Guidebook for games and demonstrations on energy efficiency in buildings

Deliverable 4.1 of the NZEB ROADSHOW project

Responsible partner: Hellenic Passive House Institute

November 2021

WWW.NZEBROADSHOW.EU

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 892378

CONTENTS

EXECUTIVE SUMMARY

The Guidebook for games and demonstrations on energy efficiency in buildings prepared under the NZEB Roadshow is designed to support the development of various tools for live demonstration events, workshops and games for youngsters, social media engagement and attraction of media interest, which are crucial for the success and large impact of the NZEB days, organized in the framework of the project. Its goal is to enable attractive design and conduction of the events, so that they attract various stakeholders important for increasing the market demand for quality energy efficient buildings and, respectively, the demand for skilled workers.

The Guidebook include specifications and instructions for live demonstrations as the Ice Challenge and live construction works demonstration with application of innovative materials, components and technologies. Children will be attracted through series of educational games regarding the sustainable use of energy and resources, stimulating also the interest of their parents in a proven learning mechanism effectively influencing decision-making and investment behaviour. In the framework of the NZEB days, these activities are backed up by a broad range of engagement instruments using the potential of social media and web applications as live polls, contests and queries, Instagrammable corners, etc. These activities are also the cornerstone for dedicated media events, attracting the attention of both journalists and local key actors through positive publicity.

The Guidebook for games and demonstrations on energy efficiency in buildings refers to the following areas: live demonstrations (including the Ice Challenge), games for children, the nZEBO comic book and the nZEB Lego. The guidelines are drawn up by the Hellenic Passive House Institute, based on their cast practical experience, and comprise a general guide for the nZEB Roadshow project partners and other interested organizers of similar events with design drawings and specification for every topic. Each user is free to adjust the guidelines to better meet their needs according to their common construction practices and capacities.

The present document is the starting point of the nZEB Roadshow project's concept of using gamification as a main instrument to attract broad public attention to the planned activities, having as main objectives the following:

- To design the main concept of live demonstrations and games with a focus on raising awareness on energy efficiency in buildings and on edifying both adults and youngsters, with full specification
- To give specification for the design and the construction of transportable demonstration equipment, mock-up sections and equipped walls.

Moreover, the document includes measurements 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.

1. LIVE DEMONSTRATIONS

1.01 THE ICE CHALLENGE

The Ice Box Challenge is a public demonstration of two identical looking small structures that have great difference on their energy balance. It's a proof of how an incredibly efficient nZEB structure such as a structure designed according to the scientifically proven Passive House Standard, delivers great thermal comfort and low energy consumption in virtually any building.

Figure 1. Ice Box Challenge Logo

To begin with, for the design of the structure the fact that it has to be transferred to each city of the roadshow was one of the most critical parameters. Furthermore, an important criterion for the final choice was to be easily stored, while keeping in mind that it has to be as much as possible environmentally friendly. Given all the above, it has been decided that every surface of the structure should be portable and has to be mounted and disassembled on site.

Based on the duration of every exhibition, it has been estimated to leave the boxes in the sun for 3 – 4 days each, with an amount of ice of approximately 240 kgs that should be placed and set the scene for a competition for the public to guess how much ice each box will have after the four days in the summer sun. It has to be mentioned that one box is designed based on the minimum legal building code requirements of each country for an nZEB and the other to Passive House standards.

(a) Approximate estimation tool of transmission losses

An approximate estimation tool has been made, so as to calculate the transmission losses of every element of each box in different climate conditions.

Country	GR
Region	[GR] - Kalamata
Heating Degree Hours	26,6

Ice box according to nZEB					
Building component	Area (m^2)	U value ($W/(m^2K)$)	Month reduction factor	G_t (kKh/a)	Transmission Losses (KWh/a)
External Wall	7,5	0,322	1	26,6	64,239
Roof slab	1,5	0,208	1	26,6	8,2992
Floor slab	1,5	0,38	1	26,6	15,162
Windows	0,78	1,207	0,75	26,6	18,782127
Total					106,482327

Estimation	2,149

Ice box according to Local Legislation					
Building component	Area (m^2)	U value ($W/(m^2K)$)	Month reduction factor	G_t (kKh/a)	Transmission Losses (KWh/a)
External Wall	7,5	0,55	1	26,6	109,725
Roof slab	1,5	0,45	1	26,6	17,955
Floor slab	1,5	1,1	0,75	26,6	32,9175
Windows	0,78	3,29	1	26,6	68,26092
Total					228,85842

Figure 2. Approximate estimation of transmission losses tool for area dimensions of EUR 6

By changing the country and selecting the region from the drop-down list, the heating degree hours appear automatically and they are included in the calculation. By keeping the area of the building assemblies the same for the two ice boxes, while changing only their U-values according to the Passive House Standards and the country's legislation, the transmission losses will be calculated. Comparing these two amounts, an approximate estimation of the ratio of the melting ice between the two boxes will result.

It has to be mentioned that the result of this calculation is only reasonable when the g-value of the window glazing for both Ice Boxes is identical. Weatherwise the transmission losses will be incomparable and the result will be unreliable.

(b) *Ice box dimensions*

The dimension of the floor plan is based on the standardized dimension of the EU palette. Compact and low scale design for 2 mock-ups with dimensions:

Either for: EUR 1 (1,20 x 0,80): 1,32 x 1,72 x 1,6/1,8 m (width x length x height min to max).

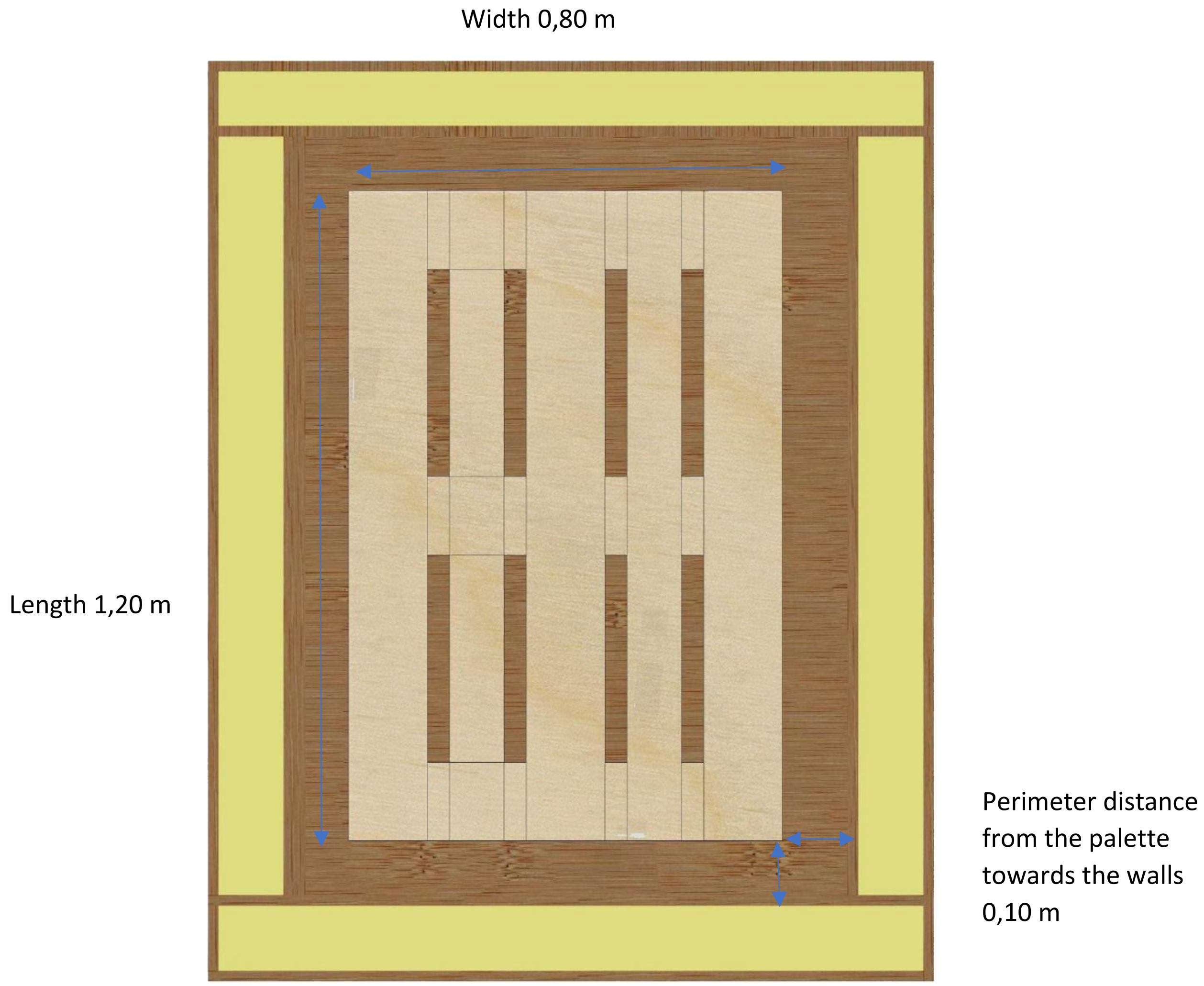

Figure 3. Top view of ice box based on EUR 1

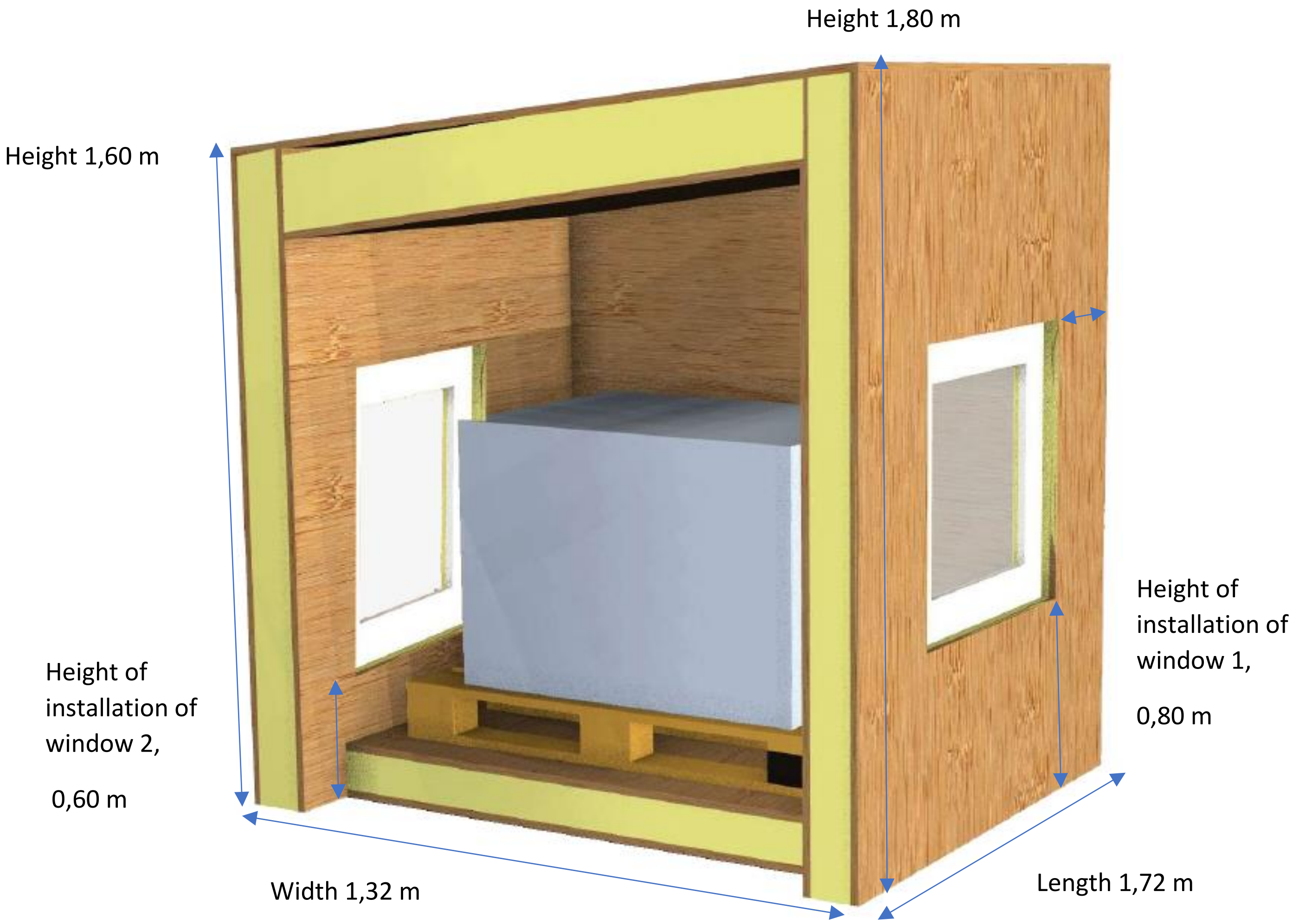

Figure 4. Ice box dimensions based on EUR 1

Or: EUR 6 (0,80 x 0,60): 1,12 x 1,32 x 1,6/1,8 m (width x length x height min to max).

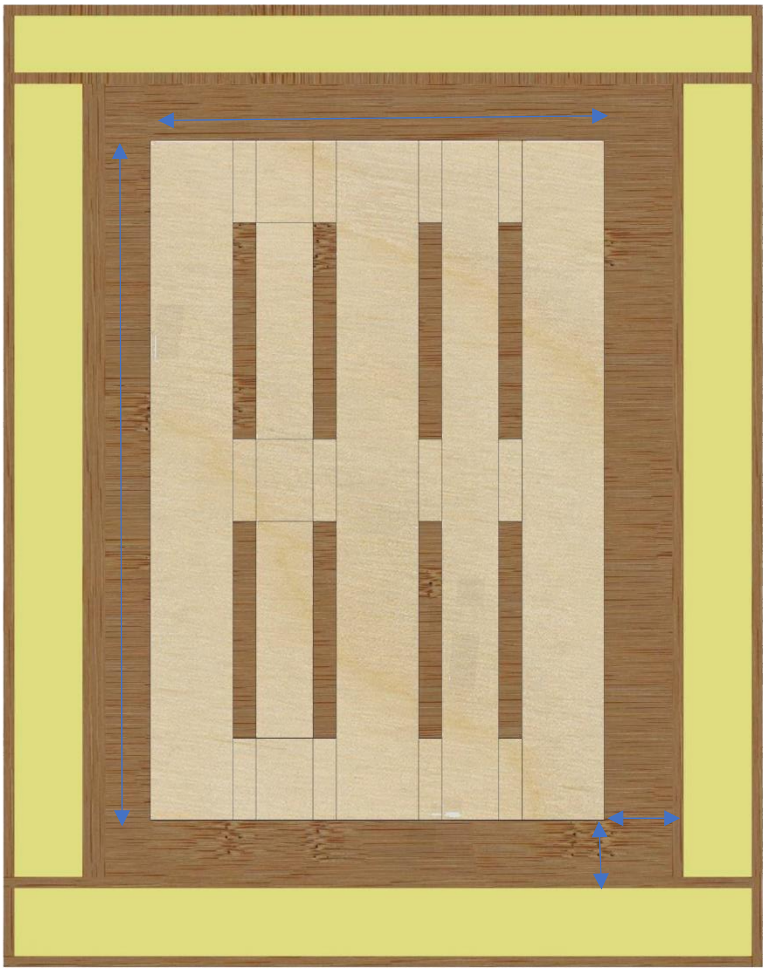

Figure 5. Top view of ice box based on EUR 60

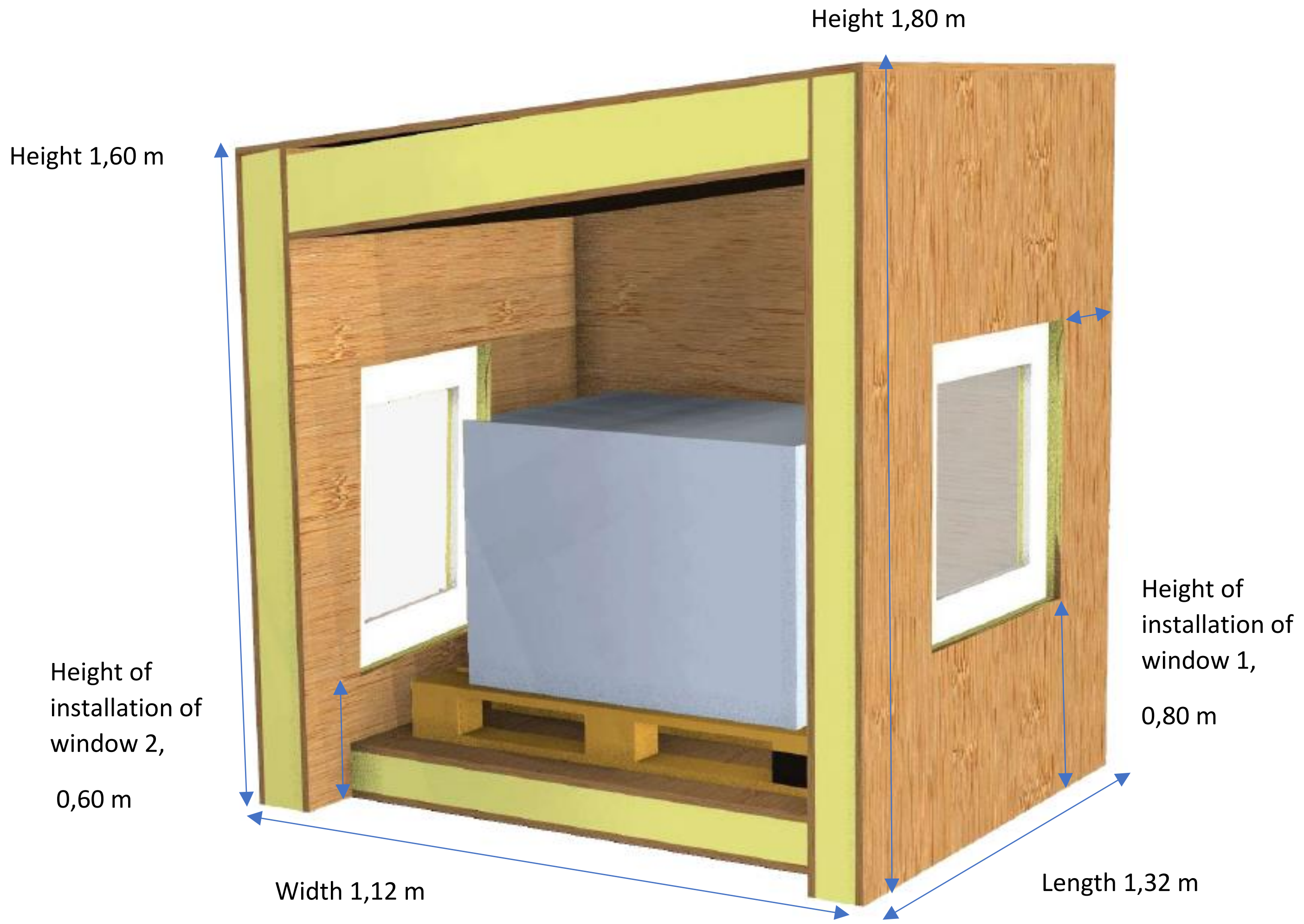

Figure 6.Ice box dimensions based on EUR 6

Windows: 0,60 x 0,60 m

The windows will be placed at the two rectangular sides of the box (North – South orientation), at different heigh so as the interior of the box can be seen even by children. It is recommended to place windows with a rather high g-value in order for the heat gains to be considerable.

(c) *Building assemblies sections and Ice Box appearance*

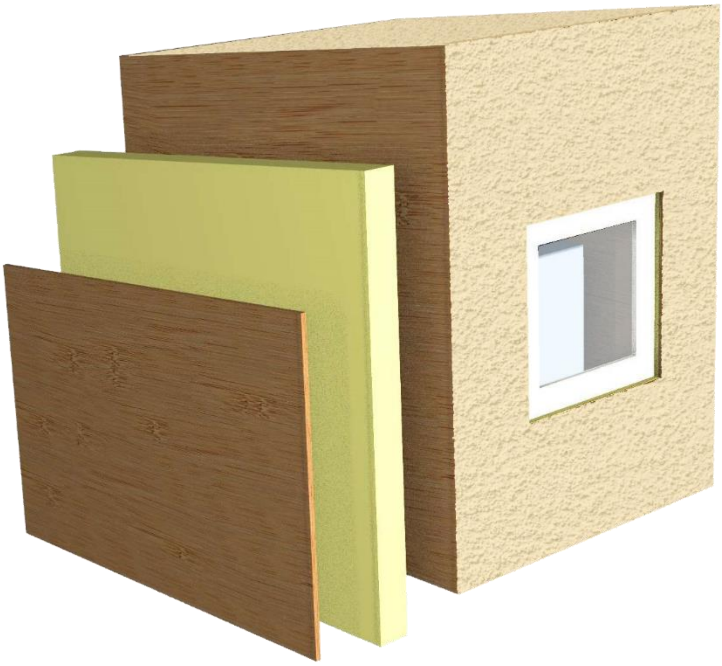

Figure 7. Typical section of wall assembly

Each side will be made of pre-fabricated sandwich panels that will be mounted on site. Namely, the section of the walls is composed of two OSB panels with a thickness of 2 cm and λ = 0,14 W/(mK) and the layer between will be filled with EPS insulation 0,033 W/(mK) with variable thickness depending on the region that will be installed. This kind of insulation offers significantly lower water absorption in comparison to conventional thermal insulating materials and high density, which makes it suitable for outdoor conditions. It has to be mentioned that since the insulation will differ in thickness, the exterior dimensions of each box must remain the same so as the two boxes look alike and observers could not notice the difference by appearance. Complementary, on the joints of the sides of the nZEB box tapes will be placed to seal the cracks and to achieve a good level of airtightness.

The walls, in which the windows are going to be installed as well as the roof, will be coated with light coloured plaster so that it will be protected from the weather conditions and resemble a real house. Moreover, on the one side of the trapezoid wall a banner will be mounted (sized about 0,9 x 1,20 m) that writes on the building assembly overview, with the average U-values of the assemblies of the thermal envelope. At the opposite side over the OSB panel a blackboard sticker will be placed, so as the people can bet on the weight of ice left in each box and write their feedback about the challenge or their whole roadshow experience. In that way the challenge will be more interactive and fun because people will be actively motivated to participate.

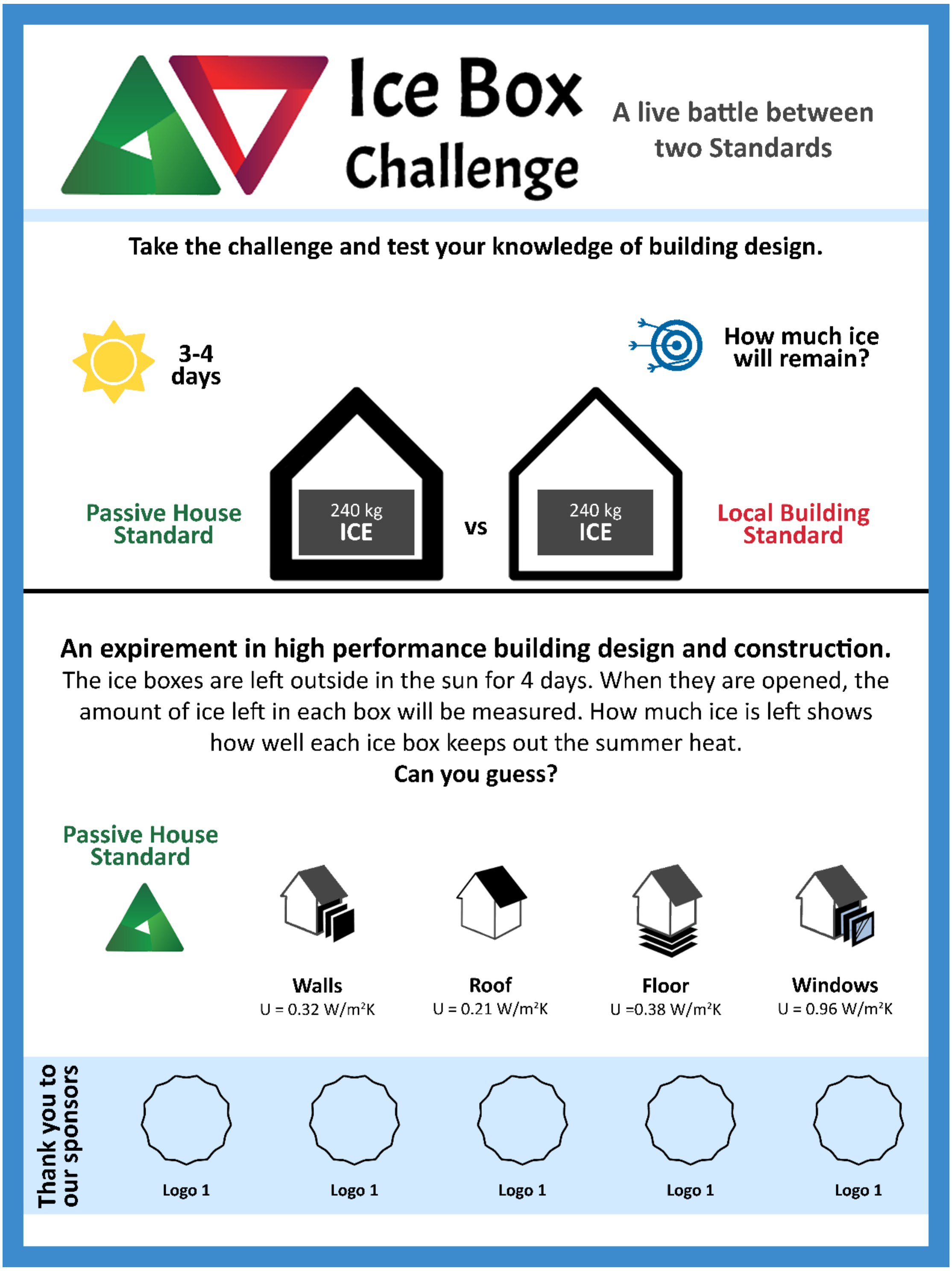

Figure 8. Banner of the ice box

Figure 9. Opposite side of ice box with the blackboard for visitors' bets and feedback

1.02 BLOWER DOOR TESTS AND INFRARED IMAGING

To achieve an nZEB, the airtightness coefficient (n_{50}) must be within an acceptable range of the standard. This coefficient may be found too challenging to achieve because most of the times a preliminary study deemed necessary but also special implementation practices that will provide a durable and continuous air barrier across the entire building envelope are needed.

The restriction of the air transportation is considered critical because of its fallouts. Through the particles of air not only thermal energy but also water vapor and airborne contaminants could be transported. When the air leakage rate is excessive, condensation phenomena or even mould could occur, as well as energy waste that leads to poor indoor quality for the users which impacts on their health and comfort.

A typical way to test the airtightness of a building is by carrying out a Blower Door Test. The procedure of this test is quite simple. It consists of a blower fun to pressurize and depressurize the building, that usually is installed on the entrance door of the building by using the special door panel and its aluminium frame. As soon as the installation is completed, the measurements begin by documenting fan airflow and pressure difference across the envelope to indicate the overall building airtightness characteristics and performance level.

In order to perform live Blower Door Tests the following equipment is essential:

Figure 10. Blower Door Test equipment

Figure 11. Thermal camera

The following link could be useful for more thermography cameras:

On the grounds that the public is not familiar enough with the concept of airtightness and it may seem quite paradoxical and less important to many in the terms of energy efficiency, its significancy must be highlighted not only by explaining how these leakages may affect the building in the long term, but also by visualizing the lack of airtightness phenomenon and identifying the air leakages. This can be done by the following ways:

- By using the *mock-up building* as the reference building for the implementation of the airtightness test. For the partners who decided to create and transport a large exhibition mock-up, it would be cost effective to invest in an airtight envelope and perform the test using the door of the equipment. Using the thermal camera, it is easy to identify the weak points of the mock-up. You may have already left some critical spots with deficiencies inside the envelope, for the visitor to find, describe potential negative effects, analyse the reasons and try to fill them by using optimal solutions.

- By using an *exhibition nZEB* in every city that is being visited. It is always interesting to perform a real time test and present it to the visitors. Be aware of the total volume of the building. Thanks to the good implementation of the air barriers, by using a thermal camera the visitors will be able to notice only some leakages that may exist (e.g., at the connection of the walls - windows).
- By using an *independent simulator*, which can also be customized. This simulator includes an easy to assemble testing enclosure with 3 adjustable leakage windows plus a duct system for a wide variety of testing scenarios. Its easy assembly and disassembly make it extremely portable so that it can be quickly moved between the training locations of the roadshow. The combination of testing enclosure, duct system and adjustable leakage windows gives maximum flexibility in testing applications. It can be also used to demonstrate building pressurization and depressurization tests, total duct leakage tests and duct leakage to outside tests.

Figure 12.Airtightness Training Simulator

Apart from the airtightness test, the good practices of airtightness to prevent the air leakages must be shown. Using suitable mock- ups with different sections of building assemblies and ways of windows installation, the visitors should practice their skills on applying airtightness tapes on its sides and using collars on the connection of ductwork to the walls. Also, the proper way of the application of plaster must be shown, so as to form the airtightness layer for the building. Furthermore, samples of airtight materials should be shown as well as special products that are used in order to restrict the air movement (such as cable sockets, airtightness membranes). Then, the procedure in which the connection between windows and walls can become airtight with tapes will be demonstrated, as well as the proper use of plaster to make airtight layers etc. In order to demonstrate and visualize the effects, depending on the weather conditions, infrared imaging will be used within different scenarios, challenging participants to identify weak spots, describe potential negative effects, and analyse the reasons and propose optimal solutions.

Figure 13. Building assembly mock - ups for the airtightness demonstration

1.03 THERMAL CONDUCTIVITY OF MATERIALS – LAMDA (Λ)

(a) Thermal phase shift model

This mock-up is made of OSB and has suitable sockets for inserting samples of insulation materials (Figure 14). It is an excellent example for the participants to understand summer comfort, in addition to the “power” of insulation, having λ-values lower than 0,10 W/(mK), the phase shift is less important, as heat transfer is significantly limited. The lower λ value is, the more the material can prevent heat transfer and thus preserve the internal conditions and the comfort of the home longer. Thanks to the two infrared bulbs that are placed on top and emulate the effect of solar radiation, this model makes it possible to highlight the capacities of insulating materials to slow down heat transfer. Temperature measurements are made very simply and very quickly to each side of the material using an infrared thermometer. It also makes it possible to follow the temperature curve over a given period. The sampling period for temperatures can be approximately 10 minutes after the system is turned on.

This model gives the opportunity to have many samples of different thermal conductivity (λ) but with the same thickness. It is recommended to compare materials with great difference in their thermal conductivity such as timber, tiles, metal, plastic and EPS samples. The size of the samples is 0,2 x 0,3 x 0,05 m (width x length x height) including their perimeter wooden frame of 0,04 m (that is optional).

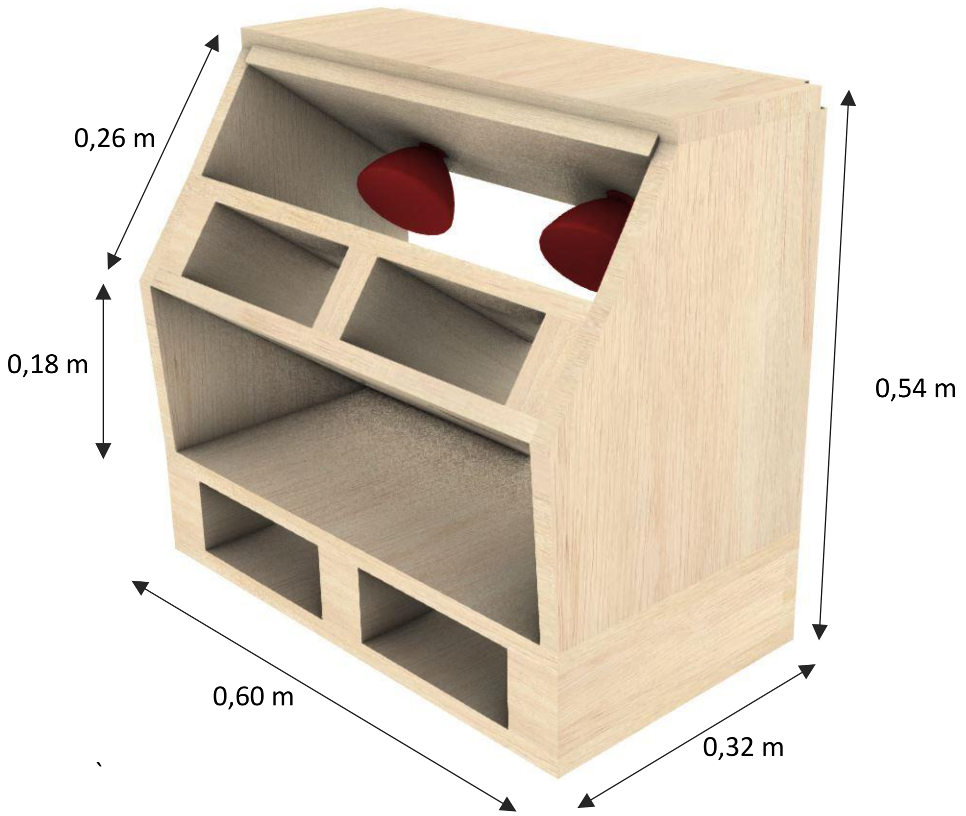

Figure 14. Thermal Phase Shift Model

(b) *Frame model with different types of glazing*

In order to make the difference between the various types of glazing distinct, a frame that is separated in four smaller parts is going to be used, each of them with a different type of glazing. Many variations can be made according to the climate of each region, some of them are shown below in Figure 15 (single, double, double with gas or double with gas and coating, triple or triple with coating). To make it portable, the width of the model is 0,8 m and its height 1 m, which leads to the dimensions of glazing being, 0,32 m for the width and 0,42m for the height. Behind this model, infrared lamps that represent solar radiation will be placed. By using a thermal camera, it is easy to show the difference between both sides and the amount of the heat that is being transferred through each sample. At the conventional parts of glazing (for Greece, single and double glazing) a conventional spacer could be used (aluminium) compared to the others which are recommended to be made with plastic spacers, so that the difference in the glazing edge could be more distinct. The sampling period for temperatures can be approximately 10 minutes after the system is switched on.

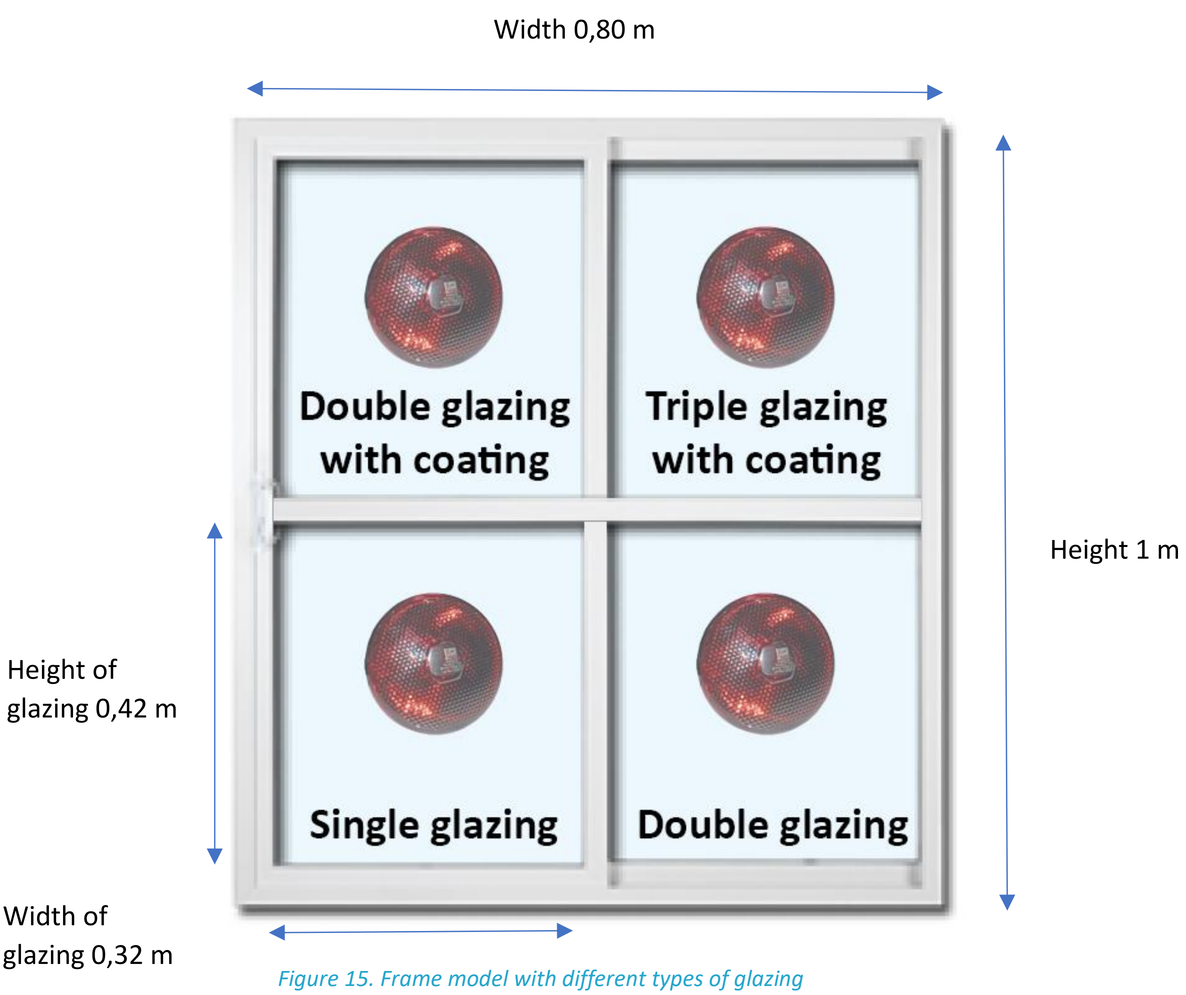

Figure 15. Frame model with different types of glazing

(c) *Experimental setup using thermocouples*

U-Value estimation using only temperature measurements

The thermometric (THM) method of obtaining the U-value of building façades is a development of the average method set in ISO 9869-1. It is based on the instantaneous measurement of the heat flow as well as the indoor and outdoor air temperatures **under steady state conditions**:

$$U = \frac{q}{T_{in} - T_{out}} \left[\frac{\mathrm{W}}{\mathrm{m^2{\cdot}K}}\right] \qquad (1)$$

Where q *(W/m²)* is the heat flux of the wall, T_{in} *(K)* is the internal air temperature, and T_{out} *(K)* is the external air temperature. Using Newton's Law of Cooling, the heat transfer per unit surface can be determined by the following expression:

$$q = h_{in}(T_{in} - T_{s,in}) \left[\frac{\mathrm{W}}{\mathrm{m^2}}\right] \qquad (2)$$

Where h_{in} *(W/(m²·K))* is the internal convective coefficient and $T_{s,in}$ *(K)* is the internal surface temperature of the wall. From Equations (1) and (2), the equation used in THM is obtained:

$$U = \frac{h_{in}(T_{in} - T_{s,in})}{(T_{in} - T_{out})}\left[\frac{\mathrm{W}}{\mathrm{m^2 \cdot K}}\right] \qquad (3)$$

It is important to highlight that this method always uses a fixed value of the internal convective coefficient, based on the value of the internal surface thermal resistance set in ISO 6946. Taking into account that the surface resistance is the reciprocal of the convective coefficient (Equation (4)) and the tabulated value of $R_{s,in}$ set by ISO 6946 for a vertical building envelope is 0.13 ((m^2·K)/W), we obtain the equation of THM for the U-value measurement of façades (Equation (5)).

$$R_{s,in} = \frac{1}{h_{in}} \qquad (4)$$

$$U = \frac{7.69(T_{in} - T_{s,in})}{(T_{in} - T_{out})}\left[\frac{\mathrm{W}}{\mathrm{m^2 \cdot K}}\right] \qquad (5)$$

In this way, the requirement to measure the heat flux is dispensed with and the calculation can be done with just the temperature data. This data can be obtained with thermocouples, which measure both the exterior and interior environmental temperatures as well as the internal surface temperature of the wall.

Note: *The terms exterior and interior as used here refer to a building façade, where exterior is the side exposed to the outdoors and interior is the side facing the building occupants. In case of an experimental setup where a heat source is placed in the centre of a box walled with different building components, what the "exterior" side is rather depends on how the experiment is viewed: If we are looking at a winter condition, then the heated side should be considered the interior, and the opposite should be considered for a summer condition.*

In any case, some manufacturers' specifications in relation to the installation of the equipment and test durations are listed below. These specifications generally echo the requirements of ISO 986901 for representative and undisrupted readings:

- Mounting the interior and exterior environmental temperature probes 30 cm away from the wall (to avoid convective effects) as well as at the same height as the internal surface temperature probes.
- Thermocouples measuring the internal surface temperature should be mounted with a space of 10 cm between them.
- No direct (solar) radiation. Any thermocouples exposed to the "exterior" should be shielded against direct radiation as much as possible. This goes both for surface and air temperature measurements.
- It is advisable to have stable "interior" conditions during measurements and a significant difference between the internal and external temperatures, preferably higher than 15 °C (this is ideal, but lower differences can be accepted if it is not possible).

There is also a differentiation made between light and heavy wall elements, where for the former only measurements during the night are suggested, and for the heavier elements measurements of an integer of 24h are suggested, and no less than 72h.

The sampling period for temperatures can be anything between 2 minutes and 90 minutes, but generally a period of 15 minutes or 30 minutes is considered a good rule of thumb. Ideally, from the accumulated series of measurements only those with a high temperature difference (> 15° C) should be considered, but if such a difference is not common, lower differences can be considered. The result obtained through this method is determined by the average value of the filtered subset of n values of thermal transmittance:

$$\overline{U} = \frac{1}{n}\sum_{i=1}^{n} U_i \left[\frac{\mathrm{W}}{\mathrm{m^2{\cdot}K}}\right] \qquad (6)$$

Where U_i *(W/(m²·K))* is the U-value obtained from Equation (5) for a certain observation i, and n is the total number of filtered observations of the dataset.

A potential experimental setup for demonstration purposes (NOT for scientifically accurate measurements) is pictured in Figure 16. The setup consists of an MDF box with 4 different material samples in its vertical sides, an infrared (IR) lamp inside the box and thermocouples linked to dataloggers and from there to pc.

Experimental setup

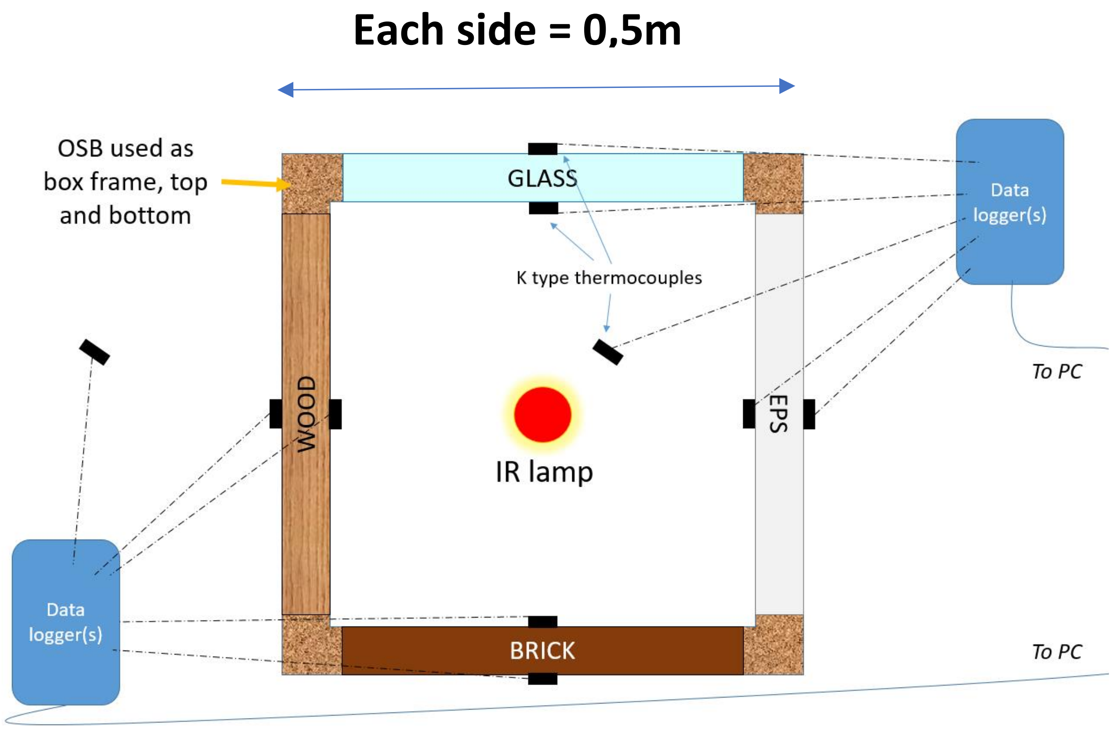

Figure 16. Simplified plan of the experimental setup (seen from above)

Requirements to measure 4 samples concurrently

BOX DIMENSIONS:

Each material of the cube shaped box will have size of width and height 0,5 m and thickness of 5 cm, except of the glass which thickness is determined by its type (a type of double glazing is recommended).

THERMOCOUPLES:

- **Thermocouples to measure surface temperature**:
  - 1 per sample side x 2 sides x 4 samples = 8 thermocouples (type K with adhesive tape (included tape is optional))

- **Thermocouples to measure ambient temperature:**
  - 1 per box side ***or*** 1 per sample per side, so 2 – 8 thermocouples (type K)

Total thermocouples for the setup: 10 – 16

THERMOCOUPLE DATA LOGGERS:

There are several data logger types ranging from all-purpose data loggers to thermocouple-specific data loggers, and from handheld 1 or 2 channel loggers to bulky 32 plus loggers (that are generally less user-friendly). Usually most of these can be used with a software to offer real-time data viewing (Caution: software may be offered at an extra charge)

- **Assuming a standard, handheld thermocouple data logger with 4 channels:**
  - 3 – 4 four-channel data loggers

    or
- **Assuming a thermocouple data logger with 8 channels:**
  - 2 eight-channel data loggers

2. GAMES FOR CHILDREN

2.01 WORKSHOP

In this section, the workshop for children between 7 to 12 years old and their parent/guardian that will give them the chance to explore the concept of sustainability in buildings is described in detail. Through educational but at the same time fun experiments and actions, the children will learn about topics such as climate change, recycling and healthy materials, but also about the five nZEB principles explained in a simple way and the reasons why we are aiming for zero emission buildings.

2.02 THE CONCEPT

The main idea is to make a path with various challenges for the children to face. They must follow it and reach it till the end, while learning about the five basic Principles of an nZEB. They will derive everything they need to know that can make them make a positive impact on the environment so on.

In the paragraphs below, the scenario and its stops are being described. Depending on the task, the children will have to act both individually and collectively.

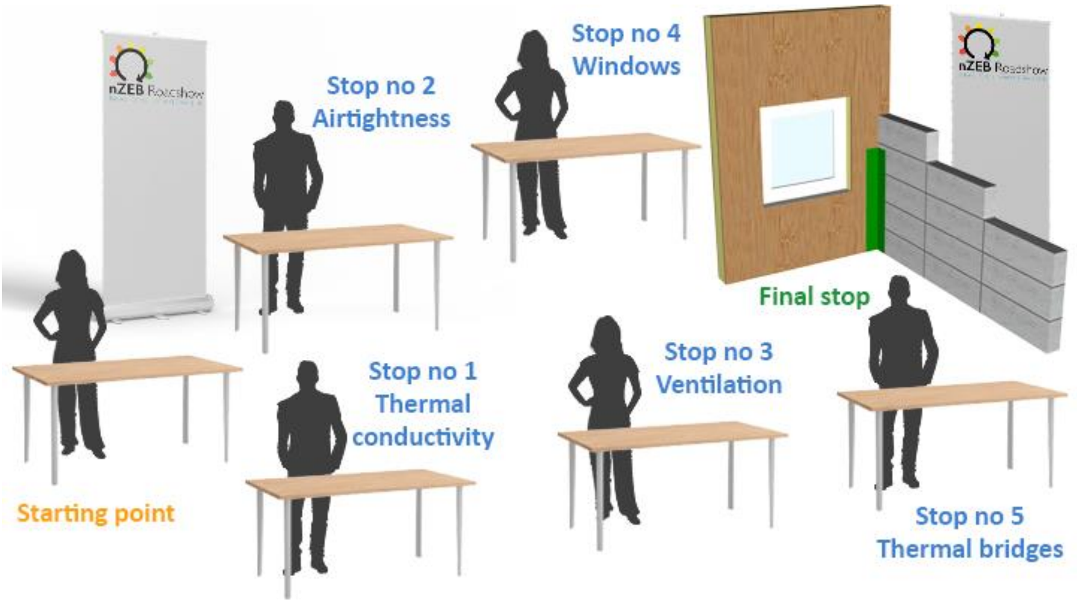

Figure 17. 3D presentation of a typical stops layout

(a) Starting point

A small group of children (up to 14) begin at the starting point. In this stop an introduction must be made about our planet, the different climate zones and the types of buildings that are made in each. Also, the climate change that is noticed in every part of our planet must be pointed out and the reasons behind it and its fallout must be explained thoroughly. This short video describes the parts that need to be highlighted for the topic from a kid's perspective.

In this point, knowing the basics about the climate change and its fallout, they can play some educational quizzes concerning that topic but also other topics for example the use of energy or recycling, by using platforms like PowerPoint, customized apps or online apps (e.g. Kahoot) to make them more interactive (questions of True/ False, Multiple Choice, Images, Polls, Corresponding). The children should be separated in two groups that will compete against each other. At the end of every question an explanation must be given with more facts about the answer and further information about the topic. Approximately this stop will take up to 15 minutes.

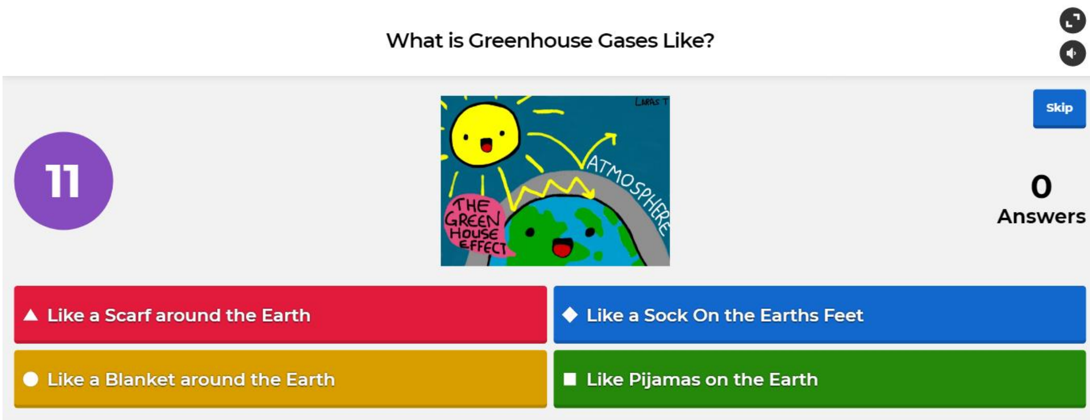

Figure 18. Example question of climate change based on the recommended video

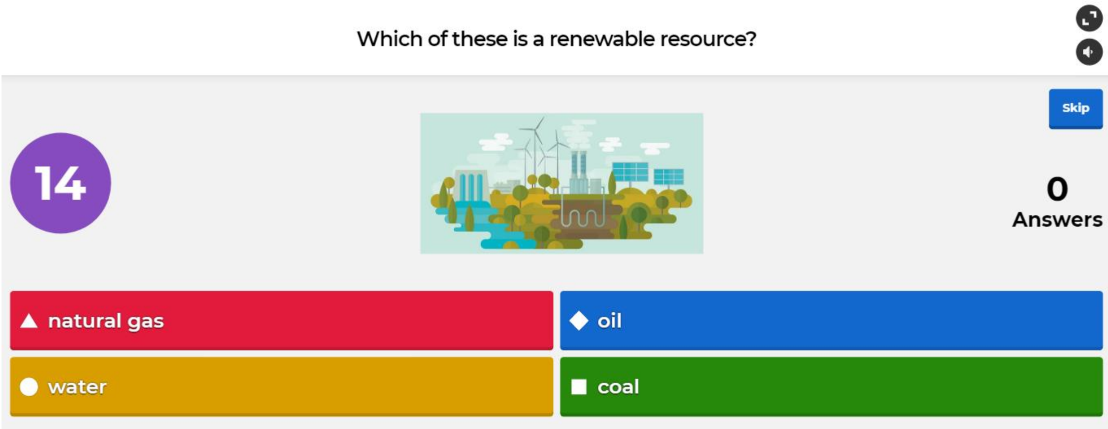

Figure 19. Example question about renewable resources

As a measure of confrontation, the buildings have a big share of the energy that is used, so we have to explain them the amount with simple examples so as to understand why the existing must be renovated or the new ones must be designed as nearly Zero Energy Buildings. From that point they can start their journey to find out how to make an nZEB and they will continue to the next stop separating the group at two smaller groups which will reunite at the final stop. The recommended order for the stops is for the group 1 stops 1,2,3,4,5 and for the group 2 stops 3,1,2,5,4. Every introduction of each stop is made out of examples from everyday life.

(b) *Stop no 1. Thermal conductivity*

In the first stop, the children should learn about thermal conductivity. Within a simple example of a metal pot and a book, that they will have the chance to touch, they will answer to the question which one feels colder. Right after the explanation that they are both in the same temperature will been given (an IR thermometer could prove it). Although there is a difference in the feel, it is a result of the difference between their thermal conductivity (the rate that heat transfers, that is much bigger to the metal pot comparing to the book).

The same could be done by using an aluminium plate and a plastic one placing on top of them an ice cube. The children should bet in which plate the ice cube will melt faster and why.

Figure 20. Example of thermal conductivity using an aluminium and a plastic plate

Following every day's life objects that could be used, are cups made of the same material, filled with hot water and a spoon made of different material placed inside them. Spoons made of metal, plastic, wood etc. can be used. The question that the children will be asked to answer is which of them they can touch without getting burned. Correspondingly, the following variation of this example could be made: the cups can be made of different materials and filled with hot water. There will be a thermometer inside them. The kids will have to answer which mug will cool down faster and why.

Figure 21. Example of thermal conductivity using cups and hot water

Another example that could be used is the visualization of the thermal conductivity through thermally sensitive materials in regards of the change of their temperature, such as thermochromatic membranes. A stick made of copper and one made of plastic can be placed at the bottom of one membrane. An ice cube is placed at the edge of each stick. In which stick the membrane will change its colour and why.

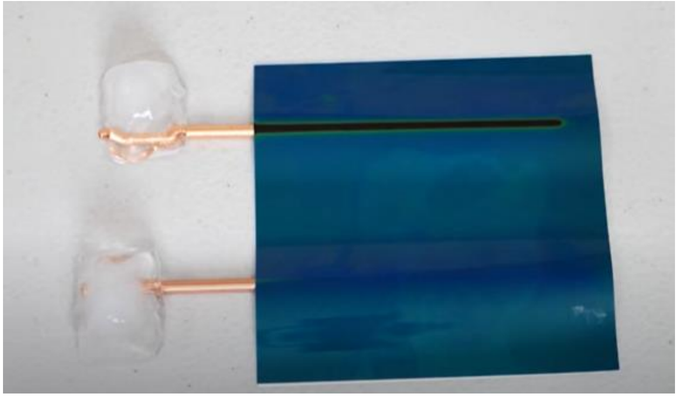

Figure 22. Thermal conductivity example using thermochomatic membranes

So as to keep the heat inside the house during the winter and out of it during summer, the buildings must be protected with a material that prevents the heat transfer. A thick layer of insulation with a very low thermal conductivity coefficient is ideal. Using the Thermal Phase Shift Model from 1.03(a) the children will recognize the difference between samples of insulating and non-insulating materials, through the sense of touching each side. Approximate duration of this stop is 10 minutes.

(c) *Stop no 2. Airtightness*

The term of airtightness is really challenging to be explained. Known airtight objects could be used like a sea mask, or a tub. It should be emphasized that each of them fits very well without leaving cracks or crevices so that liquids cannot seep through them.

Also, a volunteer could take part in this example. The scenario is that they are preparing for ski and they are trying to find the ideal outfit for the occasion. A pair of gloves and a jacket that doesn't seal on the wrists are going to be given to them. Then, using a hair dryer at the point of joint will make them understand that even though they wore a really warm jacket and gloves (at the scale of building these represent the thermal envelope) they can still feel the cold air, because there are gaps between them.

Figure 23. Example of thermal envelope and air leakages using clothes

Correspondingly, two balloons are going to be blown, one of which will have a tiny hole. The kids should recognize the difference and its cause, so as to define the term of air leakage. How many times do we have to blow each balloon?

Figure 24. Example with a balloon and a tiny hole

For the transition to the buildings, three little OSB maquettes of a house will be used, all with the same shape and two wrapped up with suitable tape and the other with masking tape. Which one will have the best airtightness? This question is going to be answered after passing the test with the blown balloon. The first model has cracks at the joints and has been sealed with a simple wrapping tape so it has the worst airtightness of all. The second model is being wrapped with proper tape but it still has some gaps at the joints of the edges of each side. The third model is perfect concerning its airtightness, because it has been made carefully in terms of built up and application of the suitable airtightness tapes. Thus, is a simple example to show that every single detail and imperfection at the design may be crucial at the implementation. Approximate duration of this stop is 12 minutes.

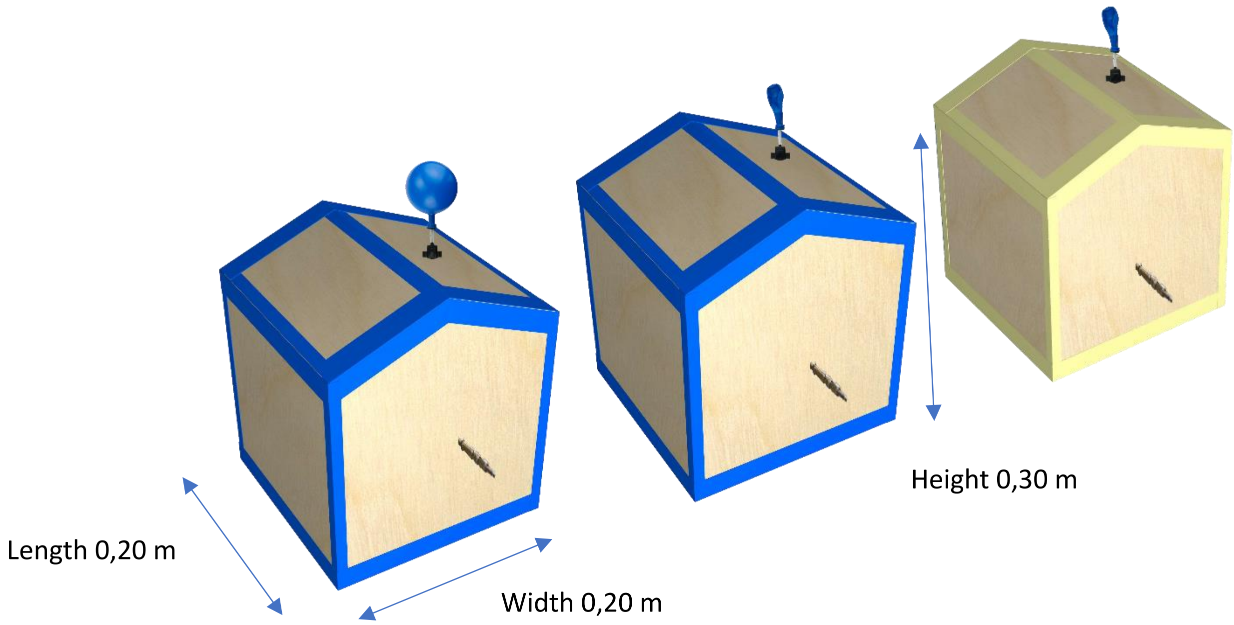

Figure 25. Airtightness mock-ups

(d) Stop no 3. Ventilation

As it has been shown in the previous stop a building should be as airtight as possible. But if we live in an airtight house after a while mould will start to grow because of the internal sources of humidity (cooking, bath) and the smells will be fuggy. Using the example of the closed tub for days this could be easily understood.

Also, passing the time by, the levels of oxygen in the space with the presence of humans in it will start to reduce. This could be explained by using an airtight transparent box with candles in it. The flame of the candles (that represents the humans in an airtight building) consumes the oxygen of the box and they go out when there is no other left.

Figure 26. Example of ventilation necessity on an airtight house

For that reason, the mechanical ventilation with a heat exchanger is necessary. The heat exchanger and its importance could be explained like the path that the air in the human breath takes. A human takes a deep breath from the nose, filtered by the nostrils (filters at the supply of the fresh air) follows the path into the chest (preheat of the fresh air) and then comes into the lungs (living spaces).

A heat exchanger with a hair dryer on its socket could be used. At first the hair dryer is being set to blow hot air through the extract's socket, so as to preheat the exchanger. Following, it will be placed at the fresh air's socket, blowing cold air. Thus, the children could feel the difference.

Figure 27. Example of heat exchanger on a mechanical ventilation system

The following model is made for understanding the concept of mechanical ventilation in buildings and how it is achieved. It is a construction made of plexiglass that simulates the areas of a house with a bedroom, a living room, a kitchen and a bathroom. It has holes and openings in the areas through which the air flow will take place. For the visualization and the better understanding of the mechanical ventilation, a smoke production device will be used, which will make the motion of air visible and the observer will be able to see its flow from place to place. A ventilation system consisting of two small electric motors and piping will be used for the entire operation of the system. The whole system will also be visible to the observer. Approximate duration of this stop is 12 minutes.

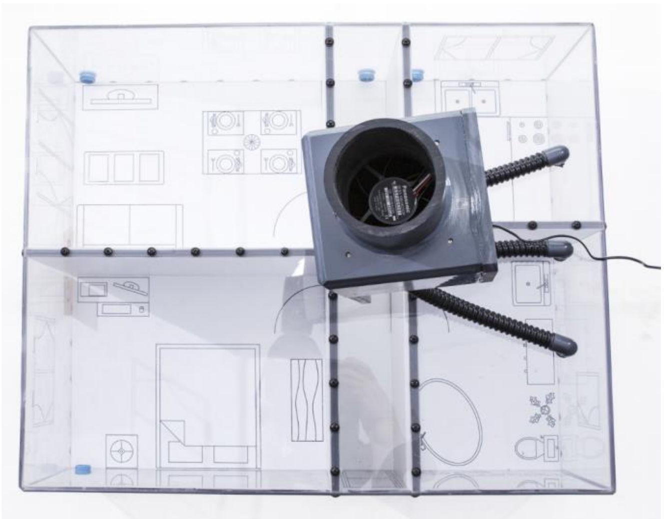

Figure 28. Visualization of air flow through smoke

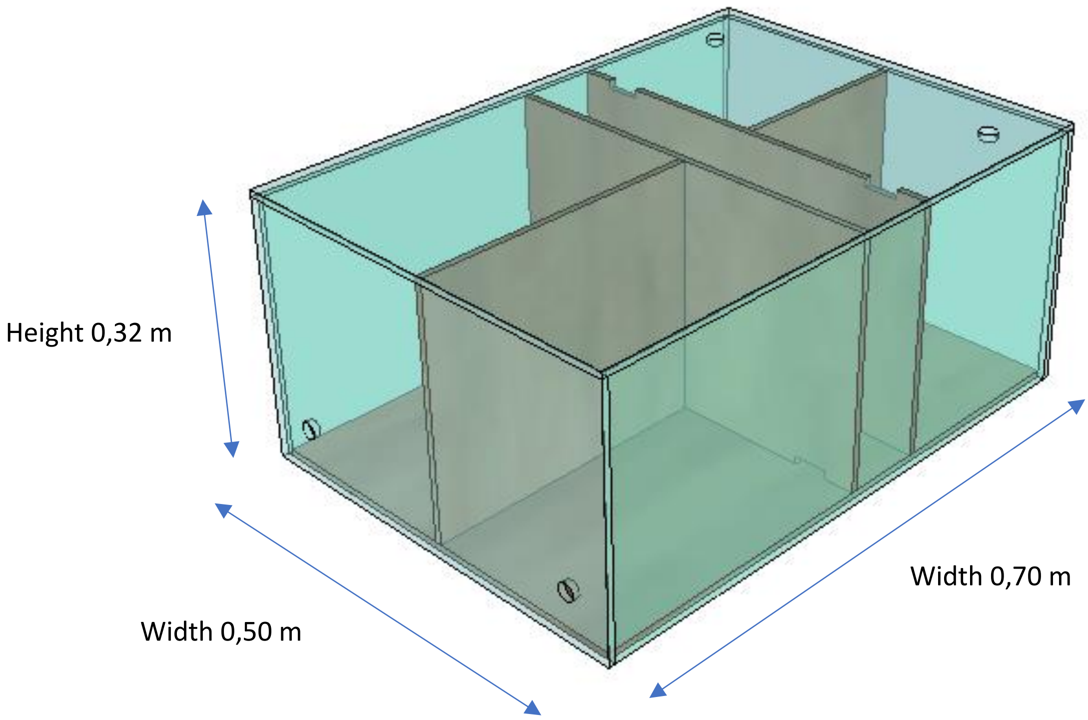

Figure 29. Model dimensions

(e) Stop no 4. Windows

This term is more familiar to children. Nevertheless, the first example comes from every day's life. Passing by the previous stops the children learn that anyone who makes a trip for ski has to be dressed with a wool (thick) jacket and gloves, that seal perfectly and prevent the air pass through. They have to breathe through the nose to filter and preheat the fresh air, but what about their eyes? How could they protect them from the cold and the sun beams? Should they use conventional sunglasses or a ski mask? What's the difference?

Figure 30. Example of a ski mask

The windows have a great impact on the energy balance of a building. The children will be able to see sections of windows with single, double and triple glazing in addition to different frame materials (PVC, aluminium, wood). But pay attention on the spacer between the glazing panes to be plastic and not aluminium because of its thermal conductivity.

Additionally, the construction from 1.03(b) will be used, so as the children to feel the difference of heat transfer between the different panes but also explain the thermal flow by using a thermal camera. Approximate duration of this stop is 10 minutes.

Figure 31. Window sections made of different materials and types of glazing

(f) *Stop no 5. Thermal bridges*

The term of thermal bridges is also difficult to be explained. Returning to the main example that connects all the stops with the skier, they finally chose to wear a jacket that is warm enough and it prevents the wind with metallic zipper that is exposed to the exterior conditions. Did they make the right choice?

It should be highlighted that even though they have chosen the jacket that will keep them warm, a considerable amount of heat escapes due to the discontinuity of fabric created by the metal zipper. In this way, we can describe that any discontinuity or interruption of the thermal envelope we have created can seem significant and this increased heat transfer phenomenon will be called a thermal bridge.

This example can also be visualized by wearing the jacket and through a thermal camera, children will be able to observe the change of colour on the zipper compared to the area of the jacket and detect by themselves the existence of the thermal bridge.

Figure 32. Giving examples from everyday life to describe a thermal bridge

Also, the following setup made of two identical insulation panels (same thickness and thermal conductivity coefficient) that is getting warm from one side using infrared bulbs could make the thermal bridge distinct. At the second panel a metal fork penetrates the insulation to create this interruption of our envelope. Did this fork create a sufficient outlet for the heat to escape?

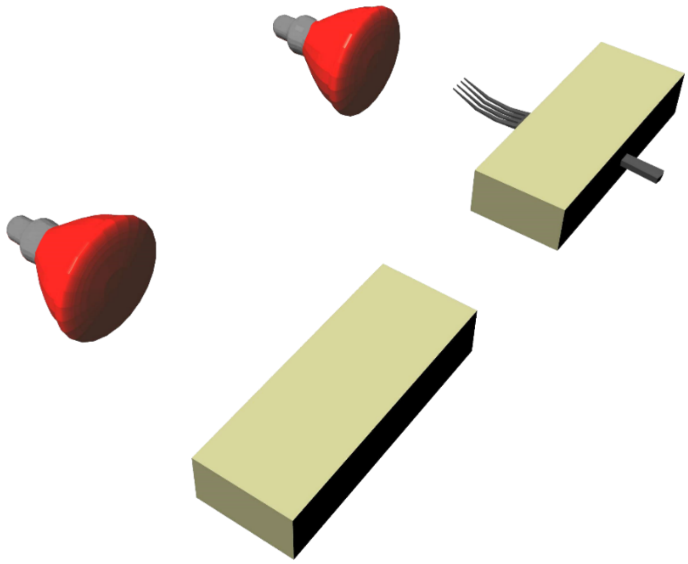

Figure 33. Thermal bridge example with a fork

Moreover, a setup that resembles a typical balcony construction could be used. Making an open metal box, where on one side there is a horizontal overhang, reminiscent of a house, children will be asked to install insulation on its 4 sides, to prevent heat escape as they learned in a previous stop. The construction will be properly configured with Velcro in each side so that the application of thermal insulation can be done in an easy way. Furthermore, inside the box an infrared bulb will be installed, in order that the construction will be heated up when it will be switched on. Thanks to thermal insulation, the results will be observable (palpable and visible with the use of a thermal camera) only in the part of the overhang that is not covered with it. At the end of this example, ways to avoid and prevent the phenomenon of thermal bridges should be mentioned in plain terms.

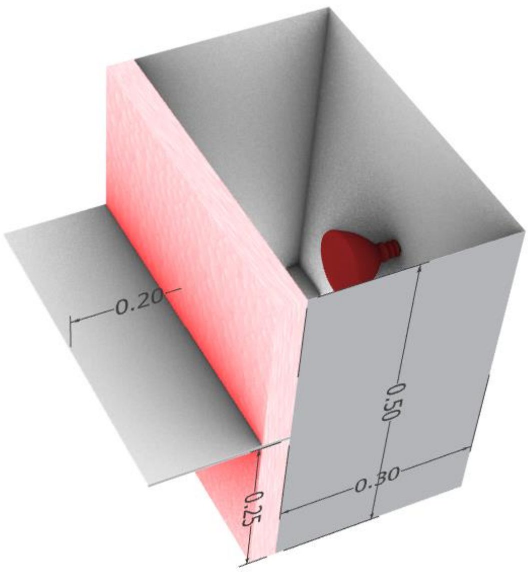

Figure 34.Balcony thermal bridge example

If the location where your event of roadshow takes place allows it, it is recommended to tour with the children with the intention of detecting examples of thermal bridges in real buildings by using a thermal camera. Approximate duration of this stop is 12 minutes.

(g) *Final stop*

Having passed both teams of children from all the stops, reach the final stop together. This stop is made to test what they have learned at the previous ones. They will compete again in a quiz made of questions about the 5 Basic Principles of a nZEB. At the end of every question, a small explanation by the team that answered correctly must be given. This stop can be combined with the 2.04 Nzeb Lego.

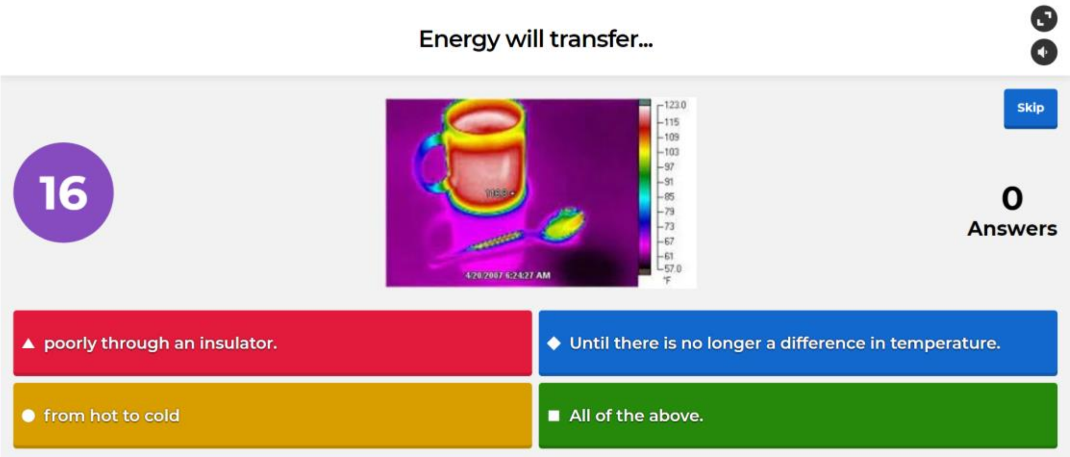

Figure 35.Quiz over the 5 basic principles of a nZEB

2.03 COMIC BOOK

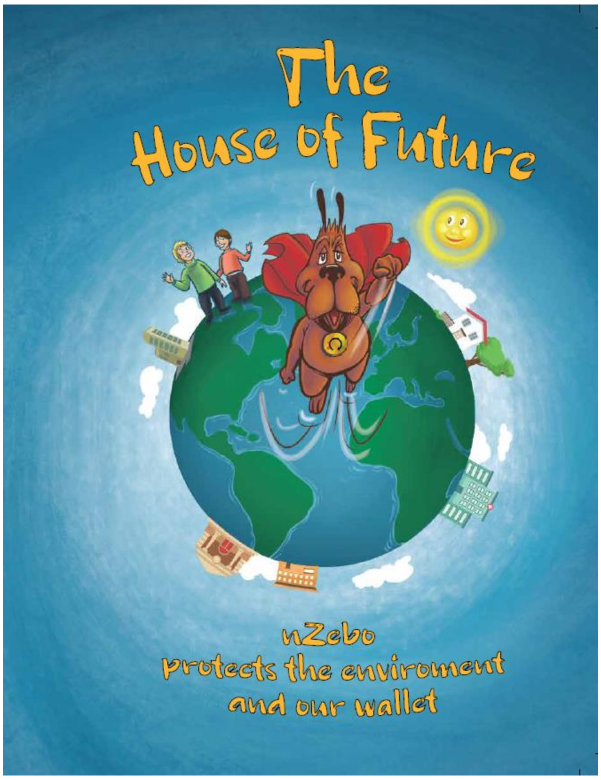

Figure 36. nZEBO the dog hero of nZEBs

A dog named "***nZEBO***" shows children with simple 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.

The book has already been delivered to the partners to translate it in their language, so as to print it and distribute it to every kid for their participation in the 7-stop journey as a souvenir. Having already passed the stops and acquiring the basic knowledge, nZEBO will help them relive the memory of the workshop within a very innovating and interactive way. The concept of making a comic book, may look exclusive for the children, but its impact will be huge to every household as well as to the public authority.

2.04 NZEB LEGO

It's the closure of the children journey at nZEB world. After successfully passing all the stops, it's time to get their reward by having fun while designing and building their dream eco-friendly home!

With the support of product suppliers, many samples of the construction materials can be shown to the children to notice the difference and be able to touch them (different kinds of insulation, samples of airtightness tapes, section of windows). At this point, it would be good to emphasize on healthy and natural materials that are suitable for the interventions on a nZEB (e.g. insulation made of wool or cellulose, cork).

Additionally, the mock-ups of the airtight connection of the wall assembly and window could be used to apply tapes at the window sides. Also, a heat exchanger suitable for display only could be used to, change the filters, explain the cross-ventilation concept and apply ducts and collars at its sockets.

Last but not least, it is the mock- up of an unfinished wall that they will have the chance to build themselves. Concerning the fact that most of the building materials are not that safe for children, our suggestion is to have already set up the two thirds of the wall of aerated concrete blocks fastened together, but at their splicing some distinct mistakes such as cracks and leakages should be made. The children should select from a basket of insulation which one should be used (different thickness and types) placed over the wall with Velcro tapes. Also, they will have the chance to fix the cracks by applying tapes and airtightness membranes at the right spots.

Figure 37. Exhibition building materials

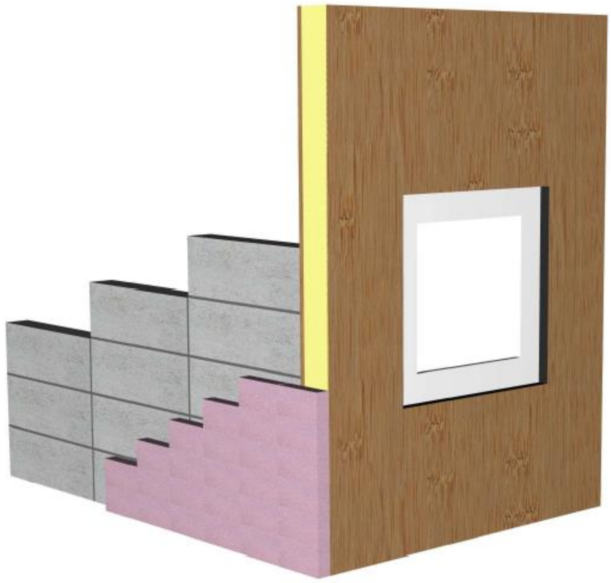

Figure 38. Exterior view of the nZEB Lego

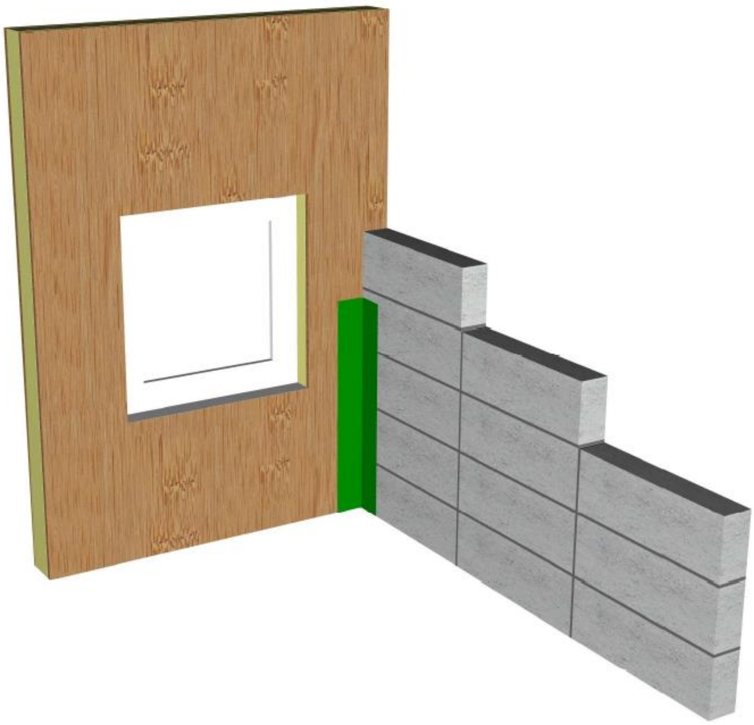

Figure 39. Interior view of the nZEB Lego

Figure 40. Prefabricated mock- up training wall for the application of tapes

Alternatively Virtual Reality (VR) technologies can be used to simulate all sorts of environments and situations. Among others, there are potential industrial companies who have developed virtual reality environments where one can experience masonry process and build a wall using the latest masonry technologies, as well as to become a roofer in the virtual reality and experience laying roof tiles (Figure 41).

The VR tool can be used also to create a small competition among children (i.e. how many bricks can be properly laid in 2 minutes etc.) thus encouraging gamification and interest for even more event visitors.

Actions have to be performed in order to disinfect the VR equipment between different users as a precaution of Covid-19 measures.

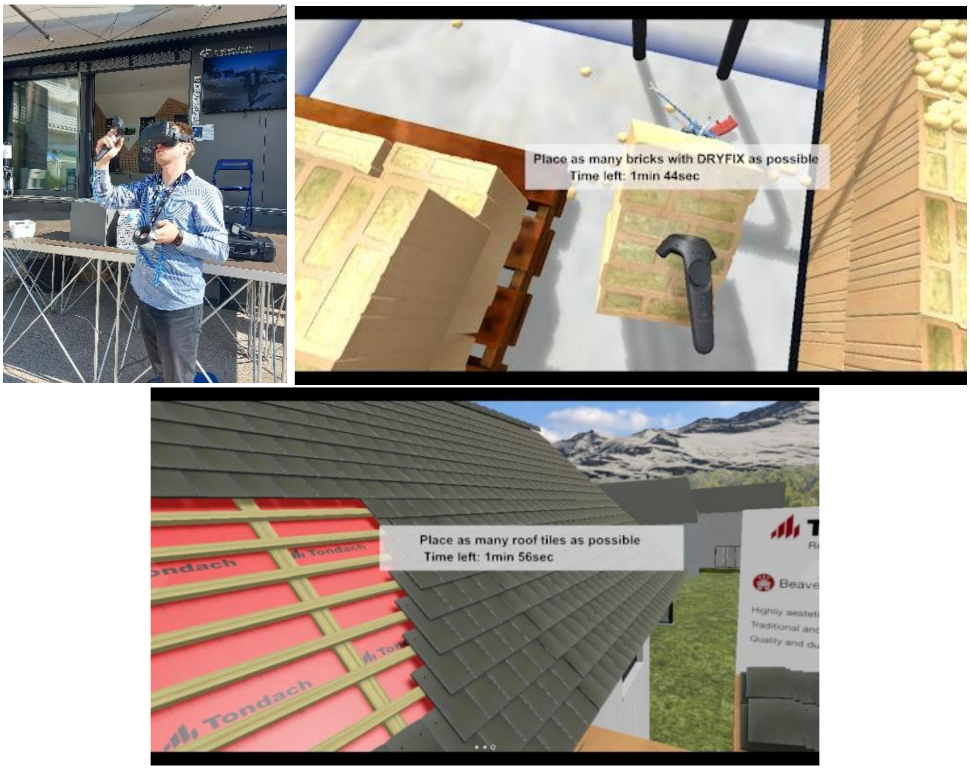

Figure 41. Virtual reality - constructing a virtual wall (or a roof)

Another option is to use readily available VR apps developed by different producers which offer users the chance to walk through a virtual house and an industrial facility using VR technology (Figure 43). Users can get to know the various products used in the construction of the buildings. The application offers a virtual walk-through in different environments which are equipped with information points. All points are interactive, which means that they enable users to explore the insulation layers and materials used in walls, floors and ceilings, which are normally not visible in the real world.

In cooperation with these industrial companies, their VR systems could potentially be used as a gamification for NZEB days and other NZEB events.

Figure 42. Readily available walk through a virtual house

WWW.NZEBROADSHOW.EU

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 892378