nZEB Roadshow
Bulgaria | Croatia | Romania | Greece | Italy

Report on the training facilities designed and produced in the pilot countries

Deliverable 3.2 of the NZEB ROADSHOW project

Responsible partner: ZEPHIR

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WWW.NZEBROADSHOW.EU

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EXECUTIVE SUMMARY

The present document, "Report on the training facilities designed and produced in the pilot countries" (Deliverable 3.2 of the NZEB Roadshow project), summarizes the activities carried out by each individual partner from the participating countries (Bulgaria, Croatia, Greece, Italy and Romania) regarding the design and construction of mobile demonstration units to support the organization and conduction of dedicated nZEB days around the territory of each country. The task is focused on the design and construction of transportable demonstration and training facilities and on the development of specifications for spatial planning for successful organization and conduction of the nZEB days.

The report sets out full specification and details of the facilities produced during the project and the related design process. It is drawn up by ZEPHIR (Italy) as a leader of the related activities, using materials as technical drawings, reports, and pictures shared by the responsible project partners EnEffect (Bulgaria), Faculty of Civil Engineering at the University of Zagreb (Croatia), Hellenic Passive House Institute (Greece), and Cluster PRO-nZEB (Romania). Additional information regarding the scenarios for organization and conduction of nZEB days is available in annexes to the report "National Marketing Strategies with monitoring and evaluation scheme", while specification and details regarding gamification instruments and equipment are presented in the report "Guidebook for games and demonstrations on energy efficiency in buildings", both available at the "Publications" section of the nZEB Roadshow website.

INTRODUCTION

Each partner, according to their capacities, the respective country's typical construction traditions, the type of planned events and the target audience foreseen in each event, designed, and realized different training facility. In the following sections, divided by country, the activities carried out within the WP3 are reported. The realized training facilities are described: mobile home units (MHU), mockups, games and other staff used to train, demonstrate and in general involve people during on-line and off-line nZEB Roadshow events.

Firstly, a general description provides an overview of the produced facilities. The selected typologies (MHU, trucks, mockups, games, and other staff used to train and involve people) are highlighted, according to the stakeholders intended to be addressed, the organized events and activities, the characteristics of each country and all the aspects related to the concept and the general vision that guided the choice. Secondly, a technical description highlights the main features of each facility linked with the nZEB principles based on the Annex 1-Checklist for demonstration equipment's design (D3.1). More in detail, especially in the case of Mobile Home Units and training trucks, the technical description presents key information related to the following elements: envelope, windows and shadings, HVAC systems, air tightness, (RES) energy systems and possibly heating and cooling systems.

In addition, supplementary data and information are included as:

- Significant features: performance, demonstrated by monitoring reports, as graphs or data sheets, highlighting the performances of the produced facility in accordance with the nZEB features, or sustainability aspects, as materials selection; RES installation; recycle and re-use aspects; etc.
- Engagement/feedback: obtained effects on the addressed stakeholders, reporting for examples comments by visitors (if there were); interest by not expected stakeholders; attraction of industrial (or other) partners; etc.
- Lessons learned: dimensions and transport difficulties; strict country regulations; difficulty in finding industrial partners, materials, workforce; unexpected costs; etc.

The present report could be a useful document for stakeholders interested in producing similar facilities, highlighting measures and practical methods to design, produce, install and transport equipment and facilities to demonstrate and train the nZEB principles.

DESIGNED AND PRODUCED TRAINING FACILITIES

ITALY

ZEPHIR, the Italian partner, was involved in the support of partners engaged in the realization of training facilities.

One of the main activities that involved the Italian team was the writing of the Guidelines for design and operation of mobile training and consultation units (D3.1).

For the writing process several key stages have been identified:

1. Identification of all the feasible mobile training and consultation units.

2. Definition of keywords and general guidelines to follow in order to be compliant with the nZEB Roadshow goals:
    a. MULTITASKING: participation of different level of attendants/visitors (e.g., end-users, students, designers, construction workers).
    b. PRACTICAL: effortless to pack, assemble and disassemble, exhibit.
    c. REUSABLE/REVERSABLE: implementation of a reuse concept to guarantee the reversibility of materials and equipment and to save costs and materials.
    d. SELF-OPERATING: able to work without (external/on-site) energy connections thanks to the implementation of renewable sources.
    e. SUSTAINABLE: use of green materials and technologies.
    f. TRANSPORTABLE: easy to move and transport.
3. General description of each mobile training and consultation unit, with indications on:
    a. GOALS: the result or achievement toward which unit is directed
    b. ACTIVITIES: actions, games, potential activities to be carried out with the help of the unit or within it (e.g., real time demonstrations; video showing; etc.)
    c. ATTENDANTS/VISITORS: interested and involved stakeholders.
4. Technical description of each mobile training and consultation unit: size and weight; country regulations and requirements, components, and materials; landing and support; heating, ventilation, and air conditioning (HVAC), renewable energy sources (RES); other equipment (e.g., monitoring and measurement staff; etc.).
5. Production of a Checklist (Figure 1) for demonstration equipment's design (Annex 1 to the D3.1 Report) to help partners in the design and production of the respective mobile training and consultation units, as well as in the report of the ongoing activities, with indication of the following main data:
    a. TYPE OF EQUIPMENT
    b. MOBILITY and TRANSPORTATION
    c. SIZE and WEIGHT
    d. PROJECT
    e. STRUCTURE
    f. ENVELOPE
    g. HVAC
    h. SECURITY SYSTEMS
    i. LIGHTING
    j. RES
    k. INTERNAL GAINS
    l. MONITORING/MEASURING EQUIPMENT
    m. IN SITU EQUIPMENT
    n. CONNECTIONS (need of external)
    o. SPECIFIC FEATURES
    p. STAFF
    q. STAKEHOLDERS/END-USERS
    r. OBSERVED DIFFICULTIES

D3.2 Annex 1: Check-list for design of demonstration equipment				
GENERIC DATA				notes
COUNTRY	BG			
LOCATION (city)	Sofia			
POTENTIAL/FORECAST LOCATIONS/EVENTS IN THE COUNTRY	Burgas, Gabrovo, Smolyan			
POTENTIAL/FORECAST LOCATIONS/EVENTS OUTSIDE THE COUNTRY	Greece, Romania			
TYPE OF EQUIPMENT	mobile home unit (MHU)			
DESCRIPTION				
MOBILITY/TRANSPORTATION				notes
fuel	electric			
transportation type	needs to be towed by another vehicle (ex:			
transportation project	necessary - not available			
SIZE				notes
width x length x height [m]	2,50 x 6,00 x 4,00			
weight [kg]				
PROJECT				notes
dwg files	available			
SketchUp model	available			
pictures	available			
promotional material	-			
other (specify)	*Plan Groungfloor (pdf file)*			
STRUCTURE				notes
technology	other	(specify ==>)	*Combined wood and steel*	
construction details	-			
ENVELOPE				notes
wall (materials and U-values)	*ext to int:* *1. Wooden cladding 2cm* *2. Wooden battens 2x3cm c-c 60cm / ventilated layer 3cm* *3. Waterproof fiberglass veil* *4. Wooden battens 2x3cm c-c 60cm/ min. wool insulation* *5. Wooden battens 5x5cm c-c 60cm / min. wool insulation 5cm* *6. Wooden battens 5x5cm c-c 60cm / min. wool insulation 5cm* *7. Steel frame / min. wool insulation 8cm* *8. Vapour retarder* *9. Wooden battens 5x5cm c-c 60cm / min. wool insulation 5cm* *10. Wooden boards finish 1.5 cm*			

Figure 1. D3.1: Annex 1 - Checklist for design of demonstration equipment consultation units.

An other considerable activity conducted by the Italian team during the first months of the nZEB Roadshow project was to made available its know-how relating to the realization of Mobile Home Unit, mock-ups, equipped walls, etc. by organizing meeting (Figure 2), making available technical drawings, showing pictures and sharing experiencing difficulties both economic, as having to stay within the budget, and technical, as the unavailability of materials and equipment or transportation issues (ex: landing gears).

The last activity that involved the Italian team is the collection and the organization of all the data, reports, images, pictures, and information received by partners to the present final report writing (D3.2).

Figure 2. Figure 0: Designer's meeting (15.01.21).

Due to the serious pandemic situation in Italy which involved the interruption of all types of live events, the Italian team had to modify the initially set objectives and the strategy to respect the nZEB Roadshow project main goals, namely:

- To increase the understanding of the benefits of nZEB and skilled labour within the stakeholders' groups shaping the real estate market.
- To provide wider opportunities for vocational training, career counselling and retraining/upskilling of professional builders.
- To conduct training for building specialists.
- To improve the reputation of the construction profession among young generations, through closely relating it to the modern environmentally responsible lifestyles.
- To raise interest in nZEB construction by using appropriate channels across different audiences and personalized communication.
- To illustrate and demonstrate the specifics of nZEB through interactive consoles, schemes, graphs and individual consultations for clients.
- To build a positive image of nZEB as a modern solution and as a comfortable and healthier alternative to standard construction.

In order to maintain all the previous commitments, the new strategy envisaged the implementation of tools for the creation of online events and the preparation and distribution of high quality materials to be shared online with all interested stakeholders, such as videos, webinar, pictures, etc.

Therefore, live events and nZEB weeks have been replaced with on-line dissemination events and materials, having the advantage of informing different stakeholders and target groups about the development of the project outputs with the assistance of communication and dissemination instruments and tools.

In particular, the Italian team used Semrush, an all-in-one tool suite for improving online visibility and discovering marketing insights, the Italian team have been able to identify and address potential promoters and interested persons in an easy way. Our tools and reports are able to reach a wide targeted audiences and to report in detail the number of engaged stakeholders with posts and announcement, the reactions, the likes and data as the geographical origin, the profession or the gender, thus saving lots of internal resources and being very precise on numbers and engagements (Figure 3).

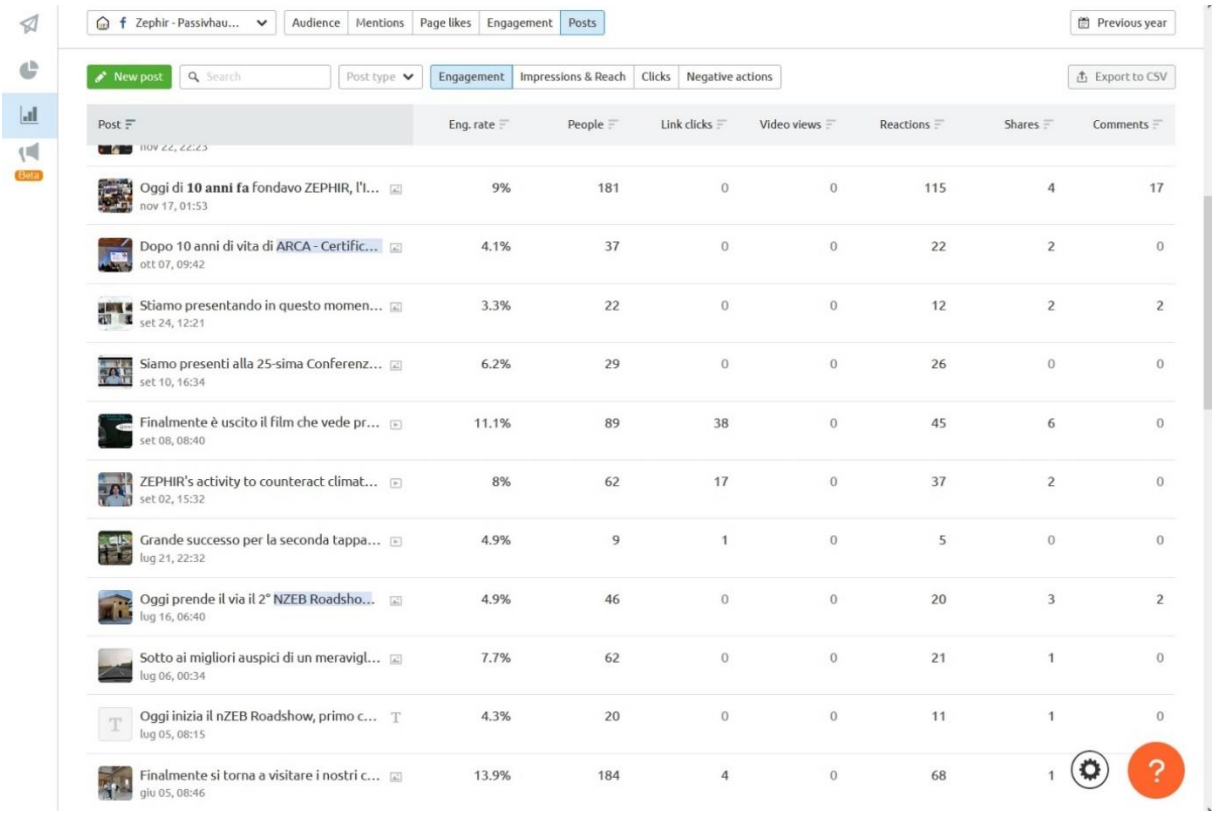


Figure 3. A view of the reports achievable through the use of Semrush.

BULGARIA

GENERAL DESCRIPTION

The main idea behind the training facilities in Bulgaria is to engage stakeholders from different working backgrounds and various trade groups and to introduce them to the nZEB concept in a straight forward manner, using a type of building that everyone can relate to and is most widely used by the majority of the people: a residential building. Presenting a mockup model of a house, helps deliver the message that nZEB buildings are achievable and affordable and can provide a better standard of living. Moreover, it stimulates the interest in non-professional stakeholders and makes the topic more relatable and engaging to the general public. Thus, the project idea to create a nearly zero energy

mobile home unit to travel from one event or site to another, demonstrating the comfort, the improved air quality, the various health benefits, and the low energy consumption, achieved by employing the basic nZEB construction principles.

The Bulgarian team have completed the design and have purchased all the necessary components and are currently monitoring the ongoing construction of the **Mobile Home Unit.** For the construction process several key stages have been identified:

6. Production of the base of the Mobile Home Unit
7. Construction of the unit's load-bearing metal structure
8. Construction of the building envelope: installation of internal and external insulation, installation of energy efficient windows, all while ensuring the airtightness of the unit
9. Completion of the indoor works: furnishing, installation of technical equipment, RES and monitoring equipment
10. Production and provision of information materials for dissemination, on the topic of nZEB, in the Mobile Home Unit

To facilitate the mobility of the unit and to reduce the costs of transportation and to improve the accessibility to various sites a decision was made to equip the Mobile Home Unit with its own chassis. It will therefore be possible for the unit to be connected to a vehicle and thus could easily be transported to any given location within the country and abroad. However, this requirement created the necessity for a stable construction that can endure both tension and vibration forces, and at the same time be lightweight. Thus, a mixed construction method was identified as the most suitable. Steel is used for the chassis and the load-bearing structure thus ensuring the durability, the low weight, and secured connections between the different elements of the unit's skeleton. Additionally wooden beams and columns are used to form the walls of the unit which in turn will lower the overall energy consumption and prevent any construction thermal bridges. There are several layers of thermal insulation all over the building envelope. The airtightness is achieved through the use of airtight membranes and tapes. The façade walls are ventilated and finished with wooden cladding. For the installation of pipes and cables in the walls a 5cm wall gap, filled with thermal insulation between the airtight layer and the wall finish, is provided. The roof is single pitched and is made out of insulated metal panels. Project details are shown in Figure 4.

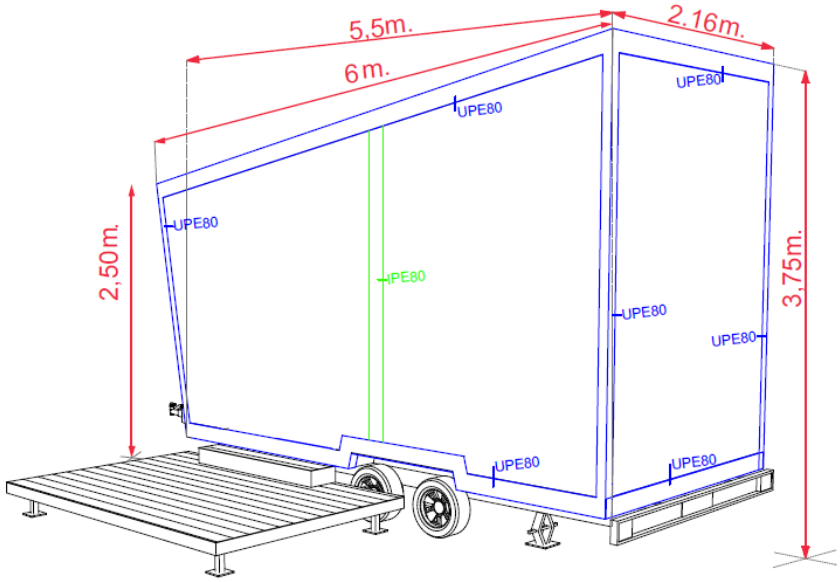


Figure 4: First stage, the steel construction and chassis.

Currently, stage one is complete, and the chassis is registered with the relevant Bulgarian authorities thus ensuring the readiness for travel in April 2022. Photos of the finished stage are shown on Figure 5.

Figure 5: Steel structure and chassis.

Due to many delayed deliveries caused by the Covid outbreak the next construction stages started several months later than planned. Nonetheless, all the materials and equipment are delivered and are currently being prepared for the start of the construction works in January 2022. The second stage is expected to be complete before the end of February and the final three stages before the end of March 2022.

The concept of the Mobile Home Unit, its simple and affordable design are all intended to capture the attention of a wide range of stakeholders: the public, white- and blue-collar professionals, the media, local authorities etc. Precisely for this reason, in and around the unit there will various demonstration, information materials such as:

- Wide screen TV displaying short but captivating presentations on the main nZEB principles
- Exhibits of different energy efficient construction products and connection details
- Live demonstrations of Blower Door testing and infrared imaging of the unit
- Measurements of the units' indoor comfort and air quality
- Measurements of the electrical consumption
- Mockups and information materials

The general idea behind every nZEB Roadshow event is to have on one hand the Mobile Home Unit on display for the public but on the other hand to have an exhibition of energy efficient building materials and products.

The events organized during 2021, before the completion of the Mobile Home Unit, were all events exhibiting building materials and components with at least 7 international and local companies presenting their highest quality products suitable for NZEB constructions, such as: airtightness materials, thermal insulations and special fasteners, systems for reducing thermal bridges, high quality window frames and windows, various types of ventilation systems and RES – both thermal and electrical ones.

All the exhibitions were conducted in parallel with trainings sessions, discussions, and awareness-raising presentations. Photos from passed exhibitions and meeting are presented in Figure 6.

Figure 6: Events under NZEB Roadshow.

TECHNICAL DESCRIPTION

The Mobile Home unit (Figure 7) will be towed by truck for transportation. Traveling and positioning the unit between different exhibitions will happen easily without police escort or other special services. The unit itself is 5,50 meters long, 2,50 meters wide and 4,00 meters high and can be parked at sites that are accessible to small trucks. After parking the unit need to be leveled.

360° overview of the inside of the **Mobile Home Unit** is available at:

https://kuula.co/post/n1/collection/7qpGH

Figure 7: Mobile Home Unit.

1. **Continuous thermal insulation (of optimal thickness)**

The basic principle followed when designing the Home Mobile Unit, besides the nZEB principles is using as light materials as possible. This is due to the fact that in order to be easily and economically transported the Mobile Home Unit must weigh less than 3500 kg. Therefore when deciding on the insulation materials, thermal conductivity and density were of high importance. Hence the insulation used is:

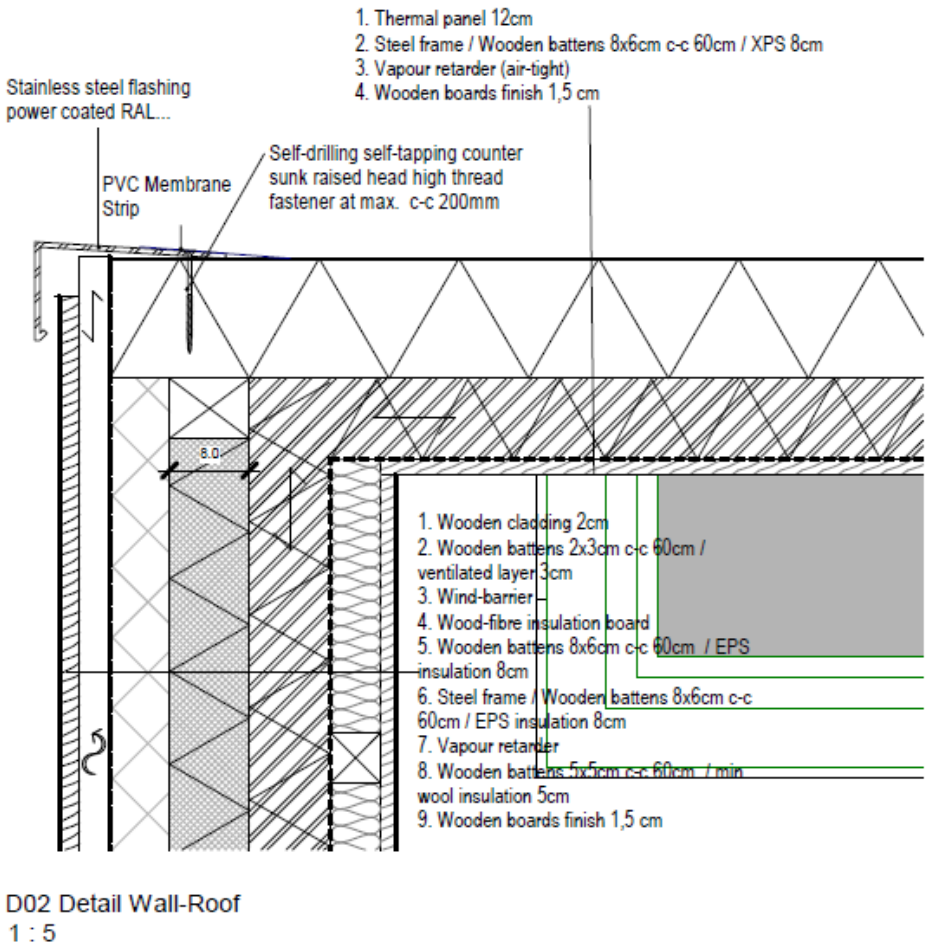
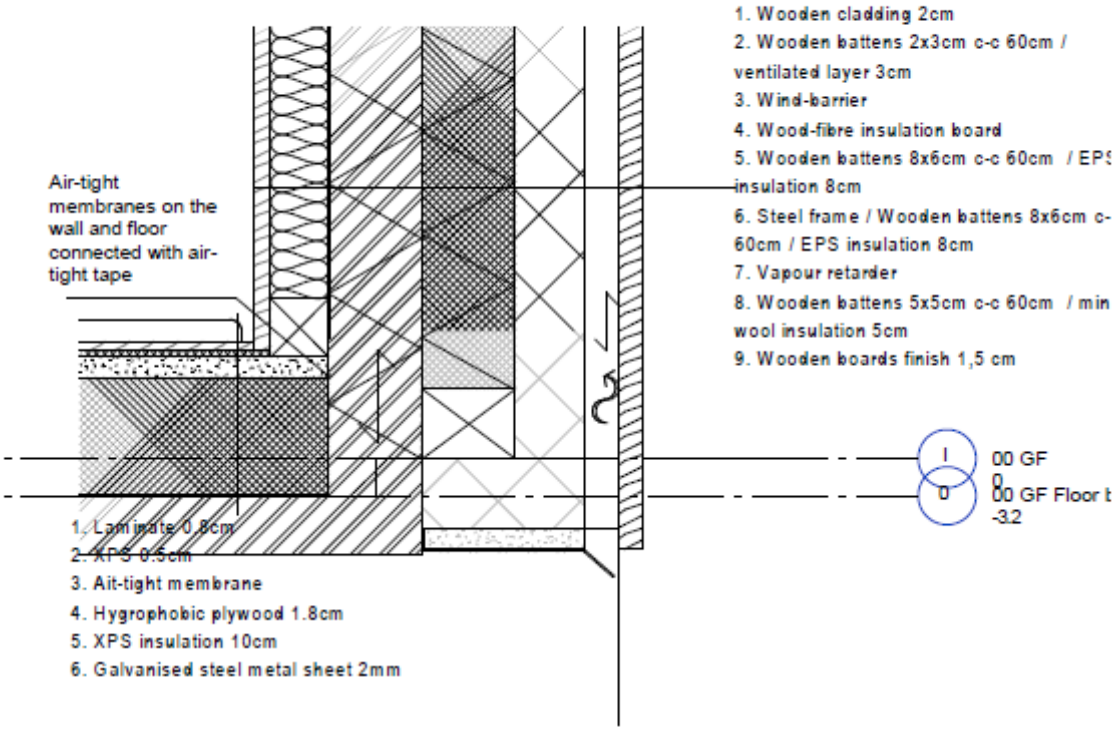


Figure 8: Wall-Roof Detail

a. polyurethane in the insulated metal panels for the roof.
b. EPS in the walls, wooden-fibre insulation board (so the outermost thermal insulation layer is installed without battens) and soft mineral wool insulation (class A reaction to fire was needed, since cables will be installed there as well) in the innermost insulation cavity layer.
c. XPS in the floor construction.



D07 Detail Wall-Floor

1 : 5

NOTES:

1. Window and door installation details are finalised after coordination with the supplier
2. GF lvl.: level ±0.00 m of the trailer construction
3. GF floor bottom: lelev -0.032 m. ,of which the floor construction starts

Figure 9: Wall-Floor Detail

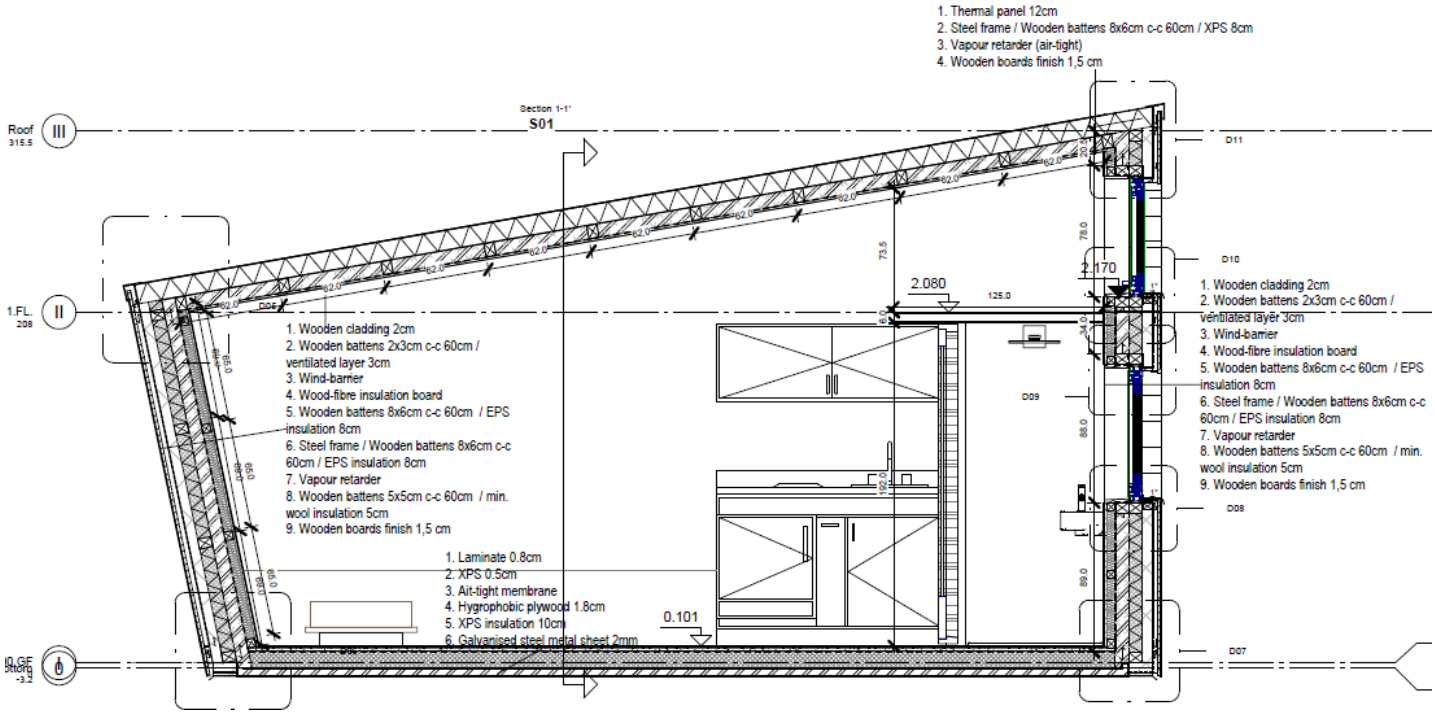


Figure 10. Longditudinal Section

2. High performance windows and shading

The triple glazing in the Mobile Home Unit is characterized by low-e coating and argon filling, with an U_g value of 0,60 W/m^{2}K. The total solar energy transmittance g=35%. The PVC Alumil windows' frames are suitable for Passive houses and U_f is 0,85W/m^{2}K.

Figure 11: Window sections.

The lift and slide system used for the main windows, that also serves as an entrance to the unit, is with low sill and allows full access to the Mobile Home Unit for people with disabilities.

Figure 12: Lift & Slide Window System Sections.

The shading of the unit will be provided separately, and installed on-site, so it can be transported in a different vehicle and thus reduce the load of the Mobile Home Unit. The shading itself is horizontal, consisting of wooden battens.

Figure 13: Visualization of the Continuous Insulation Layer and Shading Concept.

3. Continuous airtight layer

The airtightness is ensured with the use of airtight membranes on the inside of the building envelope. The membranes are thoroughly and securely connected with airtight tape. All outside connections are airtight and the passage of cables and pipes inside the Mobile Home Unit ape within the 'installation cavity' that is on the inside of the airtight layer and thus do not break it.

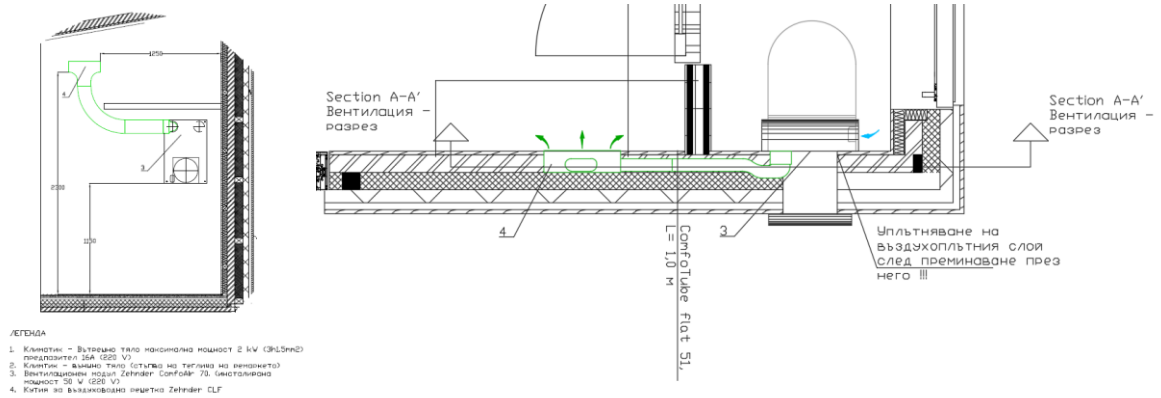
Figure 14: Position of the Airtight Layer.

4. Minimized thermal bridges

The thermal bridges are avoided altogether in the whole construction process. All the steel chassis parts are covered with 10,5 cm of XPS insulation. The metal studs of the main load-bearing frame are covered with 8cm XPS and also wood-fiber insulation boards. The steel UPE profiles are also filled with insulation since they are deliberately chosen to allow for that option.

5. Mechanical ventilation with heat recovery (MVHR)

The MVHR system is centralized with one intake and one outlet points. Fresh air will be delivered to the intake grill by flexible flat tube and the outlet will be directly through the ventilation unit which is based in the bathroom. The ventilation unit has heat recovery rate up to 90% and can provide an air flow of up to 60 m^3/h.



6. Heating and cooling systems

Taking under consideration the Bulgarian climate zones, the low specific heating and cooling demand and the small living area, the size of the smallest heat pump units on the market will be much bigger than the minimum requirements, but it will be able operate normally. The whole mobile home unit will be heated and cooled by a single wall mounted air-conditioner. The main technical characteristics of the air-conditioner are SCOP = 4 W/W, SEER = 5,2 W/W, heating capacity of 3,2 kW (range from 0,9 – 4,1 kW), and cooling capacity of 2,5 kW (range from 1,1 – 3,0 kW).

7. Renewable energy sources (RES)

One photovoltaic panel will be integrated on the roof and the produced energy will be saved in batteries and used in low voltage circle designed for the lighting and other appliances. The pitched roof provides the necessary slope for optimal positioning of the PV unit.

ADDITIONAL FEATURES/OTHER SIGNIFICANT INDICATORS

Performance

The monitoring system of the mobile unit is still not installed thus an analysis of the performance of the unit is still not applicable.

Sustainability

The wooden material used for the frame and facades has a FSC certificate, guaranteeing that the timber is not:

- illegally harvested.
- from areas where environmental and civil fundamental rights are violated.
- from forests whose basic protection values are threatened by management.
- from the conversion of natural forests into plantations or non-forest uses.
- from forests afforested with genetically modified plants.

The usage of non-natural products is limited only to the necessary ones, but these correspond to the needs of constructing a lightweight frame that can guarantee the ease of transportation on public roads without unnecessary disassembly.

Engagement/feedback

The interest of the general public is rather high even though the Mobile Home Unit is not yet completed. All industrial partners have showed great interest in the subject and are excited about the expected results. The thoughts and comments on the subject ever since the initial talks with suppliers and distributors of construction materials and products have been positive and optimistic. It is a general understanding and belief that for the national market such initiative and construction project as the nZEB Mobile Home Unit are essential and well overdue.

Judging by the interest of the professionally involved in the subject stakeholders and the relatively comprehensible matter, the Mobile Home Unit will gain popularity rather fast and reap success among the public too.

Lesson learned

When designing the Mobile Home Unit some of the main challenges that we were faced with, which were completely new to the design team, were the consideration of the total weight of the unit and the use of energy efficient materials. The nZEB concepts are already well known and commonly applied in the standard construction of the building envelope where nothing is too heavy or too wide. The challenges to adopt the construction techniques of a standard 'non-moving' nZEB house and adapt them to a mobile house are tremendous. However, by using new design solutions and highly energy efficient construction materials there are ways to achieve the goal of having a nearly zero energy mobile building that also induces the feeling of a real house, a real home.

CROATIA

GENERAL DESCRIPTION

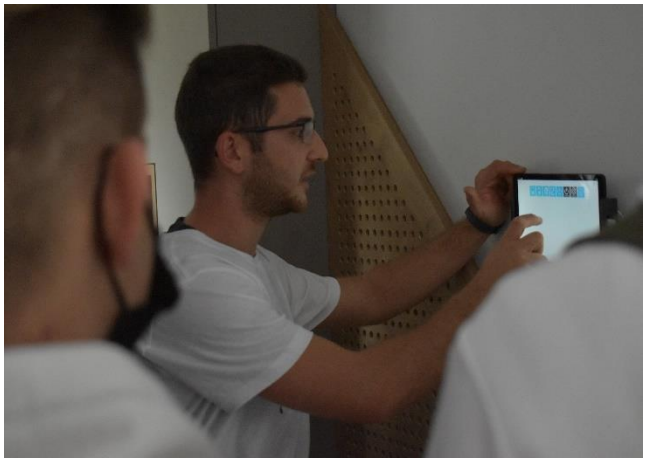
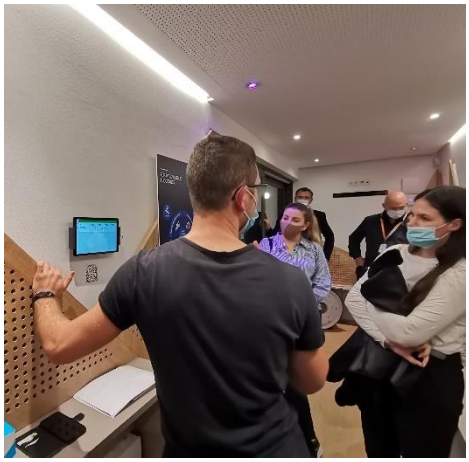
Driven by the idea to provide stakeholders a first-hand experience of what functional NZEB building should be in reality, with aim to bring that experience at the peoples' doorstep across the whole country, Croatian team decided to produce **Mobile Home Unit** called **"MUZA"** – Mobilna, Učinkovita, Zdrava, Arhitektura (eng. Mobile, Efficient, Healthy, Architecture) (Figure 15).

Figure 15. Croatian Mobile Home Unit "MUZA".

MUZA is envisioned as an educational NZEB pavilion tailored to the needs of a wide range of stakeholders with different background, such as general public, professionals, media, etc. Except the NZEB compatible materials, systems and technologies implemented in MUZA itself and accessible to the visitors, additional tools have been developed and prepared to facilitate Roadshow events, such as:

- **Interactive exhibition explaining basic NZEB principles and healthy living** – theoretical background, examples of materials and products, QR code redirecting to additional literature source for eager visitors.

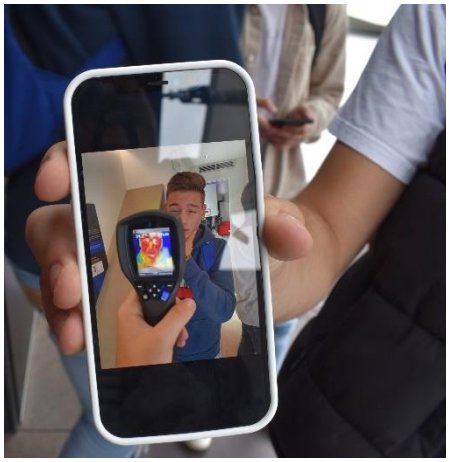
- **Tablets with MUZA's BIM model, central control unit and overview of real-time monitoring** – visitors can get information about all technical details of MUZA by exploring BIM model, they can learn how to control HVAC and other systems, they can get information about MUZA's current indoor air quality, energy consumption, energy production and hygrotermal performance of external wall.

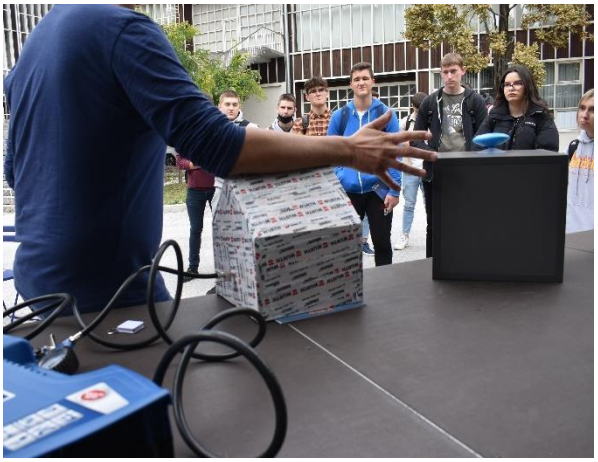
- **Online library of materials, systems and technologies installed in MUZA** – accessible through QR code. All products are structured in groups (building envelopes elements, HVAC, lighting, automation, interior, security, etc.) and their technical data sheets are joined.

- **Blower Door testing and infrared imaging** – live demonstrations





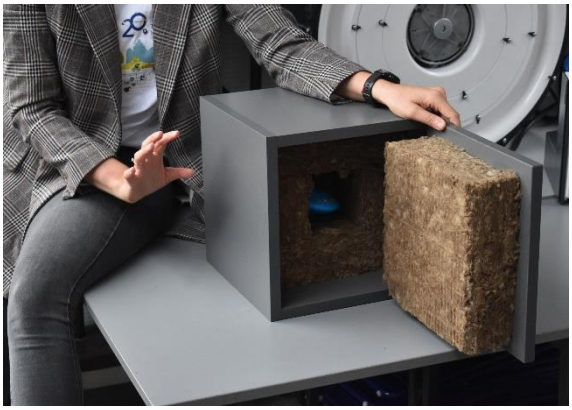
- **Airtightness mockups** – live demonstrations

- **Window sections made of different materials and types of glazing**


- **Comic book and brochure about the project and MUZA** – describing the main project goals and how basic NZEB principles are applied on MUZA

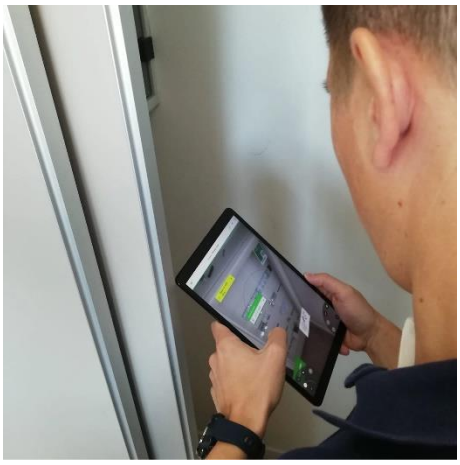

- **Soundproof box** – live demonstrations

- **Fire behaviour of materials mockup** – live demonstrations

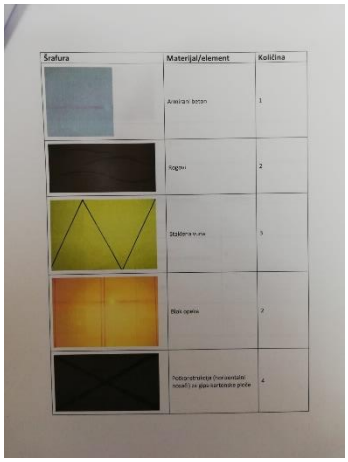
- **Security aspects of windows mockups** – live demonstrations


- **Augmented reality** – live demonstrations

- **Virtual reality**– live demonstrations


- **Condetti Creative System -** live demonstrations



Details about these tools can be found in Deliverable D4.1 “Guidebook for games and demonstrations on energy efficiency in buildings”.

TECHNICAL DESCRIPTION

MUZA needs to be transported on a flatbed truck (Figure 1) but special transportation under police escort was not an acceptable option since it would introduce additional complications and increase the transport costs. Therefore, MUZA’s external floor plan dimensions 9.00 × 3.00 m and height 3.25 m (on flatbed truck under 4.20 m) are within the dimensions allowed for road freight.

During the initial design phase, BIM model of MUZA was developed and used for preliminary analysis (Figure 16). It helped us to discuss and solve 3D details problems in digital environment, and to collaborate easier with contractors and supporters from industry. It also provided flexibility in energy variant analysis in early project phases.

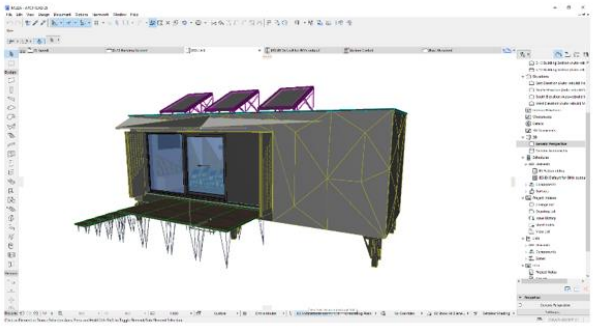
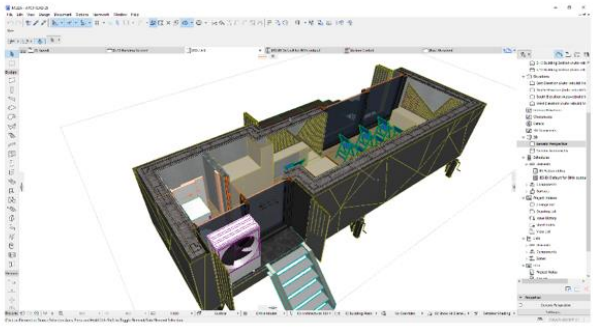



Figure 16. BIM model of MUZA and example of analyzed 3D detail.

Loadbearing structure is steel metal frame fixed to the six metal sheets which are foreseen for removable landing gears, as shown in Figure 17. Landing gears are used for loading and unloading MUZA from the flatbed truck.

Figure 17. Loadbearing steel structure and secondary substructure (left) and landing gear for lifting up the MUZA.

MUZA was designed and constructed from scratch respecting the main NZEB principles as follows:

8. Continuous thermal insulation (of optimal thickness)

Non-combustible insulation (mineral wool) is placed between load-bearing metal girders and secondary substructure, while continuity of thermal envelope is ensured by adding additional layers of thermal insulation in walls, roof, and floor. All characteristic layers of opaque building envelope elements are shown in Figure 18.

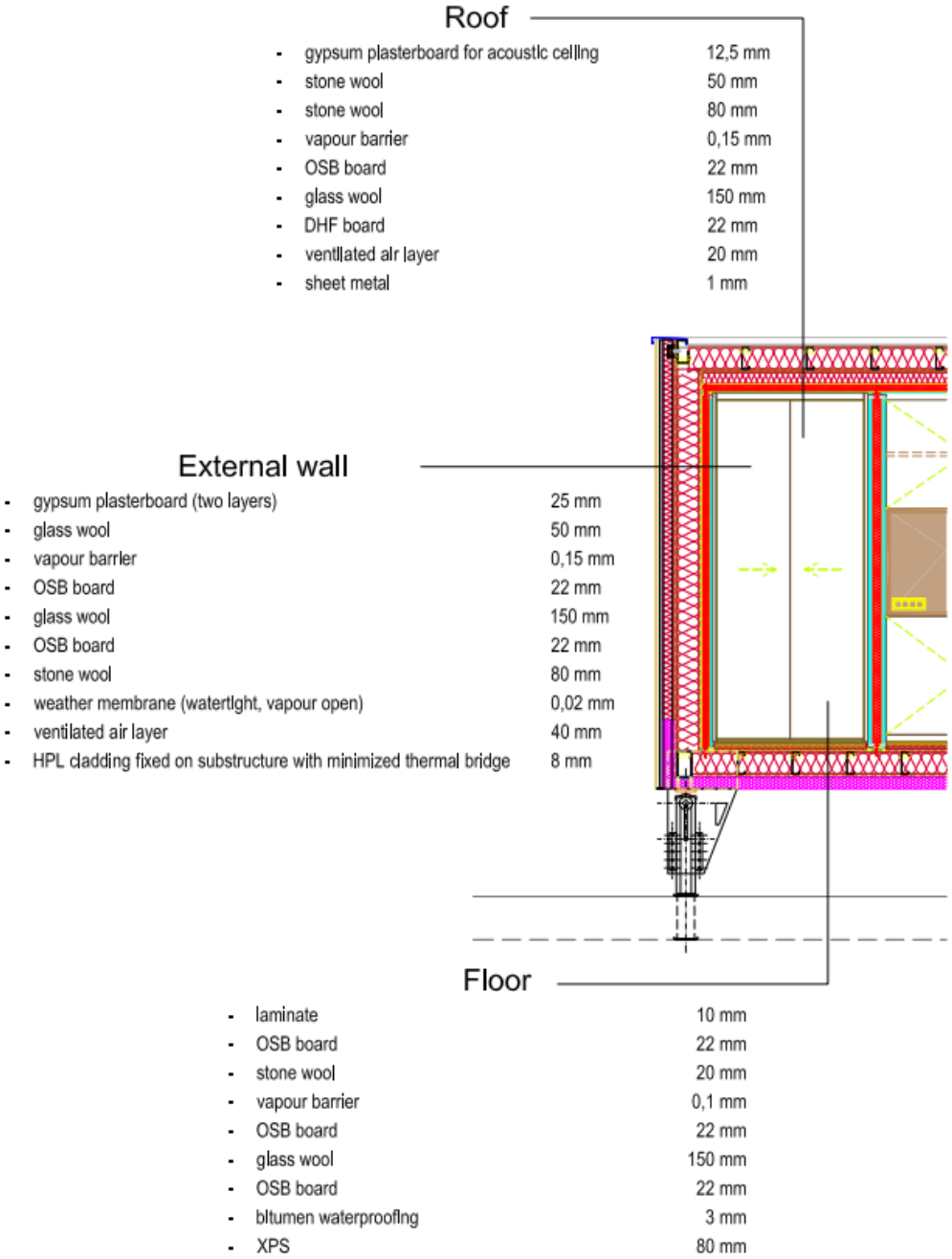
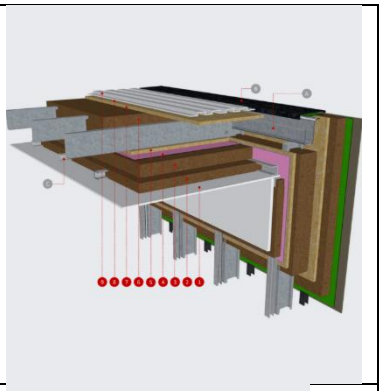
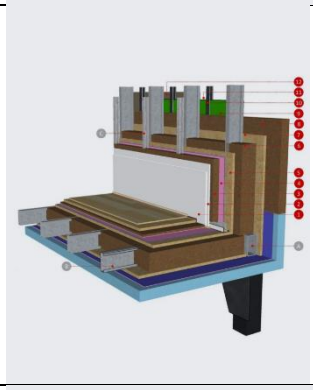
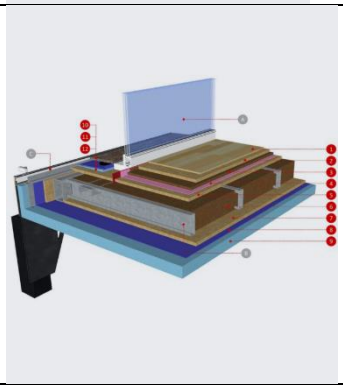


Figure 18. MUZA's opaque envelope assemblies.

The effect of thermal bridges caused by the steel loadbearing structure and secondary structure is taken into account during U-value calculation, resulting with effective U-value (Table 1.)

Table 1.

Opaque building envelope element	**Effective U-value [W/m²K]**	

External wall	0.216	
Roof	0.155	
Floor	0.155	

9. High performance windows and shading

Two sliding doors are characterized by triple glazing with low-e coating, argon filling and PVC profile. Larger sliding doors (3.7 × 2.2 m) have safety external and internal glazing (precaution measures due to the facts that MUZA will be publicly used and frequently transported).

Calculated thermal transmittance for lager sliding doors is U_w = 0.83 W/m^{2}K (U_g = 0.6 W/m^{2}K, U_f = 1.1 W/m^{2}K), and U_w = 0.97 W/m^{2}K (U_g = 0.7 W/m^{2}K, U_f = 1.3 W/m^{2}K) for smaller sliding doors (2.3 ×2.2 m), respectively.

Figure 19. Installation of larger sliding doors (first row) and smaller sliding doors (second row).

Large transparent elements in relation to relatively small useful floor area and indoor air volume, potentially can lead to overheating periods and thermal discomfort, thus adequate shading was foreseen (Figure 20):

i) *window shutters on both sliding doors acting as a lateral shading –* during transport they are closed and their primary function changes to protecting the glazing from mechanical damage caused by external factors (rocks, birds, etc.).

ii) *venetian blinds on lager sliding doors* – motorized blinds can be manually controlled through central unit, but they can be programed to start shutting down automatically at sunset.

iii) *self-load bearing textile overhang on lager sliding doors* – it can be easily removed and installed when needed.

Figure 20. Lateral shading on both sliding doors (first row); motorized blinds on larger sliding doors (second row left); textile overhang on larger sliding doors and closed window shutters (second row right).

10. Continuous airtight layer

Airtightness of the building envelope was achieved by applying (Figure 7):

i) *vapour barrier on the OSB boards* – overlapping was properly sealed using specialized sealing tapes.

ii) *all penetrations properly sealed using specialized products*

iii) *sliding doors installed in accordance with RAL guidelines using specialized products*

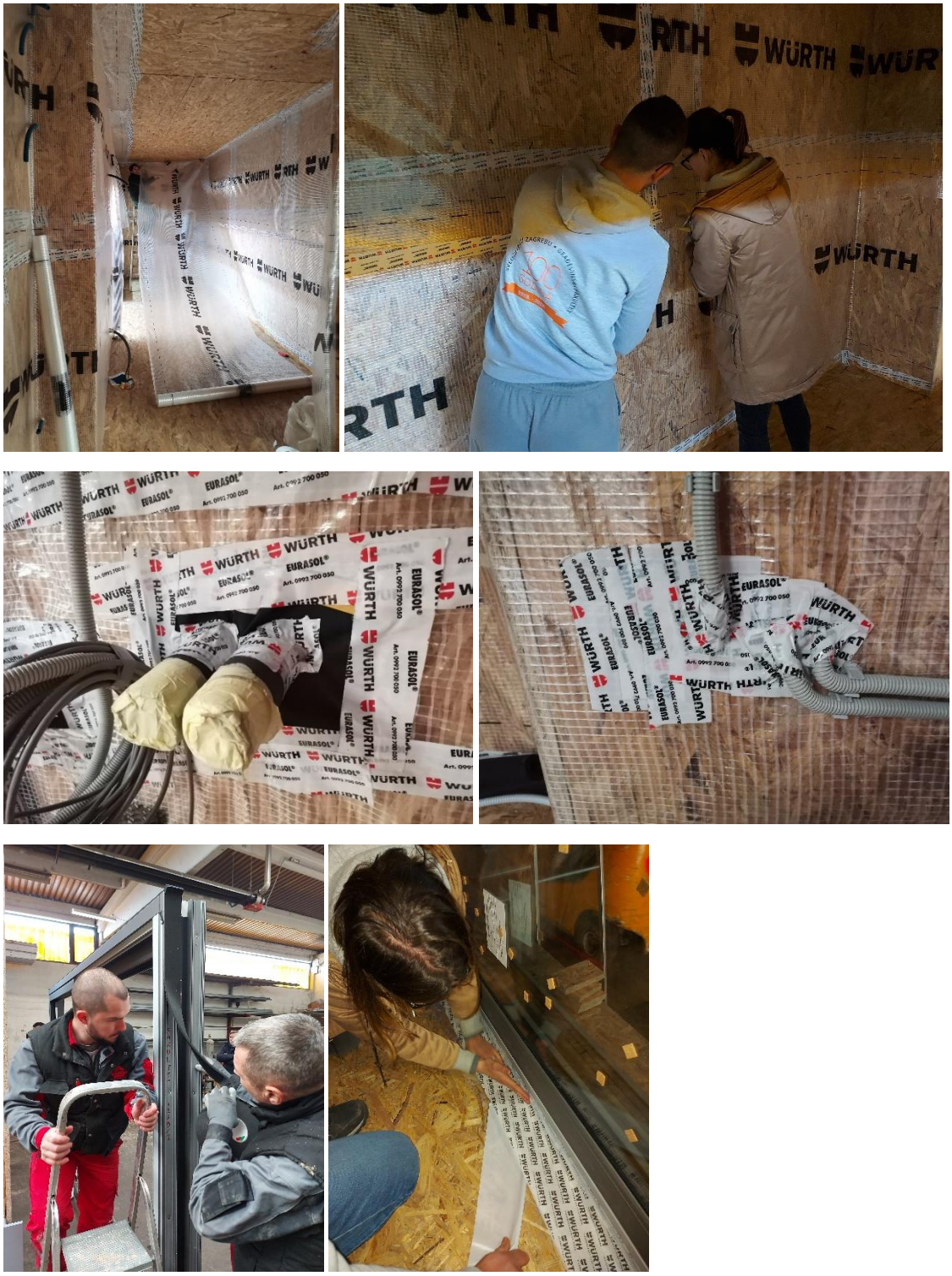


Figure 21. Installation of vapour barrier (first row); sealing of envelope penetrations (second row); installation of sliding doors according to RAL guideline (third row).

Prior the installation of gypsum plasterboards, airtightness was tested using Blower Door method (Figure 22) to detect potential leakages and improve the quality of works. Having in mind that n_{50} (air changes per hour at 50 Pascals) diminishes with building volume, it is considered that parameter q_{50} (cubic meters per hour of air leakages for every square meter of envelope at 50 Pascals) is more relevant, i.e., more realistic airtightness indicator, for MUZA's small volume. Based on Blower Door testing, airtightness of MUZA's envelope is q_{50} = 1.25 $m^3/h \cdot m^2$.

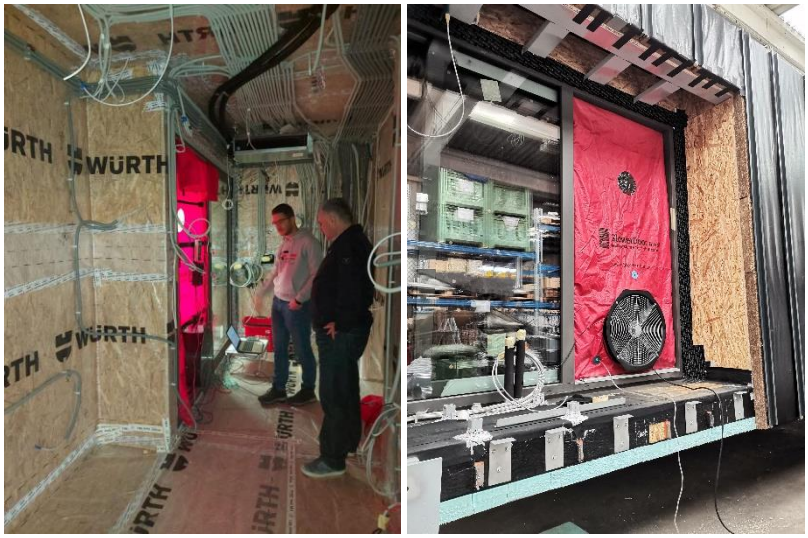


Figure 22. Determining MUZA's airtightness by means of a Blower Door test.

11. Mechanical ventilation with heat recovery (MVHR)

Intake of fresh air, crucial for a good indoor air quality, is realized by two units of decentralized mechanical ventilation with heat recovery, which at the same time allows saving energy.

Figure 23. Decentralized MVHR units installed in MUZA's external wall.

12. Minimized thermal bridges

With the goal to determine which detail solution are optimal for the case of MUZA in terms of energy efficiency, the analysis of most critical thermal bridges was performed (Figure 24).

Linear thermal transmittances (Ψ-values) and minimal surface temperatures on the interior surface ($T_{si,min}$) were calculated for different configurations of thermal bridges, and those who give the most favourable values were accepted in a way that they will be realized on the construction site.

U-values of walls, roof, and floor were calculated in a way that they include the thermal bridges caused by the steel secondary structure and substructure of the ventilated façade. This U-value is referred to as the "Effective U-value", denoted as U_{eff}.

Analyzed cases, input parameters and obtained results can be found in document "WP3 – Thermal bridge analysis" appended to this deliverable.

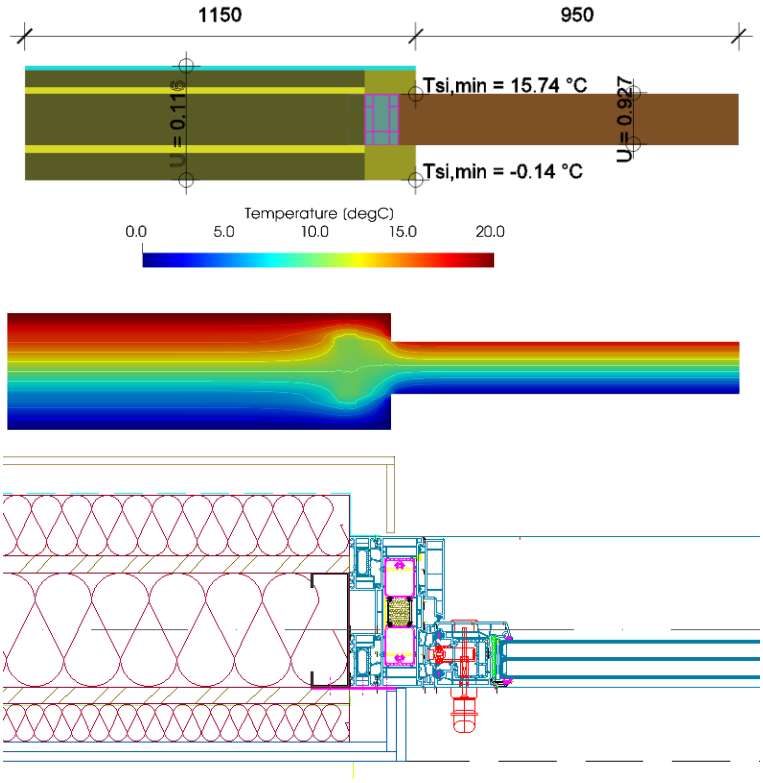


Figure 24. Example of analyzed thermal bridge case – door and wall junction.

In addition to the 5 basic NZEB principles presented above, which were applied during the design and construction process of the MUZA, other elements essential to healthy and safe NZEB building were also applied:

- **Heating and cooling systems**

In MUZA, taking into account the specifics of the Croatian climate, the heating and cooling needs are met by a highly efficient air-to-water reversible heat pump (heating and cooling power 5 kW, COP up to 4,93 for +A7/W35 according to EN 14825). Outdoor unit is located in the niche with small sliding doors, while indoor unit of the heat pump and its components are located in a technical room accessible to visitors, Figure 11. Heated or cooled indoor air is distributed by two fan coil units. One unit is located in the suspended ceiling right above the technical room (Figure 25), while another unit is located on the wall and covered by pegboard.

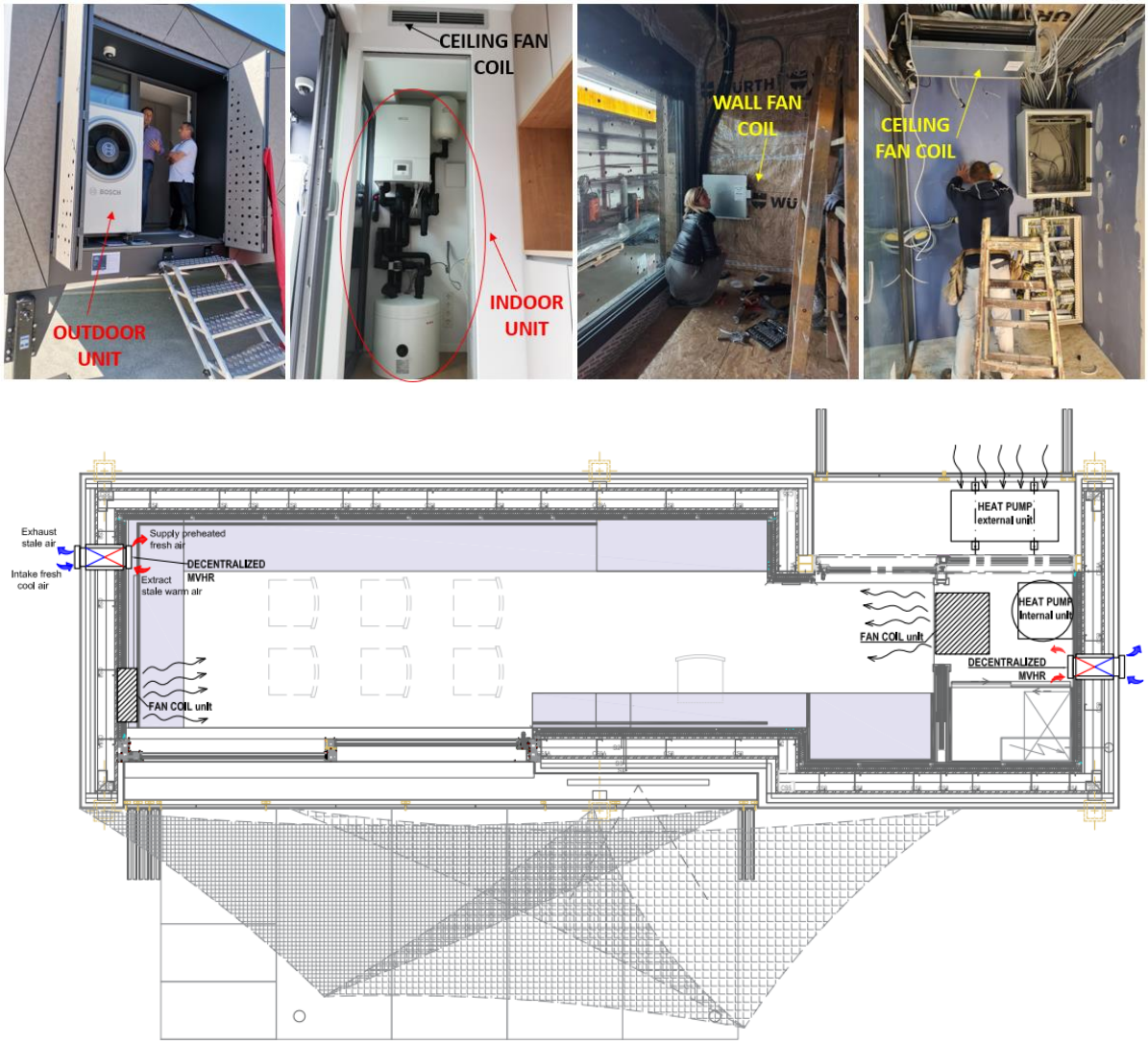


Figure 25. Installed air-to-water heat pump and fan coil unit (first row); floor plan with position of technical systems (second row).

- **Renewable energy sources (RES)**

Three photovoltaic (PV) panels of total nominal power output 1.005 kWp, are installed on the roof. Their inclination can be manually adapted in range from 15 – 45 (Figure 26). When the PV panels are inclined, they have the same orientation as a large sliding doors. Therefore, PV's orientation is actually related to the position od MUZA itself on certain location.

Figure 26. PV panels installed on MUZA.

The idea was to use the electricity generated by the PV panels only for MUZA's ongoing needs (HVAC, lighting, mechanical ventilation, TV, tablets, sensors for monitoring, etc.), i.e., to be energy self-sufficient when outdoor conditions make it possible. Moreover, due to mobility requirements (roadshow activities in different cities), it was not an option to release excess energy to the grid. Therefore, a smart inverter was chosen as the optimal solution. Smart inverter converts the direct current generated by the PV panels into alternating current, in the amount needed for MUZA's components at that particular time. In this way, no excess electricity is produced. When weather conditions are unfavorable for producing the amount of electricity needed, the difference is taken from the grid.

For MUZA it is always necessary to ensure an on-site connection to the electrical grid (industrial plug 5-pin (3P+N+E), 32 A).

- **Lighting**

Indoor and outdoor lighting consist of energy-efficient lights (LED strips and LED spotlights) that can be controlled with smart devices (Figure 27 and Figure 28).

Figure 27. Indoor and outdoor LED lighting.

Figure 28. Control options for installed lighting.

In addition to visual comfort requirements, lighting is also used to make MUZA more attractive from the architectural point of view – to make the statement that NZEB can be at the same time healthy, comfortable, technologically advanced, smart AND aesthetically attractive.

- **Automation and control**

NZEB requires the paradigm shift. Adaptability is crucial. NZEB must interact with occupants, installed systems and the external environment to realize its full potential. Therefore, in MUZA all HVAC, PV, shading and lighting systems are integrated, and they can be controlled by a central system.

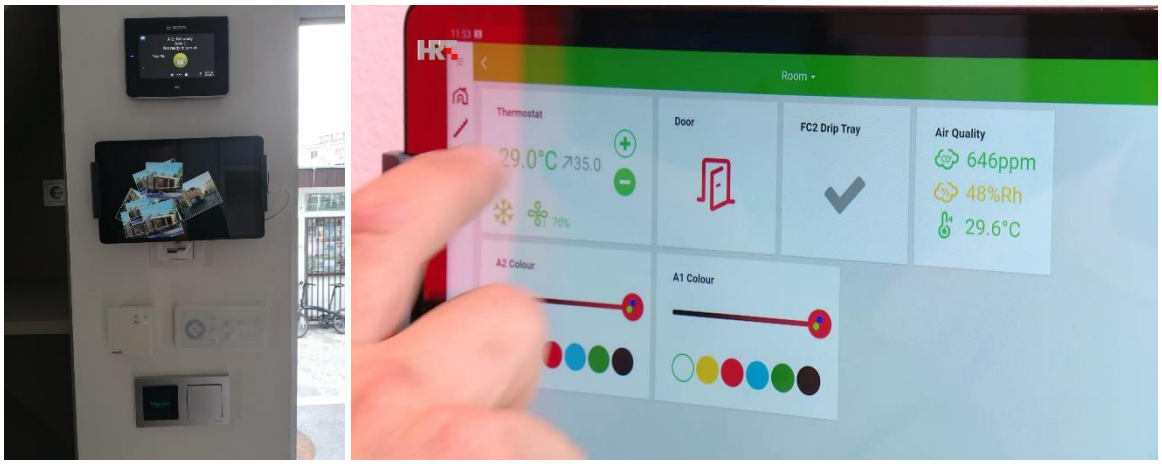


Figure 29. Components of central control unit.

The moment doors are opened (magnetic contacts disconnected), HVAC systems stop operating to reduce the energy consumption.

- **Security**

Following security equipment is installed in MUZA:

- Safety alarms and warnings – siren and keyboard
- Motion detector – 2 pieces
- Fire alarm
- Indoor security camera
- Outdoor security camera – 2 pieces
- Video recorder

Figure 30. Components of the security system installed in MUZA.

E-mail notifications for when either of the glass wall doors are open or when both doors are closed for security reasons.

Limited interior space and not being in everyday use, plus mobility requirements, were the main reasons why there is no domestic hot water tank and water installations in MUZA.

ADDITIONAL FEATURES/OTHER SIGNIFICANT INDICATORS

Performance

To understand how MUZA performs when used in real environmental conditions, but also to different parameters have been selected for real-time monitoring:

- **Energy consumption**
- **Energy produced by PV panels**
- **Indoor air quality parameters:** temperature, relative humidity, CO_2 concentration, relative indoor air quality
- **Hygrothermal performance of the external wall**: temperature and relative humidity in all characteristic layers

➢ **Energy consumption:** - The system measures energy consumption of the whole house, the whole HVAC system, heat recovery and ventilation system, and lighting. Energy consumption is measured using smart WiFi modules (Power tags) that monitor and measure energy and power in real-time (current, voltage, power, power factor, energy) and wirelessly communicate these data via a gateway to the router. Power tags are installed on the classical automatic fuses. This home automation is controlled using a logical controller (gateway) called Wiser for KNX installed in the main distribution cabinet.

➢ **Energy produced by PV panels** – selected smart inverter is actually "smart" thanks to system compatible component Energy Meter which calculates phase-exact and balanced electrical measured values and communicates these via Ethernet in the local network. In this way, all produced and used electricity can be communicated to system frequently and with a high

level of precision. This Energy Meter provides graphic visualization of current measured values in connection with the inverter in customized portal.

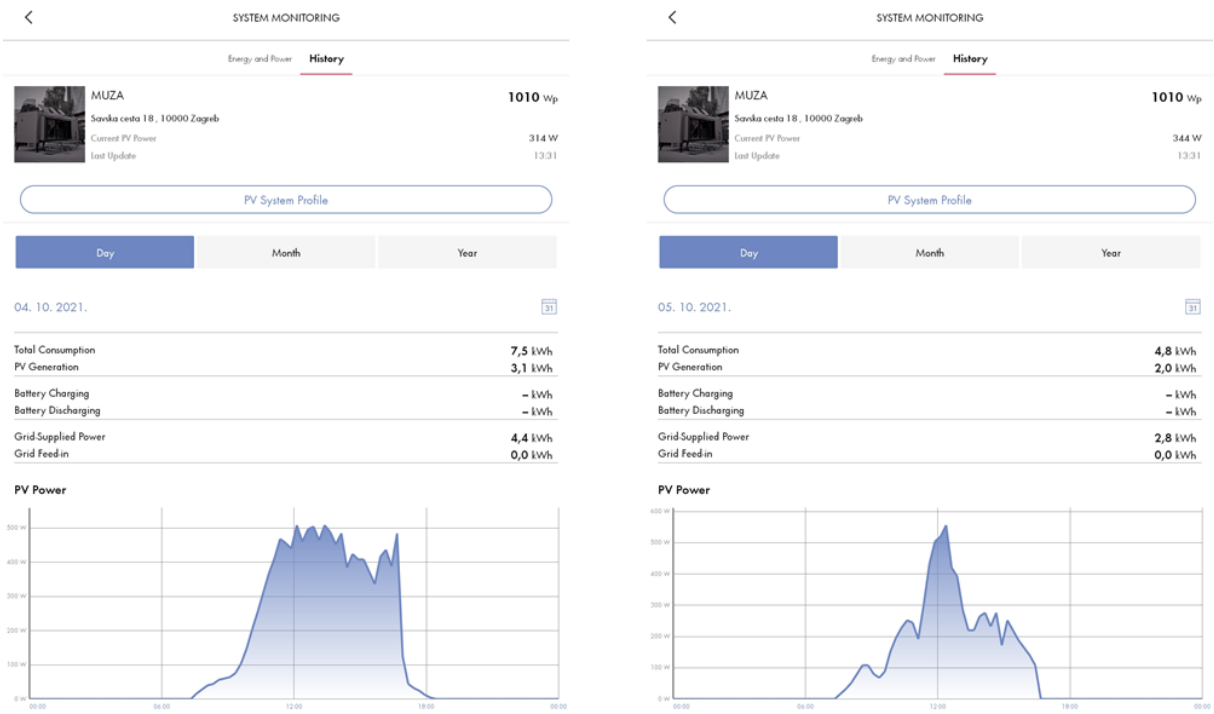


Figure 31. Overview of energy produced during 4th and 5th of October 2021 in Vodice.

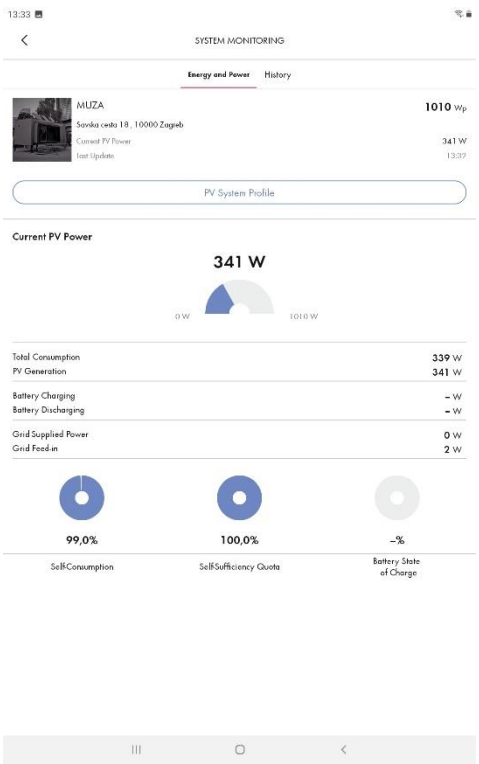


Figure 32. Self-sufficiency during daily peaks.

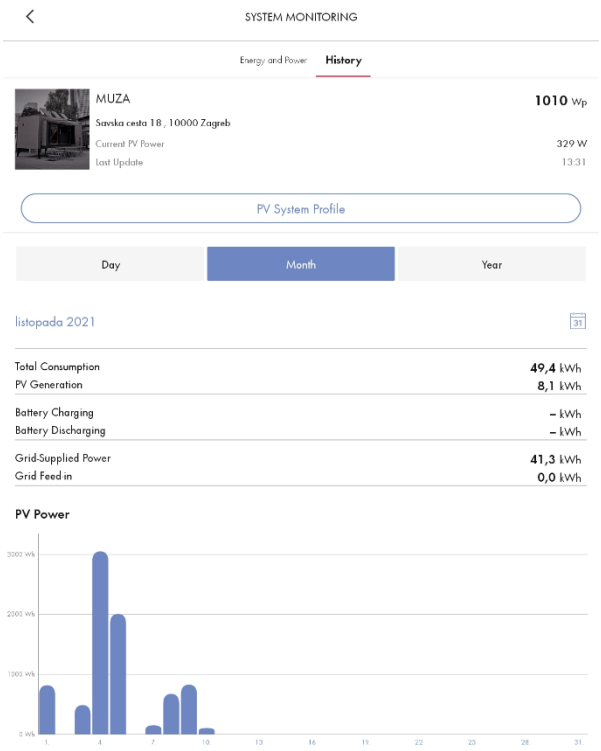


Figure 33. Overview of energy produced during October 2021.

Figure 31show the energy produced by the PV system during sunny days in October in the city of Vodice (littoral Croatia) during the #nzebweek event. It can be seen how self-sufficient (on a daily basis) the house was during these periods. During the daily peaks, the house was even completely self-sufficient (Figure 32).

- **Indoor air quality (IAQ) parameters**

There are two separate monitoring systems installed for IAQ parameters. First one is a commercial solution for industrial supporters that measures indoor air temperature, relative humidity, and CO_2 concentration. The sensors are located next to the smaller sliding doors and the real-time results can be displayed both visually in the form of a traffic light (green - very comfortable; yellow - comfortable; red - uncomfortable) and as numerical value (Figure 34).

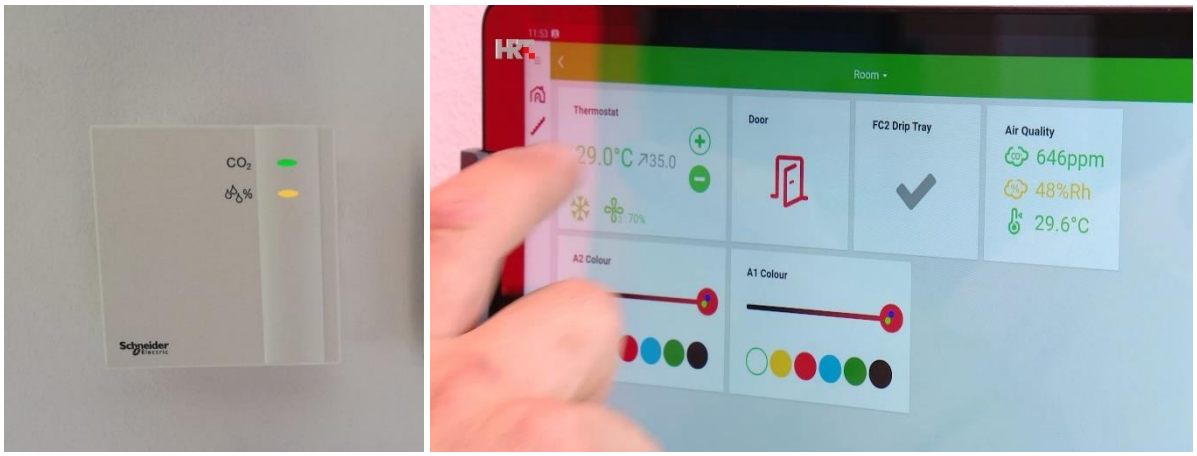


Figure 34. Commercially available IAQ monitoring system installed in MUZA and customized overview interface.

The second IAQ monitoring system and supporting overview interface are developed from scratch by the Croatian project team (Figure 35 and Figure 36).

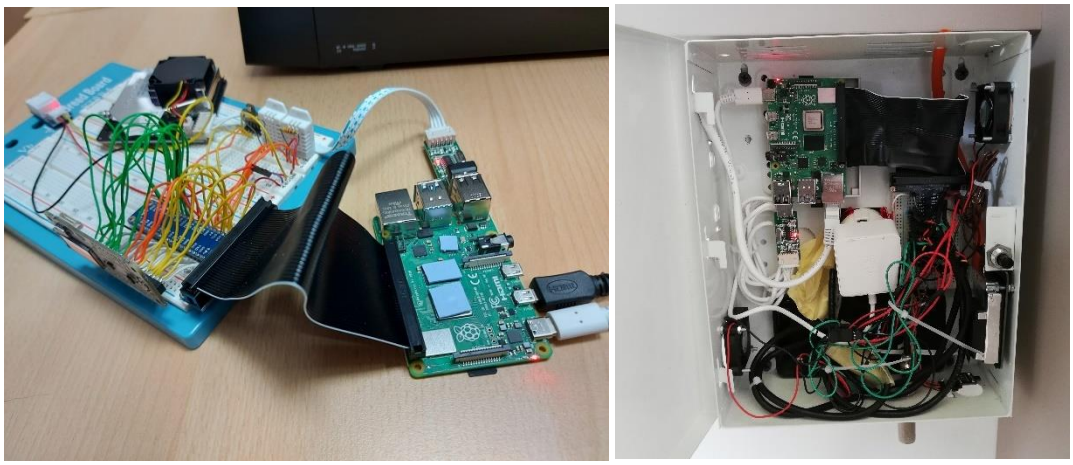


Figure 35. Custom-made IAQ monitoring system.

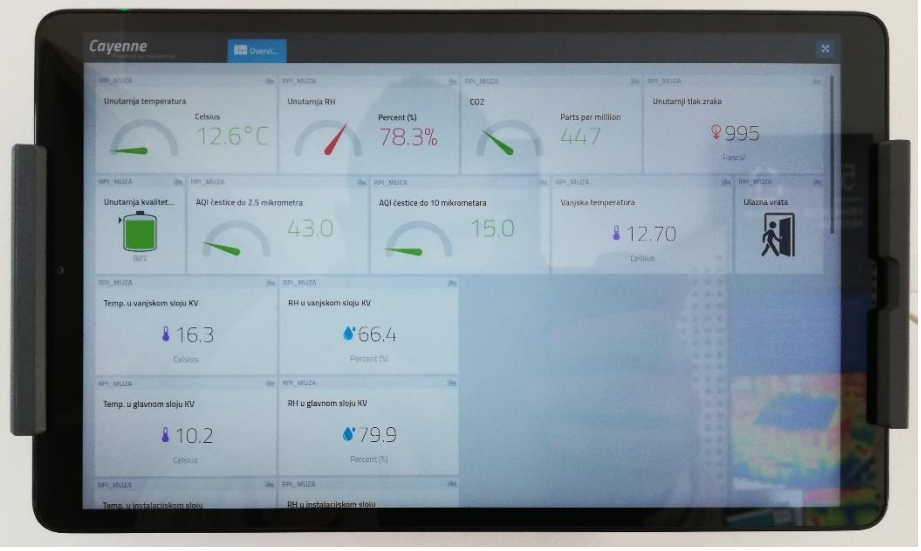


Figure 36. A monitoring dashboard for custom-made IAQ system.

All components of this monitoring system are positioned below the desk table, next to the larger sliding doors, and they are monitoring indoor air temperature, relative humidity, CO_2 concentration and relative air quality. When level of $C0_2$, relative humidity, relative air quality or temperature is too high the user gets an e-mail notification that ventilation or heating is needed. If these values are back to normal the user also gets an e-mail notification. Figure 21 shows a display for the monitoring system of the interior and exterior air parameters: temperatures and relative humidity of the interior and exterior air and the air inside of the characteristic wall layers, air quality indexes (AQI) of particulate matter (PM2.5 and PM10) in the interior air, barometric pressure of the interior air, and the energy consumption of the HVAC system and the total energy consumption of the entire house. These sensors are connected and controlled using a Raspberry Pi – a low cost, credit-card sized computer.

This custom-made monitoring system is also used to monitor hygrothermal performance of MUZA's external wall.

- **Hygrothermal performance of the external wall**

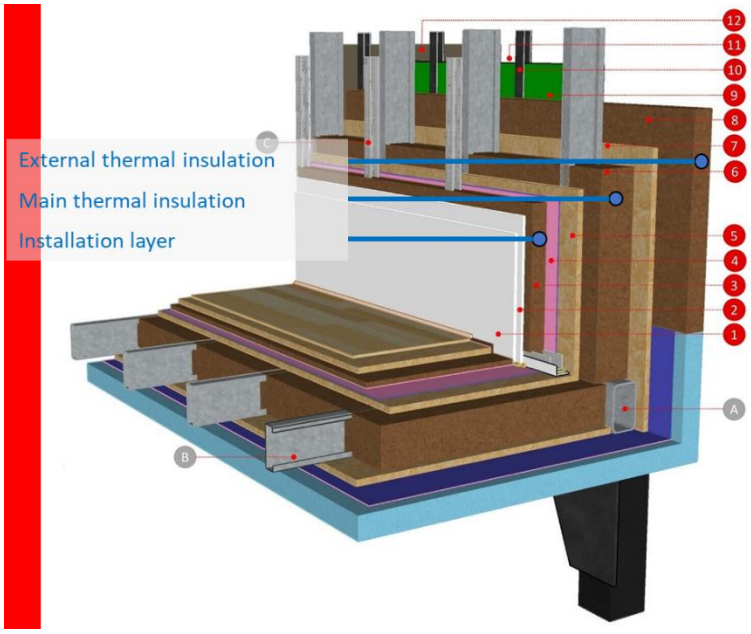


Figure 37. Position of the sensor in the layers of the external wall.

Figure 37 shows the position of the temperature and relative humidity sensors in the layers of the external wall. The sensors are positioned inside of the mineral wool: of the installation layer, between the columns of the load-bearing structure (Main thermal insulation) and the external thermal insulation.

Sustainability

Sustainability of MUZA is reflected through:

- **Reduced impact on environment** thanks to the highly efficient air-to-water heat pump system, MVHR and installed PV panels, which allow MUZA to be self-sufficient or draw very little amount of energy from the grid.
- **Perspective after the end of the project** – MUZA will continue to be used for educational purposes focused on raising awareness on energy efficiency in buildings and healthy living, therefore its lifespan extends beyond the end of the project.
- **Recycling and re-using at the end of MUZA's life cycle** – all installed materials, products and systems can be dismantled and, for the most part, either recycled (load-bearing and secondary steel structures, HPL façade panels, thermal insulation, OSB boards, etc.) or used for other purposes (e.g. wooden boards from furniture, textile overhang, etc.), which sustainably reduces the amount of waste after MUZA's use has ended and reduces the impact on the environment.
- **Opportunity for scientific research** – real-time monitoring is added value also in terms of scientific research.

Engagement/Feedback

Engagement of media, professionals, and layman around MUZA is very high which was proven with multiple television broadcasts, multiple newspaper articles and invitations to bring MUZA and NZEB Roadshow events to specific cities. Curiosity is also evident in the number of people visiting MUZA

during the events organized to date, as well as the numerous teachers from VET schools and professors from Universities organizing visits for the whole classrooms of students.

MUZA is also attractive for industrial partners which joined the events and participated with lectures, demonstrations etc. In total 36 industrial partners supported NZEB Roadshow and MUZA activities during the completed NZEB days, weeks, and other events in Croatia.

Lesson learned

When producing NZEB Mobile Home Unit, the one should have in mind:

- Keep external dimensions within the dimensions allowed for road freight. Those dimensions are country-specific (defined by national regulations).
- Think carefully about how you are going to load and unload Mobile Home Unit from flatbed truck. Our approach with six landing gears is a robust and reliable way of loading and unloading MUZA, but it requires at least three people actively involved. The whole process, together with packing other components such as outdoor stage, etc., can be physically demanding.
- Before the transport, all materials stored inside the house should be fasten so that risk from moving and damaging during the transport is minimized. In MUZA, we have foreseen mounting rails in the floor, into which the straps are inserted.

- When planning an event, the venue must be carefully checked – is it possible to access it with a flatbed truck (is there enough maneuver space, are there overpasses with a clear height lower than the overall height of house loaded on the truck, are there other installation presenting potential obstacle such as tram wires, electoral wires in the cities, etc.). Also, the on-site grid connection is required, and this should be also kept in mind when planning an event and searching adequate locations.
- If stationed outdoor between the events, mobile house should be connected to the grid during wintertime in order to avoid potential freezing of heating and cooling media. Note: it depends on the local climate.
- Good communication during the design project is crucial for foreseeing and solving details that could be otherwise critical in construction phase. Involving relevant industry partners in the design project is a prerequisite for proper installation of materials, products, and technologies from their field.

- During the construction process, constant supervision and management is required to successfully coordinate the various contractors and avoid clashes between the different groups of works. This requires enormous amount of time and effort.
- If there is no lead contractor to subcontract other contractors, it is very likely that certain works will remain "outside" everyone's domain. In the Croatian case, these works were carried out by the members of the Croatian project team.

- The entire design and construction process, as well as the organization of events and the use of MUZA, require teamwork.

- In Croatia, more than 30 companies from industry recognized the value of "The NZEB Roadshow" project and the potential lying in idea of building NZEB mobile house MUZA. Some of them were directly approached by Croatian team based on previous successful cooperation on other EU projects, while other companies approached themselves after the word about MUZA was spread in online webinars, media, and generally in construction market (Croatia is a small market and news spread quite fast). Industrial partners supported designing and construction of MUZA by their professional guidance but also with materials, systems and technologies that are installed in MUZA.
- Without the support of industrial partners, it would not be (financially) possible to realize MUZA on this level (to have all aspects described in section '*Technical description* and *Additional features'*).

GREECE

The Greek team, leader for WP4, whose main goal is raising awareness on energy efficiency in buildings both in adults and youngers, worked on design of live demonstrations and games giving to partners a full specification of the necessary to construct transportable demonstration equipment, mock-up sections and equipped walls.

Based on his practical experience, HPHI has worked out a general guide for the nZEB Roadshow project partners with design drawings and specification for every topic (D4.1). The document includes measures and practical methods to guarantee the installation and the transportation of the equipment, and a reuse concept for the sake of materials and cost savings. The project management guidelines are referring to the following areas:

a. LIVE DEMONSTRATION
b. GAMES FOR CHILDREN
c. COMIC BOOK
d. nZEB LEGO

The live demonstration area includes a general and technical description of several equipment to be used in order to show the main nZEB concepts, as:

- The ice box, a fun and interactive public installation able to give evidence that two identical looking small structures have great difference on their energy balance.
- The Blower Door Test, a typical way to test the airtightness of a building.
- The soundproof box, to demonstrate how noise can be attenuated by smart design and by using common building materials
- Mock-up sections, a simple and direct way to show the good practices of airtightness to prevent the air leakages (Figure 38).

Figure 38. Building assembly mock-up sections for the airtightness demonstration.

For children between 7 to 12 years old and their parent/guardian, the Greek team propose an interactive workshop that will give them the chance to explore the five basic principles of an nZEB through various challenges to face (Figure 39).

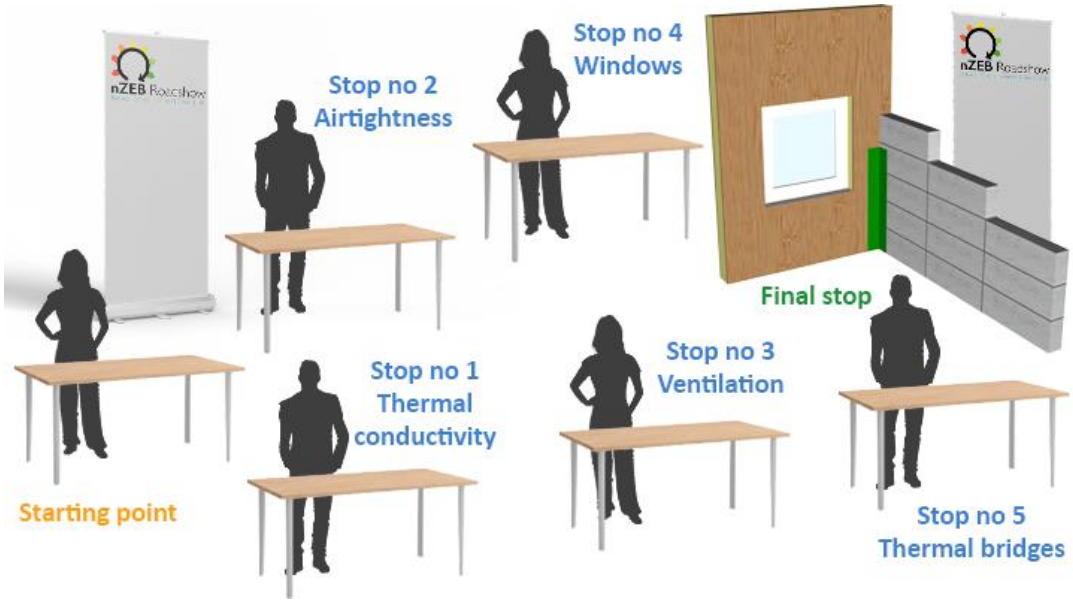


Figure 39. 3D presentation of a typical stop's layout.

Another fun but at the same time very educational activity that the Greek team has designed for children is reading the book "The house of future", written and illustrated by the Greek team itself, where a dog named "nZEBO" shows to children with simply tricks and modifications the changes that can be done to a home or a school so as to be converted to a nZEB. He invites the children to make all these changes together using stickers, their markers and a matching game imparting in the same time the basic principles of a Passive House and its benefits (Figure 40).

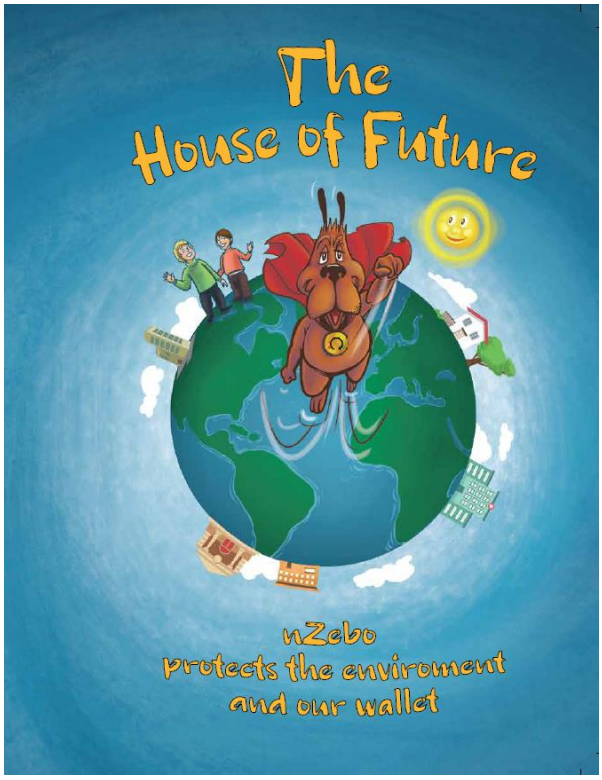


Figure 40. nZEBO the dog hero of nZEBs.

ROMANIA

GENERAL DESCRIPTION

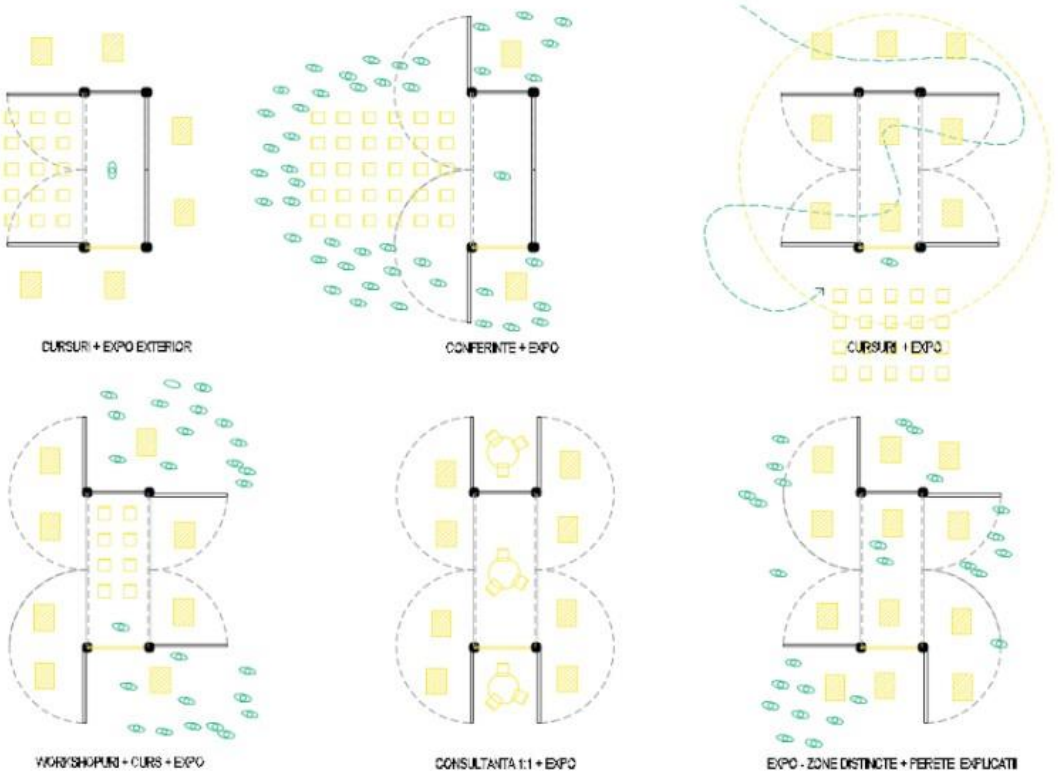
The Romanian concept for training facilities and running the nZEB weeks is based on a three-fold approach: a mobile exhibition unit, medium-sized (transportable) 1:1 mockup sections and demonstration equipment (practical activities).

Mobile exhibition unit

The concept for the mobile exhibition unit relies on adaptability both to the site and the needs regarding the events. On both long sides of the exhibition unit large double doors can open at various angles (90/180 degrees) thus managing to create different exterior spaces adjacent to the container. The predefined scenarios are as follows:

- When fully closed the exhibition unit can function as a means of transportation for the mockups and demonstration materials and as a enclosed space for conducting blower door tests.
- When opened on only one side it can be used as a stage for conferences, seminaries and demonstration activities as well as an “office space” for conducting consultation sessions for small groups of stakeholders.
- When fully opened (in various ways as depicted in the pictures below) it can reach full exhibition potential defining different zones for displaying the mockups and engaging

stakeholders in discussions and activities. Through this dynamic approach of different configurations (each day a new layout) it can improve visibility and raise awareness regarding the nZEB Roadshow project and nZEB related topics.

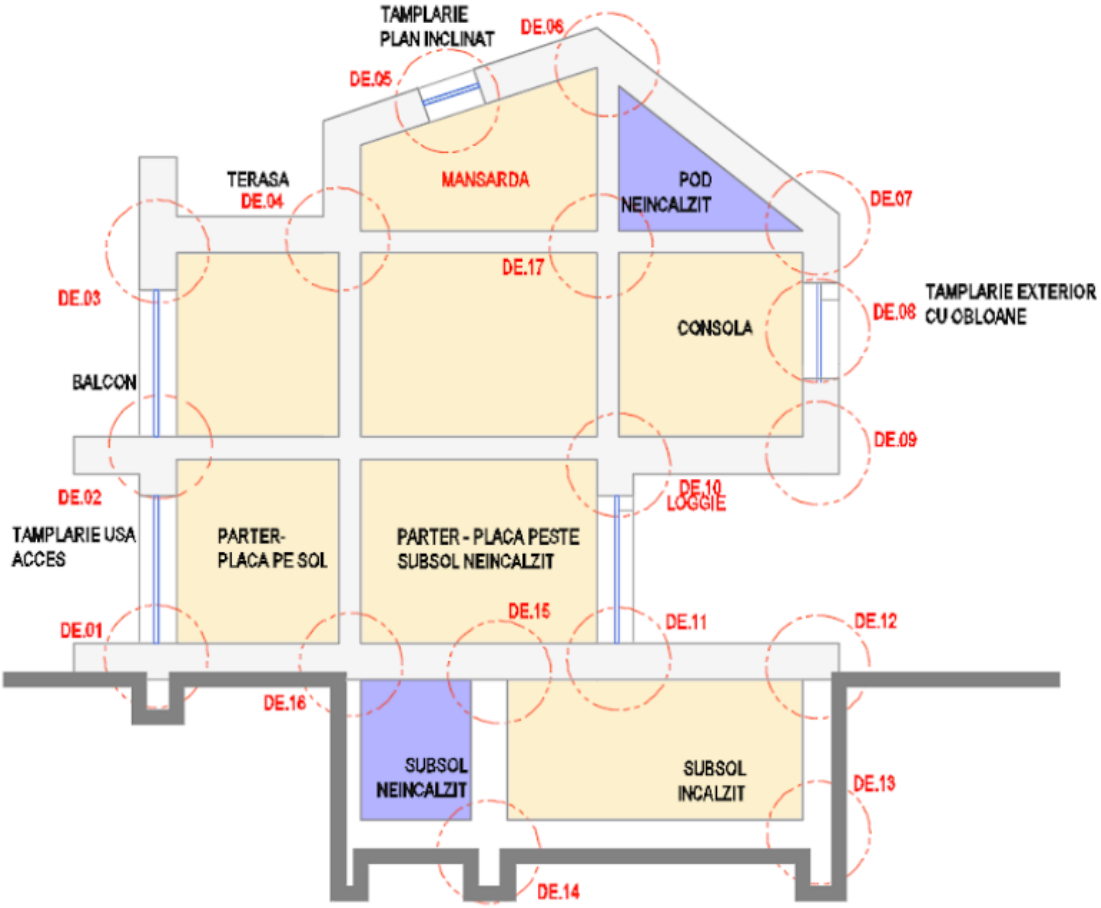


The Mobile exhibition unit is expected to be finalized until February 2022.

Full-scale mockups (exhibition activity)

- the 1:1 mockup aims to showcase the majority of common construction details realized with different solutions (ex: wall-windows system connection (bottom/top with raffstore), wall-balcony connection, Wall-eaves/roof connection, Wall-floor slab connection, as depicted below

- the 1:1 mockup were developed and constructed in collaboration with local producers and suppliers of construction materials as well as construction companies generating cooperation between different stakeholders. The Romanian team supported not only the creation of a common interest in



collaborating on a specific topic but also assured the increase of competences within the same group of societal actors.

Large mockups (exhibition activity) - 5 mockups (1:1 scale) are already built, with plans for another 4 until March 2022.

Demonstration equipment (practical activities)

Taking into account that the first nZEB Week (Bucharest, July 2021) took place during pandemic restriction and in locations such as BKH Bucharest, EFdeN and Romstal Academy the need for demonstration equipment purchased or made for the nZEB Roadshow was minimal.

The demonstration equipment includes the following:

- Insulation materials installations
- Equipped wall (practical activities)
- Training toolbox (to be developed)
- Different insulation materials/anchors
- Foils and tapes
- Windows samples with different types of glazing and frames
- Kit to check windows performances (to be developed)

- Sealing the leakages on the demonstration model (using tape and foils): ventilation ducts, electrical boxes/pipes
- Thermal imaging
- Blower door test

Demonstration equipment (practical activities) - some of the equipment is already available, further effort will be made regarding the gamification.

TECHNICAL DESCRIPTION

Mobile exhibition unit

It consists of a light steel frame mounted on a flatbed and encased in TEGO which can be trolled between the cities involved in conducting the nZEB Weeks.

The walls are made from smooth faced core 100% poplar, super quality without exfoliation, waterproof due to phenol glue, without metal inside, with water-resistant painted edges.

The exterior layer is made from TEGO with a nominal thickness of 9 mm. The walls are not thermally insulated, between the TEGO panels a vapor barrier is installed.

The flooring consists of skidproof TEGO (Wire Mesh) designed for use in automotive engineering, for floors and side walls, car trailers and other special applications.

The roofing and small walls will be covered with double fold metal sheeting (at a width less than 310 mm between the folds) providing rain shelter.

All RES systems on display will be easily removable (solar panels with inverter on racking mounted on the roof) and the racking systems are to be electrically bond and ground the solar array to prevent electrocution.

ADDITIONAL FEATURES/OTHER SIGNIFICANT INDICATORS

Adaptive architecture

The design takes into account the need for flexibility regarding space and the necessity to adapt to different sites, modes of operation (exhibition, training etc.), numbers and types of users.

Sustainability in materials selection

The mobile exhibition unit had to be designed for mobility and heavy hauling, so a light steel structure was optimal. The TEGO walls and flooring are FSC certified.

Recycle and reuse aspects

The mobile exhibition unit is designed for disassembly to facilitate future changes and dismantlement (in part or whole) for recovery of systems, components, and materials, thus ensuring that it can be recycled as efficiently as possible at the end of its lifespan.

The main components are as follows:

Base - R TH660 FLAT trailer which can be separated from the rest of the unit and reused/ recycled

Structure - steel laminated profiles (structural galvanized steel sheet class S 350 GD with protection 140 g ZnMg /sqm) with mechanical fixings can be recycled.

Both TEGO walls (Film-faced poplar plywood) and TEGO floor (wire mesh) can be reused for concrete castings (15–20 cycles).

Engagement/feedback

To this date only the interaction between stakeholders and 1:1 mockup could be observed both live during the nZEB Week in Bucharest and with a great online interest regarding videos on youtube.

The mockups proved a great way to attract and engage in constructive conversations. The mockups proved a great way of attracting industrial partners, suppliers and producers of materials and systems such as: Rockwool, Renovata, Miradex, Romehome, nZEB Shop, Danprod, Velux and many others. Other stakeholder groups were engaged in constructive conversations regarding the mockups such as: young people, highly qualified experts as well as NGO's and public authorities.

One of the smaller mockups was presented during the second edition of the nZEB Standards Conference - Energy Efficiency and Building Materials, organized at the Palace of Parliament - Human Rights Hall and held by USR MP Oana-Marciana Özmen (https://financialintelligence.ro/conferinta-standarde-nzeb-eficienta-energetica-si-materiale-de-constructii-editia-a-ii-a/).

Lesson learned

Mobile exhibition unit

Advantages:

- Marketing and communication: very high visual impact on site and on the road (mobile advertising for the nZEB Weeks)

- No additional transportation costs for the mockup and training materials
- Great potential for events replication in different cities across Romania and beyond
- Roaming training center, acts as a mobile BKH
- Personalized tasks for different kind of visitors
- Training activities in a single place.
- 15 square meters of indoor training space
- large wall area suitable for displaying posters and infographics regarding the project and different nZEB related materials
- versatile design - 4 (closed (during transportation) one side opened acting as a stage, 2 sides opened acting as an exhibition or training area

Disadvantages:
- Difficulties in finding local producers for the mobile exhibition, a benchmarking regarding local producers should be made during the design phase
- Ambitious design regarding the container's doors, difficult to implement
- Romania is very new to the mobile house/tiny house market so bespoke projects are rare, as are companies that produce them
- 6 to 10 large 1:1 mockup (1x1x2 m) are to be transported inside the container so interior finishes needed to be adapted for hardiness - TEGO anti slip flooring, TEGO (Film-faced poplar plywood) interior walls.
- Bureaucracy: obtaining permits for the events /electrical and water supply/plumbing/authorization
- Truck driver needed.

REFERENCES

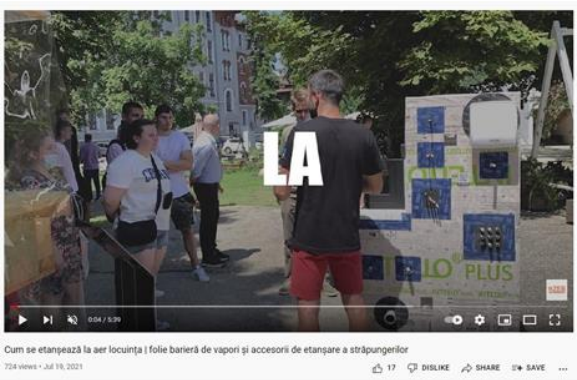
- Guidelines for design and operation of mobile training and consultation units. Deliverable D3.1. of the NZEB ROADSHOW project. Responsible partner: ZEPHIR. Version 1.1 March 2021.
- *Links to websites and/or channels where to find additional data and info:*
    - *https://www.muza-nzeb.com/crtice-s-dogaaja*
    - *https://www.youtube.com/channel/UCSVTGajtbIAZvJEPWupRbNw*
    - https://www.youtube.com/watch?v=dujChetzxk8
    - *https://www.youtube.com/watch?v=Bce5gbLaz24*
    - *https://www.youtube.com/watch?v=dujChetzxk8*
    - *https://www.youtube.com/watch?v=dujChetzxk8*
    - *https://www.pro-nzeb.ro/proiect/the-nzeb-roadshow/*
    - *https://www.facebook.com/watch/live/?ref=watch_permalink&v=1025940981481392*

ANNEX: FURHTER SPECIFICATIONS FOR THE TRAINING TRUCK IN ROMANIA

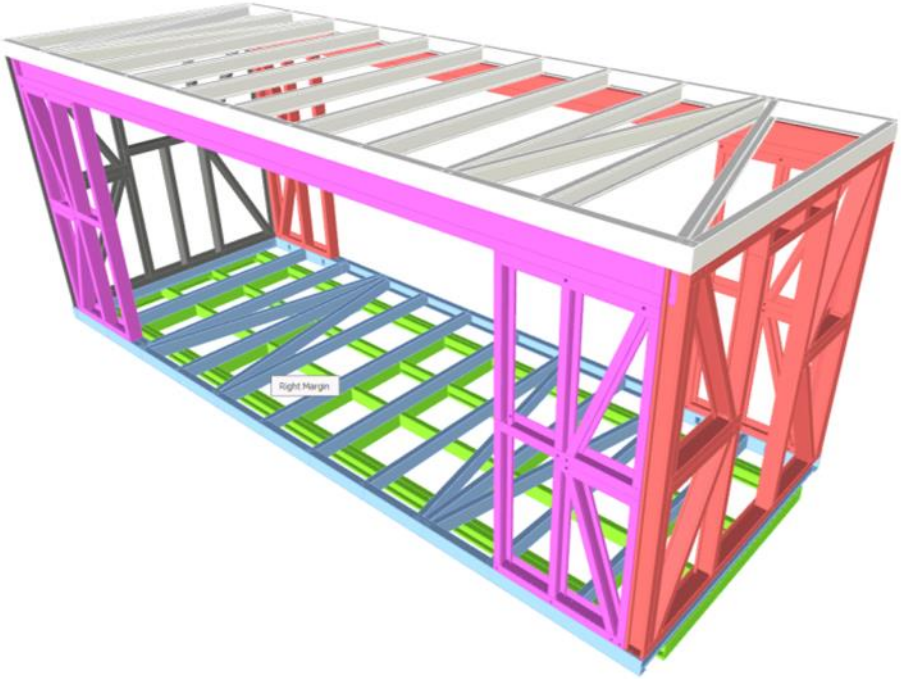
Training truck main goals, activities and involved stakeholders

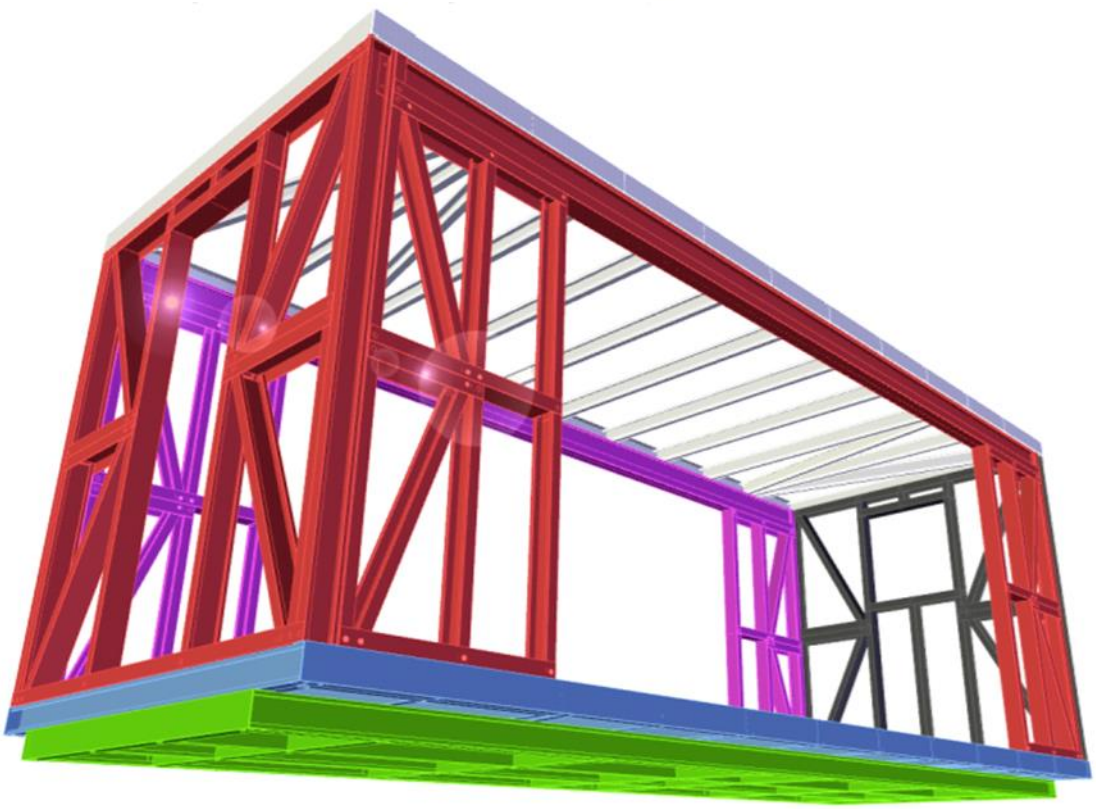
GOALS	ACTIVITIES	VISITORS
Transport *all the exhibition and training activities materials*	*- enabling the safe transport for 6 to 10 large mockup models 1:1 scale, with additional smaller size mockups and equipment between Bucharest, Brasov, Iasi and Cluj*	*not applicable,* *acts only in raising awareness regarding the project*
Exhibition - display and explain different aspects regarding nZEB principles	*- displaying 6 to 10 large mockup models 1:1 scale* *- demonstrative materials and technologies available for reaching nZEB* *- large wall area for displaying posters and infographics regarding the project and different nZEB related materials*	*Users of training: construction workers and specialists, employers, professional chambers* *Public authorities* *End-users / building owners* *Young people* *Producers and distributors of nZEB-suitable products and materials* *Highly qualified experts, designers and auditors* *Knowledge providers (universities, colleges, VTCs)* *Real estate brokers* *Financial institutions* *NGOs* *The media*
Training *visitors about: energy efficiency, materials and comfort*	*- training courses for designers, workers, and investors* *- on-site training and support for ongoing projects of local authorities* *- job fairs and career orientation events* *- demonstration & gamification* *- simple physics experiments engaging children* *- different use and physical characteristics of materials (structural, insulation, windows) with demonstrative materials assemblies targeting nZEB U values* *- mock up sections built with different materials with the focus on investigating their use with different climatic conditions (e.g. position of airtightness layer, material thickness…)*	*Public authorities* *Users of training: construction workers and specialists, employers, professional chambers* *Highly qualified experts, designers and auditors* *Knowledge providers (universities, colleges, VTCs)*
Practical activities	*- airtightness activities (foil/tape), blower door test* *- equipped wall (practical activities)* *- application of insulation materials* *- gamification package - games, book, challenges* *- MVHR installation and sealing* *- infrared thermal imaging* *- PV monitoring*	*End-users / building owners* *Young people* *Producers and distributors of nZEB-suitable products and materials* *Users of training: construction workers and specialists, employers, professional chambers*

Stakeholders' engagement and awareness raising regarding the nZEB weeks

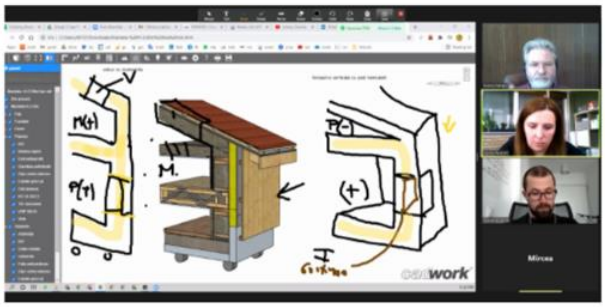


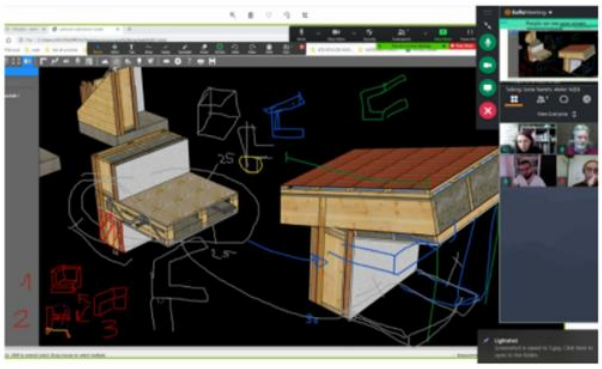
Romanian mobile exhibition unit during construction

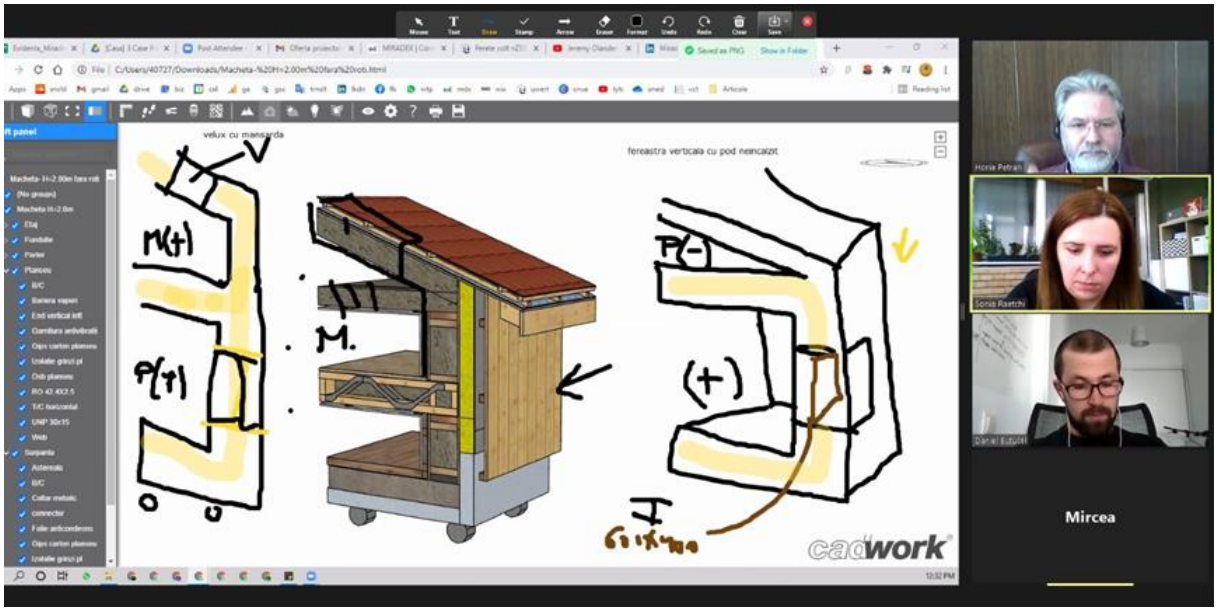




Romanian mockups design and assembly



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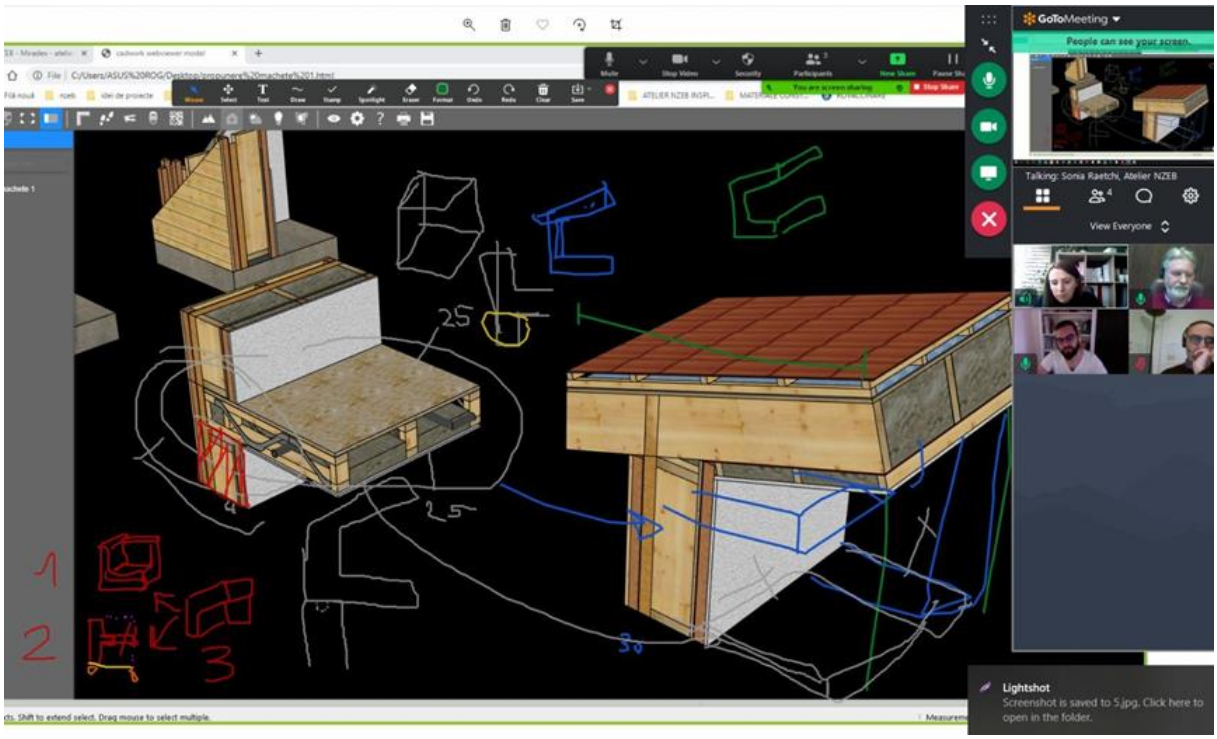
GoToMeeting
Talking: Sonia Raetchi, Atelier NZEB
View Everyone
Lightshot
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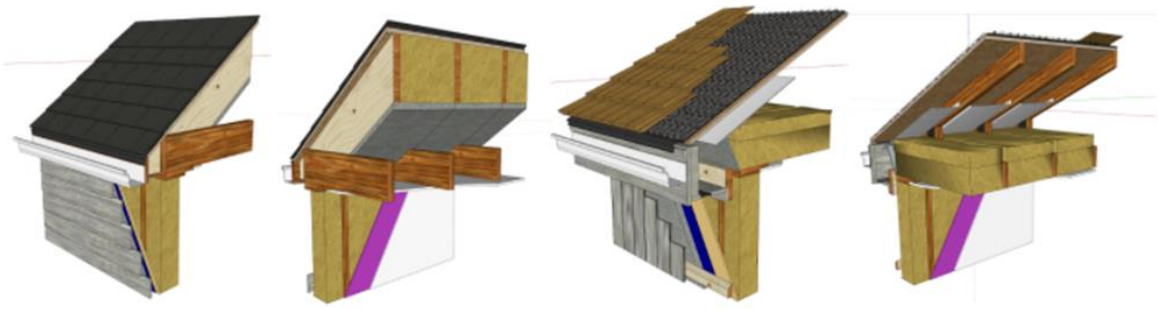

WWW.NZEBROADSHOW.EU

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