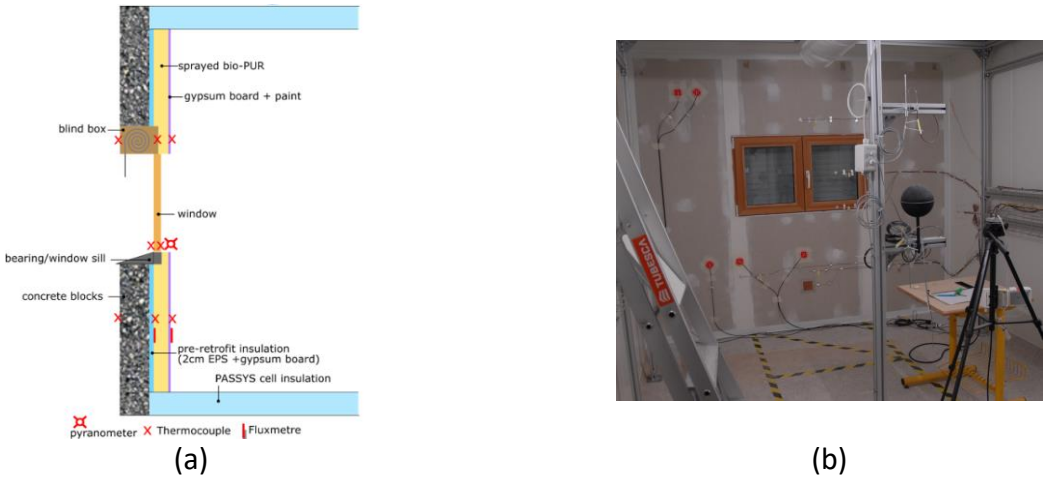
The CEA Passys test facility, located in Chambéry (France), consists of two adjacent full-scale test cells operated in parallel, where:

- Test cell 1 represents the baseline configuration with conventional pre-renovation wall assemblies;
- Test cell 2 integrates the bio-based Polyurethane insulation (bio-PUR) developed within the EASI ZERo project, both in one external wall and in the window frame.



(a) (b)

***Figure 1**. Floor plan of Test Cell 1 and 2 (with the test room highlighted in red) (a) and photograph of both Test Cells (b).*



(a) (b)

***Figure 2.** (a) schematic representation of the CEA test wall illustrating the wall layers and the locations of the installed sensors; (b) photograph of the experimental setup.*

In Test Cell 1 (non renovated), the **test wall 1** consists of conventional materials, including a concrete block core and an integrated blind box (approx. 0.35 m²).

In Test Cell 2 (renovated), the **test wall 2** features a novel bio-polyurethane (Bio-PUR) foam insulation developed within the EASI ZERo project, integrated into a wooden framework. The wall also includes an integrated blind box with Bio-PUR and wood fibre board.

The **other external walls** of the test rooms consist of steel sandwich panels with PUR insulation, whereas the technical rooms use wall assemblies incorporating EPS insulation, an air gap, and external cladding. The **internal partition wall** and **door** between rooms are built with steel and PUR, with the door featuring triple glazing. **Roof** and **floor** assemblies vary slightly between technical and test room, with combinations of wood-based panels, insulation, and waterproof membranes.

Note that the building components of the technical room, namely the external walls, roof and floor, affect the test only slightly, as the technical and test rooms are separated by a highly insulated internal wall. Table 1 and Table 2 present thicknesses and U-values of the various building components of the facilities.

***Table 1**. Main characteristics of envelope components for the CEA Passys Cells.*

Building component	**Material**	**Thickness** [mm]	**Thermal conductivity** [W/(m·K)]	**Density** [kg/m^3]	**Specific heat** [J/(kg·K)]	**U-value** [W/(m^2·K)]
Test wall – non renovated (Test Cell 1)	Gypsum board	13	0.25	900	1000	0.24 (insulation-section)
	Expanded polystyrene (EPS)	20	0.04	15	1400	
	Gypsum board	10	0.25	900	1000	0.54 (wooden studs-section)
	Concrete blocks	200	0.87	900	1000	
	Cement render	15	0.16	950	840	
	Gypsum board	13	0.25	900	1000	
Test wall – renovated (Test Cell 2)	Gypsum board	13	0.25	900	1000	0.93
	Bio-PUR foam (EASI ZERo material)*	100	0.033	80	1600	
	Wooden framework*	100	0.14	720	1680	
	Gypsum board	10	0.25	900	1000	
	EPS	20	0.04	15	1400	
	Gypsum-based render	10	0.25	900	1000	
	Concrete blocks	200	0.87	900	1000	
	Cement render	15	0.16	950	840	
Blind box (Test Cell 1)	Polyvinyl Chloride (PVC)	20	0.16	1379	1004	0.99
	Polyurethane (PUR)	20	0.028	30	1470	
	Air gap/roller shut**	150	-	-	-	
	PVC**	20	-	-	-	
Blind box (Test Cell 2)	Gypsum board	13	0.25	900	1000	0.42
	BioPUR foam	45	0.033	80	1600	

	Wood fiber board	10	0.07	250	1700	
	Hemp jute fibers	20	0.041	45	1500	
	Wood fibre board	10	0.07	250	1700	
	Air gap/roller shut**	220	-	-	-	
	Wood fibre board**	20	-	-	-	
	Cement render**	5	-	-	-	
Other external walls (equal in Test Cell 1 and 2)	Steel	0.6	50	7800	450	0.08
	PUR	173.8	0.028	40	1400	
	Steel	0.6	50	7800	450	
	Steel	0.6	50	7800	450	
	PUR	173.8	0.028	40	1400	
	Steel	0.6	50	7800	450	
Roof (equal in Test Cell 1 and 2)	Steel	0.6	50	7800	450	0.07
	PUR	173.8	0.028	40	1400	
	Steel	0.6	50	7800	450	
	Rockwool	50	0.055	92	840	
	Steel	0.6	50	7800	450	
	PUR	173.8	0.028	40	1400	
	Steel	0.6	50	7800	450	
	Air gap with steel beams	100	1.2	1.2	1008	
	OSB	22	0.13	620	1700	
	Bitumen membrane	2.5	0.23	1100	1000	
Floor (equal in Test Cell 1 and 2)	PVC flooring	1	0.4	1380	1000	0.10
	Wooden board	30	0.13	540	1600	
	Rigid PE mousse	52	0.028	40	1400	
	EPS	300	0.040	15	1400	
	OSB	22	0.13	620	1700	
Internal wall (equal in Test Cell 1 and 2)	Steel	0.6	50	7800	450	0.08
	PE	173.8	0.028	40	1400	
	Steel	0.6	50	7800	450	
	Steel	0.6	50	7800	450	
	PE	173.8	0.028	40	1400	
	Steel	0.6	50	7800	450	
Internal door (equal in Test Cell	Steel	1	50	7800	450	0.15
	PE	160	0.024	40	1400	
	Steel	1	50	7800	450	

**In the actual construction, Bio-PUR foam is installed within the wooden framework.*
*** Layers not included in the simulation models.*

The test wall of Test Cell 1 includes a **window** with a total area of 0.9 m². The glazing accounts for approximately 53% of the total window area, while the frame represents 47%. The thermal transmittance of the glazing is Ug = 1.34 W/(m²·K) and the frame thermal transmittance is Uf = 1.14

W/(m²·K). The overall window thermal transmittance is Uw = 1.3 W/(m²·K). The window has a total solar transmittance (g-value) of 0.6 and a direct solar transmittance (T) of 0.57.
The window of Test Cell 1 is equipped with an integrated roller shutter system located inside a blind box above the window frame. The shutter is made of PVC, approximately 1 cm thick, and is positioned about 2 cm from the glazing surface.
The test wall of Test Cell 2 also includes a window with a total area of 0.9 m². In this configuration, the glazing represents approximately 55% of the total window area, while the frame accounts for about 45%. The glazing thermal transmittance is Ug = 1.338 W/(m²·K) and the frame thermal transmittance is Uf = 0.81 W/(m²·K), resulting in an overall window thermal transmittance of Uw = 1.1 W/(m²·K). The window has a total solar transmittance (g-value) of 0.6 and a direct solar transmittance (T) of 0.57.
Similarly, the window of Test Cell 2 includes an integrated roller shutter system contained in a blind box above the window frame. The shutter is made of 1 cm-thick PVC and positioned approximately 20 cm from the glazing.

***Table 2**. Thickness and U-value for envelope components of the technical rooms (adjacent to the test rooms).*

Building component	**Total Thickness** [m]	**U-value** [W/(m²·K)]
External walls (equal in Test Cell 1 and 2)	60	0.50
External door (equal in Test Cell 1 and 2)	52	0.44
Roof_Test Cell 1	125	0.34
Roof_Test Cell 2	25	2.90
Floor (equal in Test Cell 1 and 2)	53	1.75

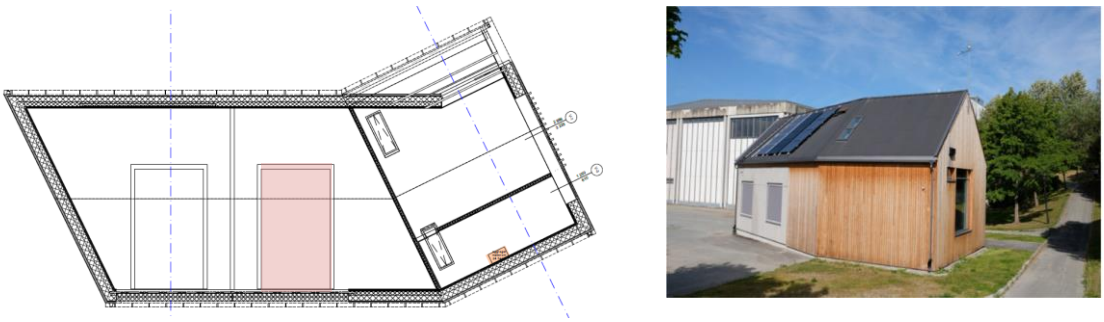
The test and technical rooms' **heating system** consists of convector units. No cooling equipment or mechanical ventilation system is present.
The **airtightness** of the building envelope was evaluated using a blower door test, which measured air leakage rates of 2.64 ACH for Test Cell 1 and 2.76 ACH for Test Cell 2, at a pressure differential of 50 Pa.
The facility is mounted on a rotating platform that allows the test wall's **orientation** to be adjusted.

2.2 SINTEF Test cells

The SINTEF test facility, located in Trondheim (Norway), consists of two adjacent units; however, only Test Cell B was available for testing. Consequently, this cell was used for two measurement and simulation periods (Cases 1 and 2), where:

- **Non-renovated configuration** represents the baseline configuration using traditional, pre-renovation building components typical of Norwegian single-family homes.
- **Renovated configuration** integrates the wood-fibre insulation developed within the EASI ZERo project in the external wall.

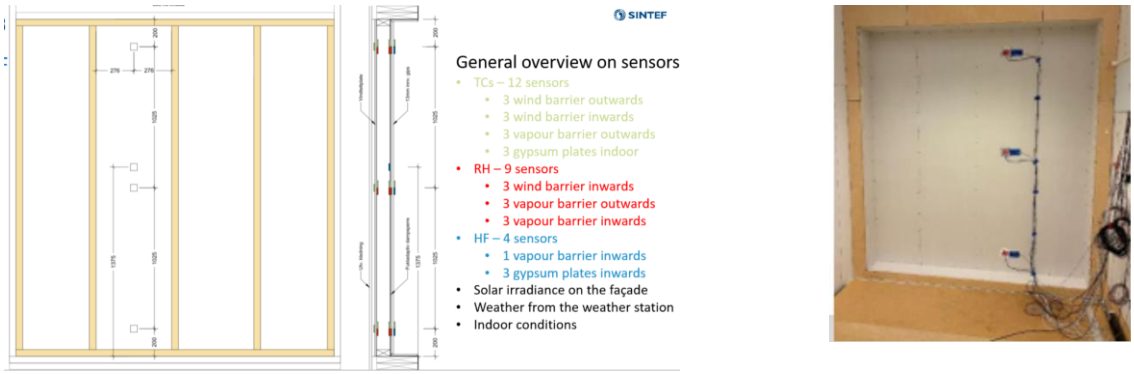
The layout of the SINTEF test facility and the location of the analysed test room are shown in Figure 3.



(a) (b)

Figure 3. *Floor plan of the SINTEF test cells with the analysed test room highlighted in red (a), and photograph of the experimental facility (b).*

Figure 4 illustrates the experimental setup of the facility, including the sensor locations within the test wall.



(a) (b)

Figure 4. *(a) schematic representation of the SINTEF test wall assembly, with an overview of the sensor locations; (b) photograph of the instrumented test wall.*

In the non-renovated configuration, the **test wall** consists of a gypsum board, a vapour barrier, a layer of wood fibre-based insulation within wooden framing, OSB sheathing, a polyethene-based wind barrier, a ventilated air gap, and wooden cladding as the exterior finish.
In the renovated configuration, the wall has a similar structure but includes an additional insulation layer. The extra layer of insulation was installed in an additional wooden frame built between the

gypsum board and the vapour barrier. The test cell's internal walls, floor, and ceiling are constructed from stainless steel sheets enclosing a PUR insulation core.

Regarding the **other building envelope components** of the facility, the external walls consist of gypsum board, a polyethylene vapour barrier, mineral wool insulation within wooden framing (two layers of 350 mm and 50 mm), a polyethylene wind barrier, an air gap, and wooden cladding. The roof assembly includes gypsum board, a polyethylene vapour barrier, two layers of mineral wool insulation within wooden framing, an OSB board, and a wind barrier made of polyethylene fibres laminated with polypropylene felt. Above this layer is a 48 mm ventilated air gap and an asphalt-based waterproofing membrane.

The facility is also equipped with an external door and several windows. Both windows and door have a thermal transmittance of 0.7 W/(m²·K).

Table 3 and Table 4 present thicknesses and U-values of the various building components of the SINTEF test facility.

***Table 3**. Main characteristics of envelope components for the SINTEF test cells.*

Building component	**Material**	**Thickness** [mm]	**Thermal conductivity** [W/(m·K)]	**Density** [kg/m³]	**Specific heat** [J/(kg·K)]	**U-value** [W/(m²·K)]
Test wall – renovated	Gypsum board	12.5	0.25	900	1000	0.22 (insulation-section) 0.63 (wooden studs-section)
	PE membrane	0.15	0.33	920	2200	
	Wood fibre insulation	98	0.038	50	2100	
	Wood fibre insulation (EASI ZERo material)	48	0.032	50	2100	
	Wood fibre/bitumen-based membrane	12	0.049	230	1800	
	Air gap (ventilated)*	23	–	–	–	
	Wooden cladding*	19	–	–	–	
Test wall – non renovated	Gypsum board	12.5	0.25	900	1000	0.33 (insulation-section) 0.82 (wooden studs-section)
	PE membrane	0.15	0.33	920	2200	
	Wood fibre insulation	98	0.032	50	2100	
	Wood fibre/bitumen-based membrane	12	0.049	230	1800	
	Air gap (ventilated)	23				
	Wooden cladding	19				
Internal walls/ ceiling / floor	Steel	0.6	50	7800	450	0.14
	PUR	150	0.022	30	1500	
	Steel	0.6	50	7800	450	

Internal door	Steel	1	50	7800	450	0.18
	Insulation	0.12	0.022	30	1500	
	Steel	1	50	7800	450	

* Layers not included in the simulation models.

***Table 4**. Thickness and U-value for envelope components of the other rooms (adjacent to the test rooms).*

Building component	**Total thickness** [m]	**U-value** [W/(m^2·K)]
External walls	0.41	0.11
Roof	0.48	0.09
Floor	0.3	0.18

The test rooms' **heating system** consists of convector units. No cooling equipment or mechanical ventilation system are present.

The **airtightness** of the SINTEF test cells was verified by blower door testing, yielding a value of 2.31 ACH at 50 Pa.

SINTEF test facilities are not rotatable like the Passys cells but are fixed with a south-facing **orientation**.

2.3 Numerical models

IDA ICE and EnergyPlus [1,2] were used to simulate the test cell incorporating the innovative EASI ZERo wall components. Both simulation tools rely on advanced mathematical frameworks to model heat transfer in buildings by solving surface energy balance equations that consider solar radiation, longwave radiation exchange, convection, and conduction at the interior and exterior envelope surfaces.

The models in IDA ICE and EnergyPlus were developed using consistent input data in the two software. The facility's geometry, thermal zoning, and orientation were replicated through IDA ICE's graphical interface and DesignBuilder [3] for EnergyPlus. Opaque building envelope components were defined in both tools with identical layer configurations, ensuring consistent thermal and optical properties, as detailed in Sections 3.1 and 3.2. Specifically, the test walls were modelled using two separate components to account for the contributions of their main materials explicitly: one component including the insulation and the surrounding layers, and the other with wooden studs in place of the insulation.

Simulation parameters such as interior and exterior surface heat transfer coefficients, longwave emissivity, and shortwave reflectance were aligned across models. Table 5 and Table 6 show the radiative properties of the CEA Passys Cells' and SINTEF Test Cell' components, including longwave emissivity (thermal absorptance) and shortwave absorptivity for both inner and outer surfaces.

***Table 5**. Radiative coefficients in CEA Passys Cells.*

Building components	Inner surface		Outer surface	
	Longwave emissivity [-]	**Shortwave absorptivity** [-]	**Longwave emissivity** [-]	**Shortwave absorptivity** [-]
Test wall	0.9	0.4	0.9	0.4
Other external walls	0.9	0.2	0.9	0.1
Roof	0.9	0.2	0.9	0.8
Floor	0.9	0.4	0.9	0.5
Window frame	0.9	0.2	0.9	0.2
Internal wall	0.9	0.2	-	-

***Table 6**. Radiative coefficients in SINTEF Test Room.*

Building components	Inner surface		Outer surface	
	Longwave emissivity [-]	**Shortwave absorptivity** [-]	**Longwave emissivity** [-]	**Shortwave absorptivity** [-]
Test wall	0.9	0.3	0.9	0.1
Ceiling	0.9	0.3	0.9	-
Floor	0.9	0.5	0.9	-
Internal walls	0.9	0.3	0.9	-

As both IDA ICE and EnergyPlus compute heat transfer through building envelope components using one-dimensional heat conduction models, linear **thermal bridges** cannot be represented explicitly. This simplification may introduce noticeable errors, particularly in small-scale experimental structures such as the test cells.

To account for these effects in the CEA facility, linear thermal transmittance coefficients (Ψ-values) were calculated for the wall–wall, wall–ceiling, window–wall, and wall–floor junctions using two-dimensional finite element simulations in Flixo 8.2 [4]. These Ψ-values were subsequently implemented in both simulation models. The resulting thermal bridge coefficients are reported in Table 7.

***Table 7**. Linear thermal transmittance (Ψ-values) for the main junctions between building components in the test room, based on internal and external dimensions.*

	Linear thermal transmittance, internal dimensions, Ψi [W/(m·K)]	**Linear thermal transmittance, external dimensions, Ψe** [W/(m·K)]
External wall/Test wall	0.042	-0.090
External wall/Floor	0.077	0.010
Test wall/Floor	0.042	-0.114
External wall/Roof	0.021	-0.046
Test wall/Roof	0.043	-0.137
Window/Test wall	0.016	0.016

Thermal bridges were not explicitly calculated for the SINTEF test cell, since only the test wall is exposed to outdoor conditions, and their influence was therefore considered negligible.

An ideal **heating system** was used in both models. In IDA ICE, this was implemented using a PI controller, while in EnergyPlus the IdealLoadsAirSystem object was used. These control strategies avoid unrealistic high-frequency cycling and provide a stable representation of heating demand, which is appropriate for envelope-focused performance analyses.

Weather data were obtained from local meteorological stations located near the laboratory facilities in Trondheim and Chambéry. To ensure consistent boundary conditions, custom weather files were generated for each simulation tool. For EnergyPlus, site-specific measurements were incorporated into a base EPW file using the Weather Converter utility. The same dataset was used to generate a PRN weather file for IDA ICE, with variables adapted to match the software input requirements.

Operational conditions, including occupancy and heating setpoints, followed the measurement plans defined for each facility (Table 8).

For the Passys cells, four **simulation cases** corresponding to the experimental configurations were analysed (Table 8). All cases apply to both Passys cells, which were operated in parallel.

For the SINTEF test cell, two simulation cases were considered (Table 9). Case 1 represents the non-renovated configuration, while Case 2 corresponds to the renovated configuration. Note that, in both facilities, the temperature set-point was kept constant by a thermostat connected to a convection heater. A slight, consistent error was observed between the fixed set-point and the actual temperature in the room. Therefore, in the simulation we have preferred to use the actual average temperature rather than the selected set-point.

The simulations were performed using the default temporal discretization approach of each simulation engine, namely a fixed time step of 10 min in EnergyPlus and an adaptive time-stepping scheme in IDA ICE. Simulation outputs were recorded at 10-minute intervals for the CEA Passys cells and at 1-hour intervals for the SINTEF test cell, to match the temporal resolution of the available measurements.

The **analysed variables** included the operative temperature in the test room, the surface temperatures of the test wall and window, and the heat flux through the wall.

***Table 8**. Measurement plan for both CEA Passys Cells, run in parallel.*

Case	Simulation/measurement period		Window's blinds	Temperature set-point in test room	Temperature set-point in adjacent room	Ventilation	Occupancy	Orientation
	Starts	Ends						
1	13-Feb 2025	25-Feb 2025	drawn	20 °C	15 °C	Off	None	North
2	27-Feb 2025	16-Mar 2025	open	20 °C	15 °C	Off	None	North

3	18-Mar 2025	30-Mar 2025	drawn	22 °C	15 °C	Off	None	South
4	1-Apr 2025	13-Apr 2025	open	free floating	15 °C	Off	None	South

***Table 9**. Measurement plan for SINTEF Test Cell*

Case	Simulation/measurement period		Temperature set-point in test room	Temperature set-point in adjacent rooms	Ventilation	Occupancy	Orientation
	Starts	Ends					
1	02-Feb 2025	25-Mar 2025	19.5 °C	19.5 °C	Off	None	South
2	04-Apr 2025	5-May 2025	19 °C	19 °C	Off	None	South

2.4 Results

2.4.1 Simulation output and comparison with measured data

In this section, only the results for the renovated test cell are presented to illustrate the thermal and energy performance of the newly developed insulation material.

2.6.1.1 CEA Passys Cells

Figure 5 shows the measured and simulated operative temperature in the test room of CEA Passys Cell 2, across all four experimental cases.

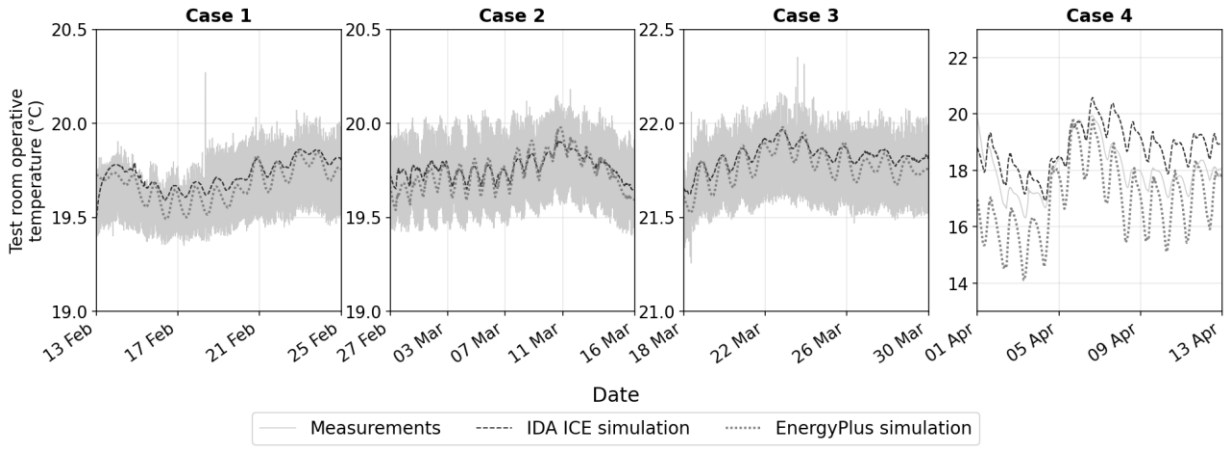


***Figure 5**. Operative temperature in the test room: measurements and model predictions for all cases.*

Both IDA ICE and EnergyPlus accurately capture overall trends and daily variations, with the strongest agreement in heated north-facing cases. Larger discrepancies appear in south-facing, free-floating scenarios, where indoor temperatures are more affected by solar gains and transient thermal effects.

Figure 6 illustrates the results for the interior surface temperature in the bio-PUR section of the test wall.

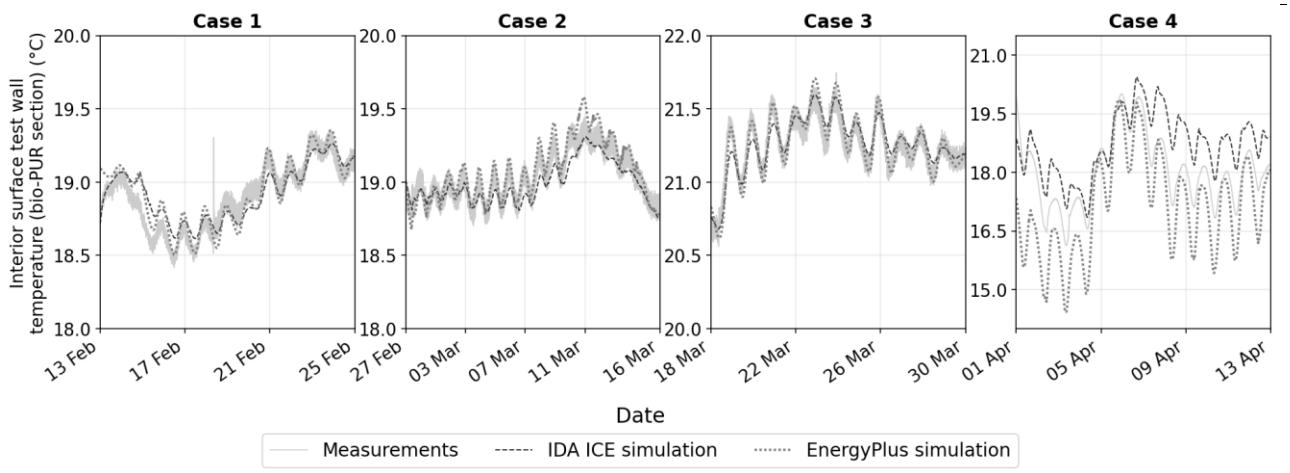


***Figure 6**. Interior surface temperature of the test wall (bio-PUR section): measurements and model predictions for all cases.*

The measurements show clear diurnal cycles, with distinct differences between daytime and nighttime conditions. Both simulation tools reproduce the magnitude and timing of these variations well. However, larger deviations occur during periods of high solar exposure, most notably in Case 4.

Figure 7 compares the measured and simulated interior temperature of the window glazing.

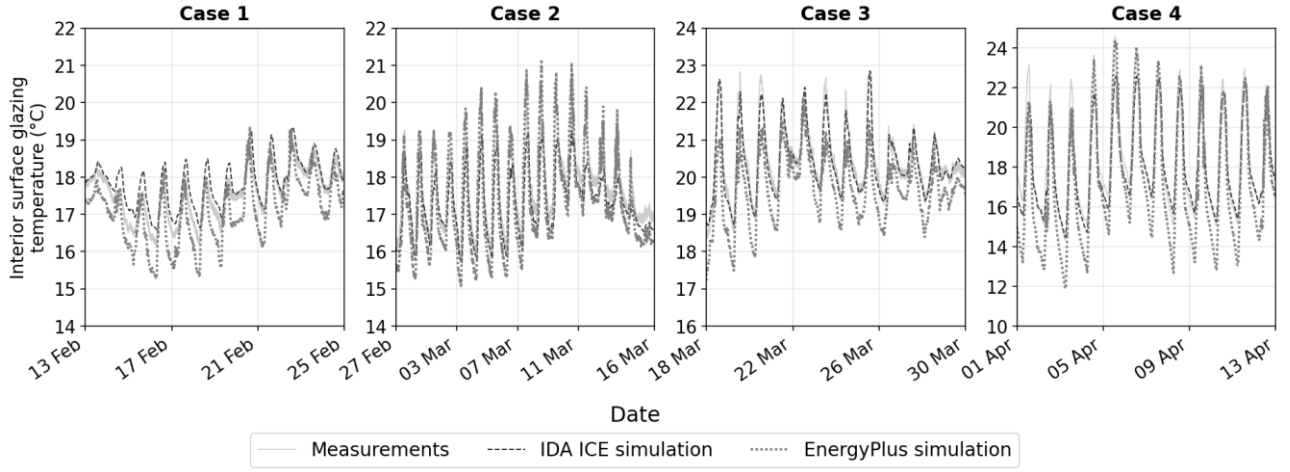


***Figure 7**. Interior surface temperature of the window glazing measurements and model predictions for all cases.*

The measurements show pronounced daily shifts. Both simulation tools capture the overall trends; however, differences in peak temperatures are observed, especially under south-facing, unshaded conditions, suggesting the sensitivity of glazing temperature predictions to solar radiation modelling and convective heat-transfer assumptions.

Figure 8 shows the results for the heat flux through the bio-PUR section of the test wall.

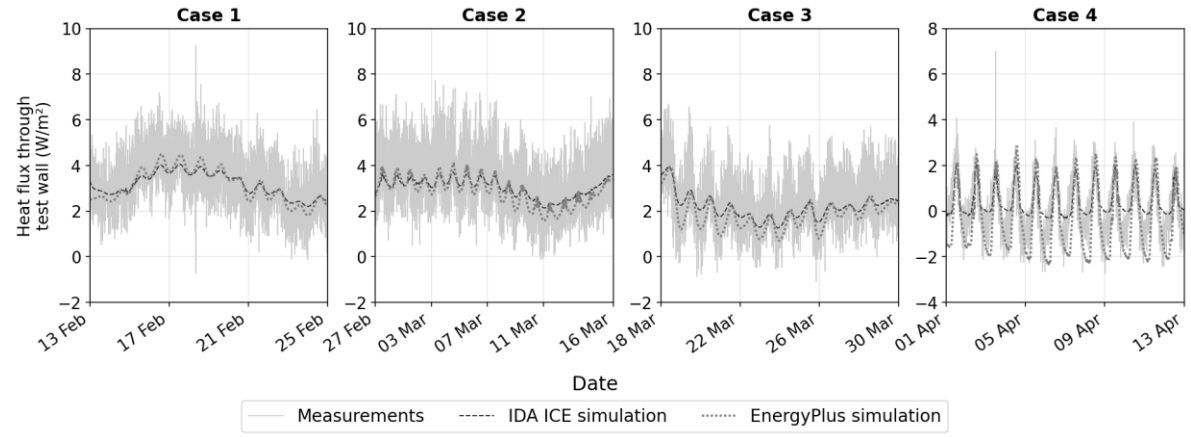


***Figure 8**. Heat flux through the test wall (bio-PUR section): measurements and model predictions for all cases.*

As visible in Figure 8, measurements are characterised by significant high-frequency fluctuations, most likely related to sensor sensitivity and dynamic boundary conditions. Despite this variability, both IDA ICE and EnergyPlus reproduce the main trends and average heat-flux levels, with larger relative deviations associated with increased solar exposure and reduced control damping.
Table 10 compares the simulated energy use from IDA ICE and EnergyPlus with measured data for the three assessed cases with the heating system on.

***Table 10**. Simulated and measured energy use for the three experimental/simulation cases of the renovated CEA Passys cell.*

	Case	Period	IDA ICE	EnergyPlus	Measurements
Total energy use (kWh)	1	13.02-25.02	41.7	45.4	46.3
	2	27.02-16.03	55.7	56.5	56.5
	3	18.03-30.03	32.2	35.3	35.9

2.6.1.2 SINTEF Test Cells

Figure 9 shows the measured and simulated operative temperature in the test room of SINTEF Test Cell 2.

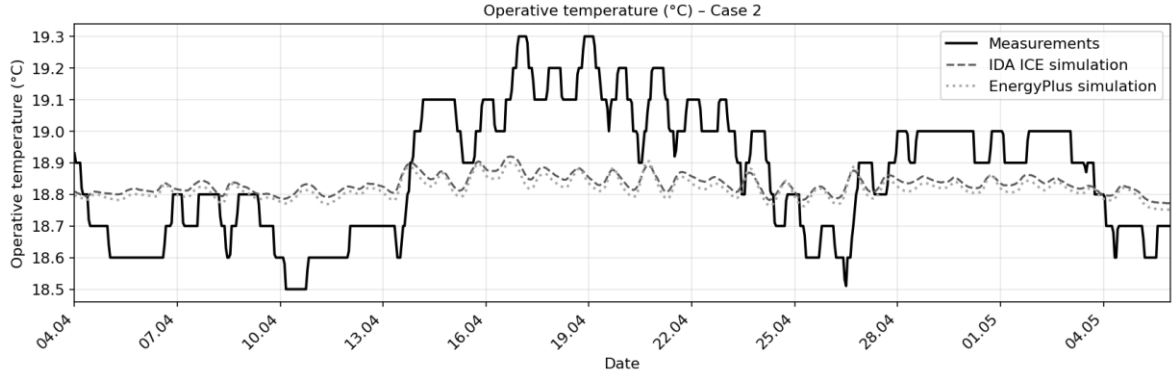


***Figure 9**. Operative temperature in the test room: measurements and model predictions for Case 2.*

The measured operative temperature shows relatively small variations over the assessment period, with step-like changes reflecting the control strategy and internal conditions. Both IDA ICE and EnergyPlus reproduce the overall temperature level and the temporal evolution well. The simulated temperatures are smoother than the measurements and slightly underestimate short-term variations but remain close to the measured values throughout the period.

Figure 10 illustrates the results for the interior surface temperature in the bio-PUR section of the test wall.

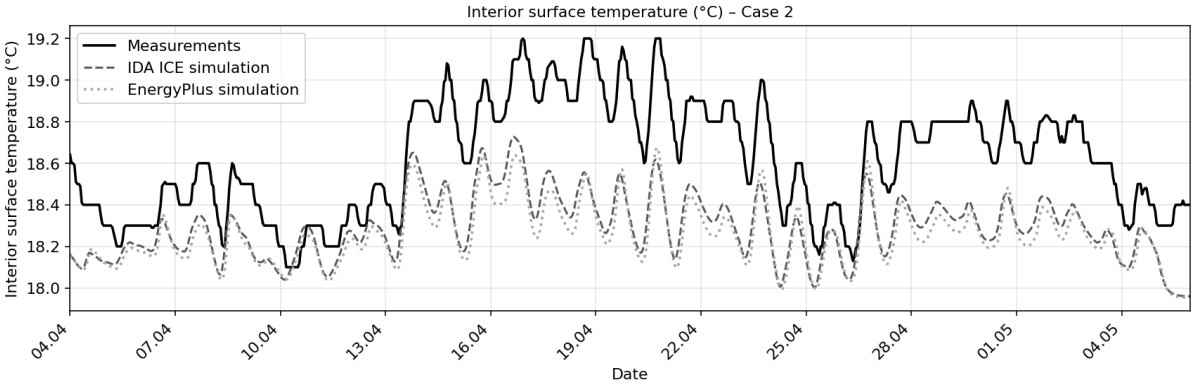


***Figure 10**. Interior surface temperature of the test wall: measurements and model predictions for Case 2.*

In contrast to the operative temperature, the surface temperature exhibits more pronounced diurnal variations. Both simulation tools capture the timing of these daily cycles reasonably well. Differences between simulations and measurements are more evident during daytime periods, when surface temperatures are influenced by transient boundary conditions.

Figure 11 shows the results for the heat flux through the bio-PUR section of the test wall.

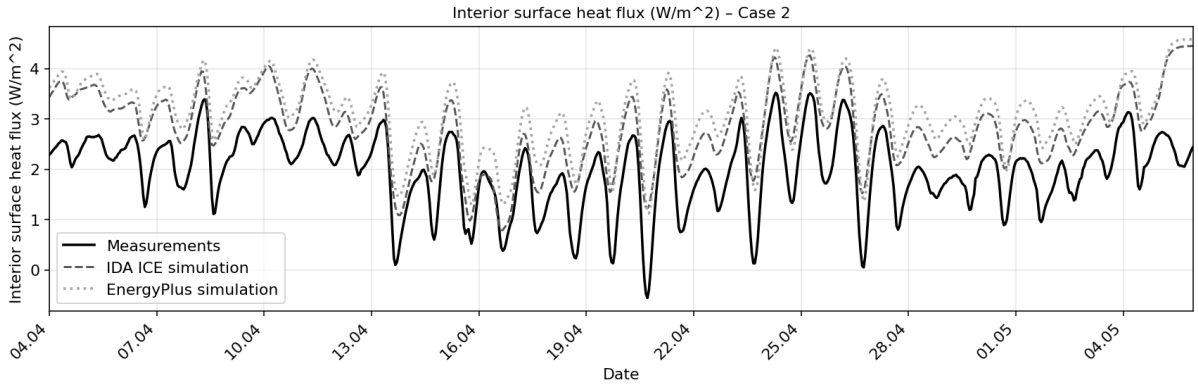


***Figure 11**. Heat flux through the test wall: measurements and model predictions for Case 2.*

The measured heat-flux displays clear diurnal oscillations, with higher magnitudes during daytime periods. Both IDA ICE and EnergyPlus reproduce the main temporal patterns and average heat-flux levels. However, short-term deviations between simulations and measurements occur intermittently, particularly during periods of increased solar influence, indicating a higher sensitivity of heat-flux predictions to transient effects compared to temperature-based variables.

Table 11 compares the simulated energy use from IDA ICE and EnergyPlus with measured data for the two assessed cases.

Table 11. *Simulated and measured energy use for one experimental/simulation case in SINTEF post-renovation test cell.*

	Case	Period	IDA ICE	EnergyPlus	Measurements
Total energy use (kWh)	2	4.04-5.05	26.3	30.6	24.8

Although both tools show good agreement with the measured operative temperature, surface temperature, and heat flux, EnergyPlus over-predicts the measured heating energy use by approximately 23%. This difference is likely attributable to the cumulative effect of small discrepancies in the modelling of transient heat transfer, solar gains, and heating-system control.

3 Conclusion

The numerical models for the EASI ZERo experimental facilities were developed in two simulation software packages, i.e., IDA ICE and EnergyPlus, using consistent assumptions regarding geometry, material properties, boundary conditions, and operational settings. The use of aligned input data and calibrated parameters ensured comparability between the two simulation environments and the measurements.

The results show that the adopted modelling approach is robust and suitable for assessing the thermal and energy performance of the EASI ZERo renovation solutions. The validated numerical models can support further analyses and optimisation of building envelope designs within zero-energy renovation scenarios.

References

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