nZEB Roadshow
Bulgaria | Croatia | Romania | Greece | Italy

Guidelines for design and operation of mobile training and consultation units

Deliverable 3.1. of the NZEB ROADSHOW project

Responsible partner: ZEPHIR

Contents

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EXECUTIVE SUMMARY

The present document is the starting point of the nZEB Roadshow project's work on design and construction of demonstration equipment. Its main objectives are as follows:

- To support the design and construct mobile consultation centres with full specification of the necessary equipment for quality organization of local nZEB weeks.
- To support the design and construct transportable demonstration and training facilities.
- To develop specifications for spatial planning for successful organization and conduction of the nZEB weeks.

The current document offers specific guidelines for design and operation of mobile training and consultation units. The guidelines are drawn up by ZEPHIR (Italy), based on the experience gained from the successful application of demonstration models and practical training facilities in training courses and consultations within the Train-to-nZEB and Fit-to-nZEB projects. In addition, the guidelines utilize the know-how and practical experience related to the implementation of the BiosPHera project (1st and 2nd phase), during which mobile plus-energy self-sufficient residential units certified to the Passive House standard were designed and constructed by ZEPHIR, and were tested in real-life conditions in different climatic zones (**Figure 1** and **Figure 2**).

Figure 1. Example of MHU: BiosPHera 1.0, ZEPHIR, 2012-14.

This document is intended as a general guide how to design and build-up several types of demonstration equipment, as mobile homes, facilities, training trucks, mock-up sections, equipped walls, etc. The instructions aim to provide basic guidance for the nZEB Roadshow project partners and potential replicators via multiple visualisations, design drawings and specification of different units. Any interested party is free to use the guidelines and to adjust them better to their needs and according to their construction traditions and capacities. Moreover, 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 material and cost savings.

Figure 2. Example of MHU: BiosPHera 2.0, ZEPHIR, 2015-17.

1. DEMONSTRATION EQUIPMENT

Demonstration equipment play an important role in communicating and disseminating the benefits and specificities of nZEB, creating the necessary prerequisites for effective communication between stakeholders. Demonstration equipment are designed and construct as information and demonstration centres, to offer real-life experience of quality of nZEB, involving several stackeholder, from students to end-users, or from designers to construction product manufacturers, with the following main goals:

- Exhibition events
- Practical activities
- Training sessions.

In the present guidelines, several types of equipment for demonstration purpose are considered (Figure 3), namely:

- Mobile Home Units
- Training Trucks
- General demonstration facilities, as mock-up sections, equipped walls and training toolboxes.

All of them can be equipped with all necessary technologies to provide full information of the nZEB processes, with relevance to the building's performance in terms of comfort, internal air quality parameters, and energy consumption. The following is an outlined of these demonstration equipment types. These models provide the basis for solutions that should be adapted to and developed in each Partner country and workshop environment.

Figure 3. Examples of demonstration equipment.

1.1. MOBILE HOME UNIT (MHU)

A MHU is a transportable module that offers all the relevant solutions required for the design of low-energy buildings. It can be designed as a miniature house and equipped with furniture and appliances usually used in the home (Figure 4).

Figure 4. Mobile Energy-Saving House (MESH), BASF (2009).

The main goal of this kind of demonstration equipment is to offer visitors the possibility to directly experience the high indoor air quality and to demonstrate benefits to live in nZEB buildings in terms of health and internal comfort. Considering different visitors (from end users to designers or construction workers) and levels of knowledge regarding nZEB principles and buildings, several activities to do inside can be designed (**Figure 5**), namely:

- Living experience
- Gaming/apps
- The “Ice challenge”
- Air quality with MVHR
- PV monitoring
- Infrared thermal imaging

Figure 5. Suggested activities to do inside the MHU.

The MHU could be useful to training visitors about energy efficiency, materials, and comfort. To reach this goal, the Partners are encouraged to:

I. build according to current technologies.

II. choose a single building system or different systems for each wall/floor slab (e.g., wooden frame/cross-laminated timber, masonry/monolithic bricks, etc.)

III. choose different window frames and shading systems (**Figure 6**).

IV. build with different materials with the focus on investigating their use with different climatic conditions (e.g., position of airtightness layer, material thickness, etc.)

V. design activities to do inside for:

   - **end users:** show different windows frames, insulation, air quality, gaming/apps.

   - **designers/construction workers:** show material assemblies, insulation layers, airtightness activities: foil/tape applications, Blower Door Test.

Figure 6. Different materials and components demonstrations.

2. To demonstrate real-time energy efficiency performances, it is possible:

    I. To show performances on monitors (**Figure 7**).

    II. Personalize videos for different visitors.

    - **end users:** gaming/apps, management costs, nZEB principles, comfort, nZEB end-users' feedbacks, etc.
    - **designers/construction workers:** temperature/humidity performances inside building assemblies, U-value, infrared images, CO_2 monitoring while switching on/off the ventilation system, etc.

Figure 7. Monitor to show the performances.

Table 1. MHU main goals, activities and involved stakeholders.

Goals	**Activities**	**Attendants/Visitors**
→ live experience	→ comfort feedback → gaming/app → ice challenge → real time demonstrations	→ end-users → students
→ exhibition	→ real time demonstrations	→ designers → end-users → students → construction workers
→ training	→ video showing	→ designers → students → construction workers

Table 2. MHU main advantages and disadvantages.

Advantages	**Disadvantages**
→ Marketing and communication: very high visual impact. → Different kind of visitors: end-users/designers/construction workers/students. → Durable and re-usable. → Ready to be used.	→ Exhibition area: few people inside. → Expensive construction and transport costs. → Location: large occupation area. → Realization time. → Bureaucracy: land use/electrical and water supply/plumbing/authorization.

1.2. TRAINING TRUCK

A training truck is a mobile on-site training, exhibition and experience center. Through this kind of demonstration equipment, several stakeholders can be addressed: designers know the variety of nZEB solutions, while professionals expand their theoretical and practical knowledge and can test the products themselves (**Figure 8** and **Figure 9**).

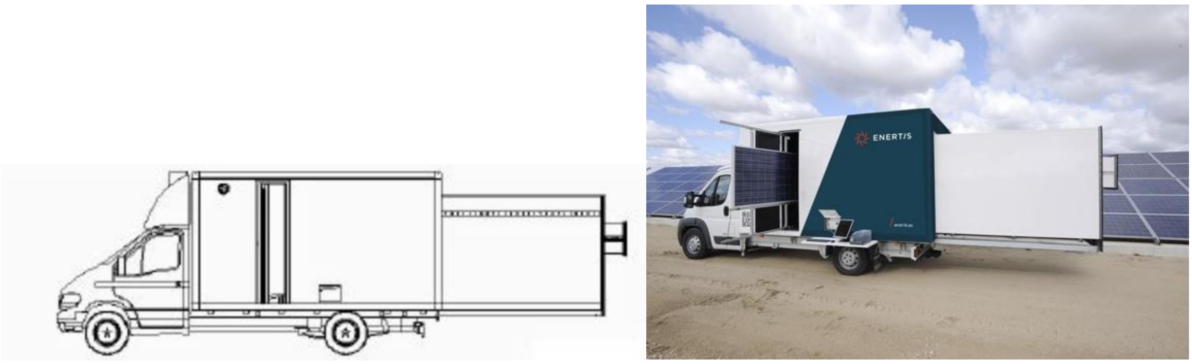

Figure 8. PV Mobile Lab. J. Coello et al. (2014).

Figure 9. Fisher TourTrack inside (left) and outside (right) view (2019).

Between the main goals of a training truck are:

1) To design and build training truck aiming at <u>training visitors</u>.
2) To offer attendants the possibility to <u>directly experience</u> and <u>learn</u>.
3) To <u>demonstrate real-time</u> applications and construction best practices.

Several different training sessions and activities could be chosen for:

- **Designers/construction workers:** demonstrative material assemblies (U-value…); airtightness activities (foil/tape, BDT…); different use of materials (insulation materials, windows…); insulation materials application; MVHR installation and sealing; etc.
- **End-users**: nZEB principles (**Figure 10**); insulation materials and windows; gaming/apps; nZEB end-users' feedback, etc.

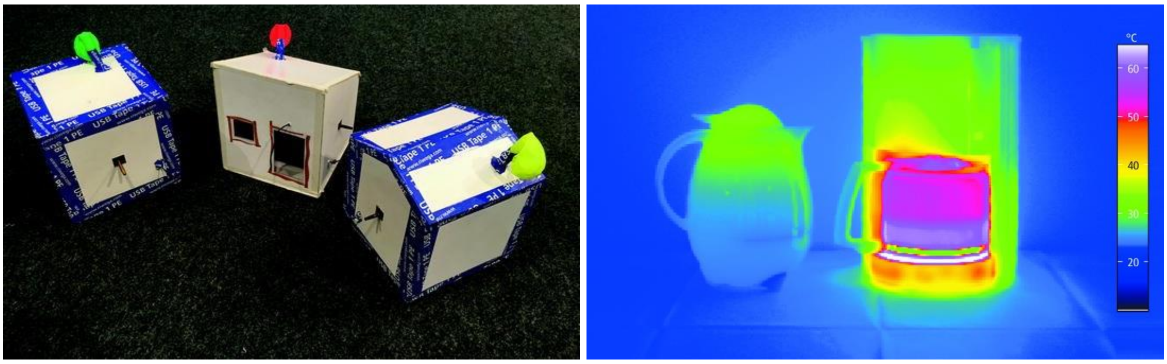

Figure 10. Teaching nZEB's principles.

The following practical design concepts can be adopted:

- To create some equipped mobile walls/drawers/trolley (**Figure 11**), easy to move.
- To create different levels of training: for example, each side of the truck can be personalized for training level and stakeholders.
- To increase interest by means of videos/live streaming.
- To use replaceable materials in order to satisfy potential personalized needs for different markets or countries.

Figure 11. Example of equipped walls.

Table 3. Training truck main goals, activities and involved stakeholders.

Goals	**Activities**	**Attendants/Visitors**
→ exhibition	→ living experience → gaming/apps → demonstrative materials and technologies on market	→ end-users → designers → students → construction workers
→ training	→ different use and physical characteristics of materials (insulation materials, windows, etc.) → demonstrative material assemblies (U-values)	→ designers → students → construction workers
→ practical activities	→ airtightness activities (foil/tape, BDT, etc) → insulation materials application → MVHR installation and sealing	→ construction workers → designers

Table 4. Training truck main advantages and disadvantages.

Advantages	Disadvantages
→ Marketing and communication: very high visual impact. → Personalized tasks for different kind of visitors. → Roaming training center. → Training activities in a single place.	→ Training area: only few people. → Expensive construction and transport costs. → Truck driver needed. → Location: large occupation area. → Realization time. → To create reusable equipped walls. → Bureaucracy: land use/electrical and water supply/plumbing/authorization.

1.3. DEMONSTRATION FACILITY

In this section, a description of three core model types of demonstration facilities is provided. These kinds of equipment have the main advantage to have a reduced volume, allowing easy transport and placement and lower costs of production. The physical size can be adjusted in order to ensure models fit into a given workshop or into a MHU or a training truck.

a) Mock-up section

A mock-up is a full-sized structural model built for study, testing, or display (**Figure 12**). It can be used to exhibit and show construction connection details as:

- wall-window system connection, showing doorway threshold with thermal breaks and/or solar shading alternative (e.g., bris soleil/raffstore or integrated louvered blinds)
- wall-balcony connection with a demonstration of the right insulation of the balcony (e.g., insulating materials or thermal break connections)
- wall- roof and wall-floor connections.

Figure 12. Mock-up sections.

Moreover, thinking to an audience of mechanical system's professionals and designers, details for the right connection and insulation of pipes and cables penetrating walls, roofs and structures in general could be provided (**Figure 13**), in order to raise awareness of the importance of those kinds of details and connections, as airtightness layers.

Figure 13. Flue insulation mock-up.

Partners are expected to develop demo sections best suited to the typical constructive methods of their respective countries. The demonstration facility should be selected depending to the goal of the exhibition or to the target audience.

For example, regarding the ventilation systems, in the case of renovation exhibition, space-saving systems could be shown, as integrated window systems (**Figure 14**)

Figure 14. Integrated window system. www.alpac.it

In the case of the target audience is connected to apartment building, all the several potential solutions could be presented, as centralized, semi-decentralized, or decentralized ventilation systems (**Figure 15**).

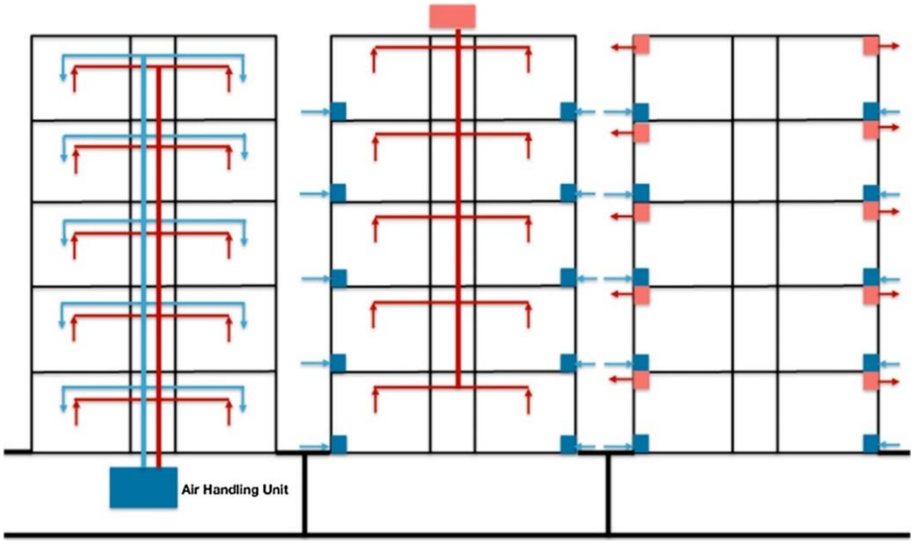

Figure 15. Comparison of centralized, semi-decentralized, and decentralized ventilation systems. Kim et al. (2016).

b) Equipped wall

Walls with several kind of equipment could be designed with the purpose to conduct training and practical activities. As an example, to inspire Partners, an interesting activity could be sealing the leakages on the demonstration model, using tapes and foils. It is an easy way do show best practices of a right airtightness layer installation and application for example around ventilation ducts, electrical boxes and pipes, windows, and other components on the airtightness (**Figure 16**). Another activity could be a real demonstration about the right installation of insulation materials and the possible mistakes to avoid.

Figure 16. Example of equipped wall.

c) Training toolbox

Toolboxes, mainly used for training and practical activities, can be an ideal way to contribute to an improved nZEB culture and to disseminate nZEB principles. Easy to move and transport, can be provided by manufacturers and used by construction workers and professionals to test materials (e.g., insulation materials and/or anchors), check component performances (e.g., glazing and frames) (Figure 17) or learn laying techniques (foil and tapes).

Figure 17. Example of training toolbox.

Table 5. Demonstration facility main goals, activities and involved stakeholders.

Goals	Activities	Attendants/Visitors
→ exhibition	→ living experience	→ end-users → designers → students → construction workers
→ training	→ different use of materials (insulation materials, windows, etc.) → demonstrative material assemblies (U-values)	→ designers → students → construction workers
→ practical	→ airtightness activities (foil/tape, BDT, etc) → insulation materials application → MVHR installation and sealing	→ construction workers

Table 6. Demonstration facility main advantages and disadvantages.

Advantages	Disadvantages
→ Attractive (mock-up section). → Personalized tasks for different kind of visitors. → Easy to transport and move. → Reduced size. → Low cost (toolbox). → Short time for realization.	→ Transport costs (excl. toolboxes). → To create reusable equipped walls/toolboxes. → Reduced volume to allow easy transport and placement.

2. KEYWORDS AND GENERAL GUIDELINES

The following are some keywords describing general guidelines and approaches that can facilitate Partners in the design and construction of successful demonstration equipment:

a) MULTITASKING

The design of all kind of equipment should focus on the participation of different level of attendants and visitors. The stakeholders whose addresses the project are several: end-users, students, designers and construction workers. Moreover, locations and workshops where to move and use the demonstration equipment could be various, e.g., technical conferences, exhibitions, etc. Therefore, Partners are encouraged to design multitasking equipment that could address simultaneously to different stakeholder or that could easily change and be adapted for different countries and local architectural features and traditions.

b) TRANSPORTABLE

To transport and move equipment have implications affected by several factors. In line with the Deliverables of the project, the demo facilities will be brought in exhibitions and events to showcase the importance of energy efficiency and will be promoted accordingly. Therefore, the demo facilities need to be easily transportable, with specific dimensions to occupy a space ranging from 25 to 35 m^2, in order to be arranged both in open spaces (e.g., city center) and inside exhibition spaces. See **Section 4** for more details.

c) PRACTICAL

The construction should be as simple as possible to become a versatile tool, easy to move, transport, exhibit, assemble and pack. The main strategy is to build modular equipment, composed mainly by assembled prefab components. This will reduce construction timing and provide quality control before delivering them. See **Section 4** for more details.

d) REUSABLE/REVERSABLE

A reuse concept should be implemented to save costs and time, and to guarantee the reversibility of materials and equipment. See **Section 5** for more details.

The keywords mentioned above refer to all the considered demonstration equipment types. In addition, regarding systems like MHUs or training trucks, other general guidelines need to be considered as:

e) SELF-OPERATING and ENERGY-AUTARCHIC:

To design, build and set up self-sufficient grid-connected modules, which use renewable energy source, as the solar energy, in order to guarantee the energy autarchy and to facilitate the standalone operation (**Figure 18**).

Figure 18. Housing prototype using only solar energy, SMLsystem, Solar Decathlon Europe (2012).

f) RESILIENT

The equipment is expected to work in several climatic condition, therefore strategies to guarantee the resilience and the adaptation needs to be adopted. For example, the installation of solar shadings or the use of adaptive solar blind systems (Figure 19).

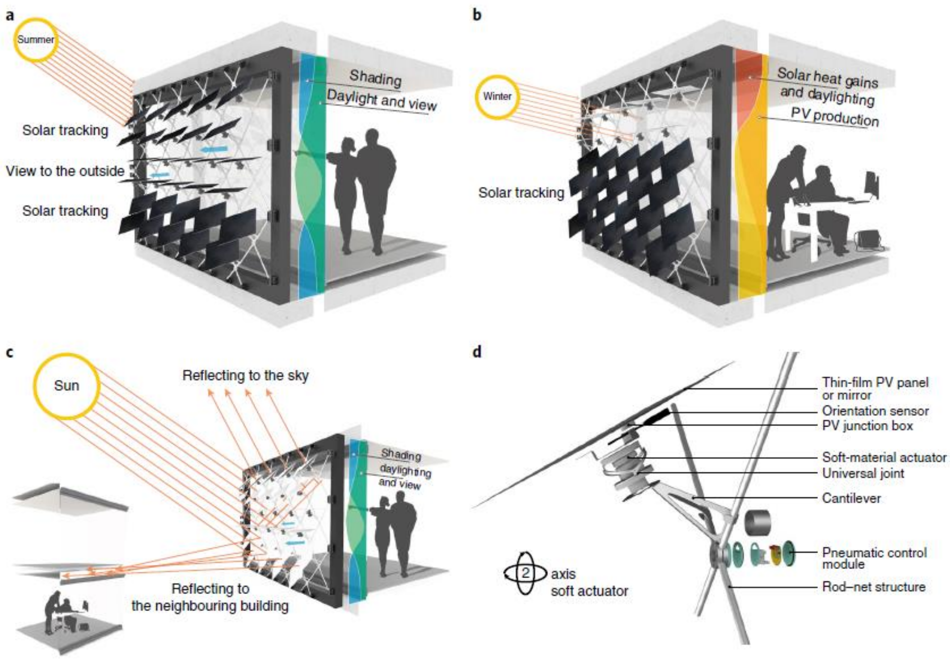

Figure 19. Dynamic PV building envelopes for adaptive energy and comfort management. Svetozarevic et al. (2019).

g) SUSTAINABLE

It would be suitable to take environmental issues into consideration when designing, developing, and constructing the demonstration equipment. See **Section 5** for more details.

3. DESIGNING TRANSPORTABLE AND PRACTICAL EQUIPMENT

To transport and move equipment have implications affected by several factors, in addition to the distance of the move:

a) Size and weight

The size of the MHU will have a big effect on the overall moving cost. The weight directly influences the fuel consumption, while if the MHU is too wide to safely drive down the street (i.e., it takes up more than one lane), it may be the need to pay for a police escort or a temporary road closure.

Figure 20. Moving BiosPHera 2.0.

b) Country regulations and requirements

If moving the MHU to another country or state, permits may need to be acquired for each individual territory it enters or travels through.

c) Moving materials

Moving a MHU means moving lot of materials. The Partners need to ensure that the MHU is safe and up-to-code prior to the move (Figure 20). It would be useful to provide elements for moving movable walls or components. The prefabrication of façade systems with all the needed equipment, from windows to HVAC ducts, is one of the strategies to realize easily movable equipment.

d) Landing and support

Considering that the demo equipment will be brought in different contexts, as open or exhibition spaces, it is necessary to foresee practical landing and support systems to place the demo equipment on several types of surfaces (**Figure 21**). Moreover, it would be useful to forecast an additional surface on which place the equipment. It is necessary a detailed study of the anchors, from both a static-structural and thermal point of view, keeping in mind that pass-through metal elements become punctual thermal bridges, to be solved with insulation and airtightness.

Figure 21. BiosPHera 2 landing gears.

4. SPECIFIC GUIDELINES FOR MHU AND TRAINING TRUCK

4.1. HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

The Partners are encouraged to consider the following issues:

a) Size

It is necessary to choose appropriate mechanical systems, considering the dimension of the demonstration equipment, in order to save space and avoid overheating. Small and space-saving systems are to be preferred, as decentralized mechanical ventilation (**Figure 22**) or compact systems.

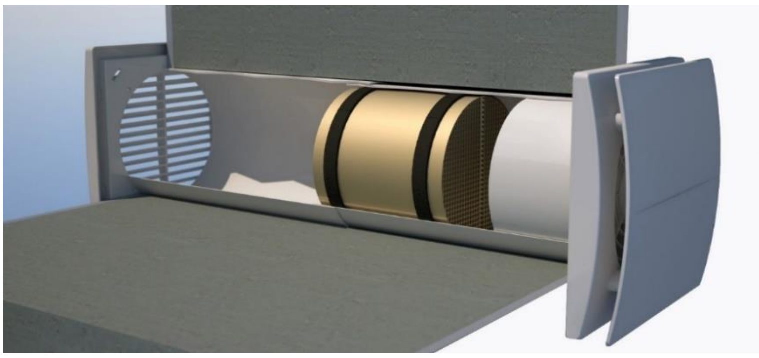

Figure 22. Decentralized punctual mechanical ventilation.

b) Noise

In such small spaces, conventional HVAC systems could result noisy, giving a negative feeling of these kind of systems, which we know to be of fundamental importance in nZEBs. A ventilation system that operates unnoticeably requires careful design, which involves paying attention to the characteristics of the building, the users and the purpose of use. Designers should consider the following tips:

- Correctly sized ventilation unit
- Correct location of the vents in the rooms
- Air vents differentiation (size and type)
- Obtaining a flow balance to avoid excessive noise
- Installation of duct silencers.

c) Internal gains

Considering the dimension of the demo equipment, it is important to pay attention to the following factors that influence the internal thermal gains in order to avoid discomfort or overheating:

- nr of potential hosted people, considering different scenarios (e.g., single visit, group tour, open spaces, internal exhibition spaces, etc.)
- electric equipment (e.g., lighting, monitor, etc.), considering different uses.

4.2. RENEWABLE ENERGY SYSTEM (RES)

Energy autarchy could be achieved by installing solar thermal or PV panels (Figure 23). Installing of the roof, it would necessitate (internal or external) stairs for easy access and safety.

Figure 23. Casas em Movimento, Portugal. Solar Decathlon Europe 2012.

The installation of PV panels should include DC/AC inverter, PV generation meter and battery bank for energy storage inside. The solar thermal panels could feed a heat pump, for heating and (if necessary) hot water.

4.3. OTHER EQUIPMENT

As follows, a list of potential tools to install with the aim of attracting the attention of the visitors:

a) Monitoring and measuring equipment

- weather station
- data-logger
- digital sensors
- anemometer
- indoor/outdoor air quality devices

b) In-situ equipment

- blower door test
- thermal imaging camera
- membranes and tapes

- mock-ups
- demonstration models
- touchscreen monitor
- video showing
- ice challenge
- VR gaming/apps

5. STRATEGIES TO IMPROVE SUSTAINABILITY, REUSABILITY AND REVERSIBILITY

In order to improve the environmental and economic sustainability of the demonstration equipment, several strategies are viable, from a single from a single aspect to the entire life cycle.

5.1. ENVIRONMENTAL IMPACT OF MATERIALS, STRUCTURES, AND COMPONENTS

a) Databases and average values

One of the first strategies to design environmentally sustainable equipment, is the selection of materials, structure and components with low embodied energy and lifetime environmental impact. Standing the fact that it is not easy to compare different products, average values can be consulted on several existing databases.

As follow a list of some existing free available databases:

- https://www.oekobaudat.de/en/database/database-oekobaudat.html
- https://greenbuildingencyclopaedia.uk/wp-content/uploads/2014/07/Full-BSRIA-ICE-guide.pdf
- https://www.natureplus.org/index.php?id=43&L=2

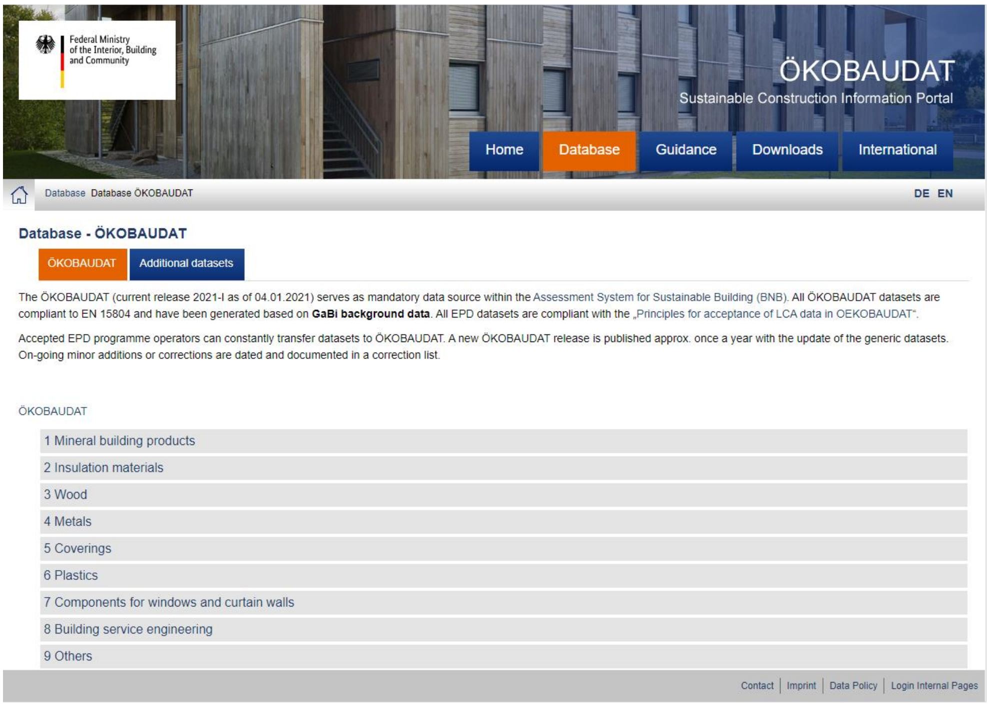

Figure 24. https://www.oekobaudat.de/en/database/database-oekobaudat.html

b) Environmental product declarations (EPDs) libraries

EPDs use life-cycle assessment (LCA) to quantify and then communicate the lifetime environmental impact of a product. They are third party verified and based on international standards, so provide an objective, credible and neutral assessment. In creating an EPD, a manufacturer is not making claims of low impact, but rather showing a commitment to measure and transparently declare environmental impact in an accessible format. Construction product EPDs are published by different program operators on several different platforms. With the ECO Portal (https://www.eco-platform.org/epd-data.html), ECO Platform offers a central access point for users to digital EPD data (Figure 25).

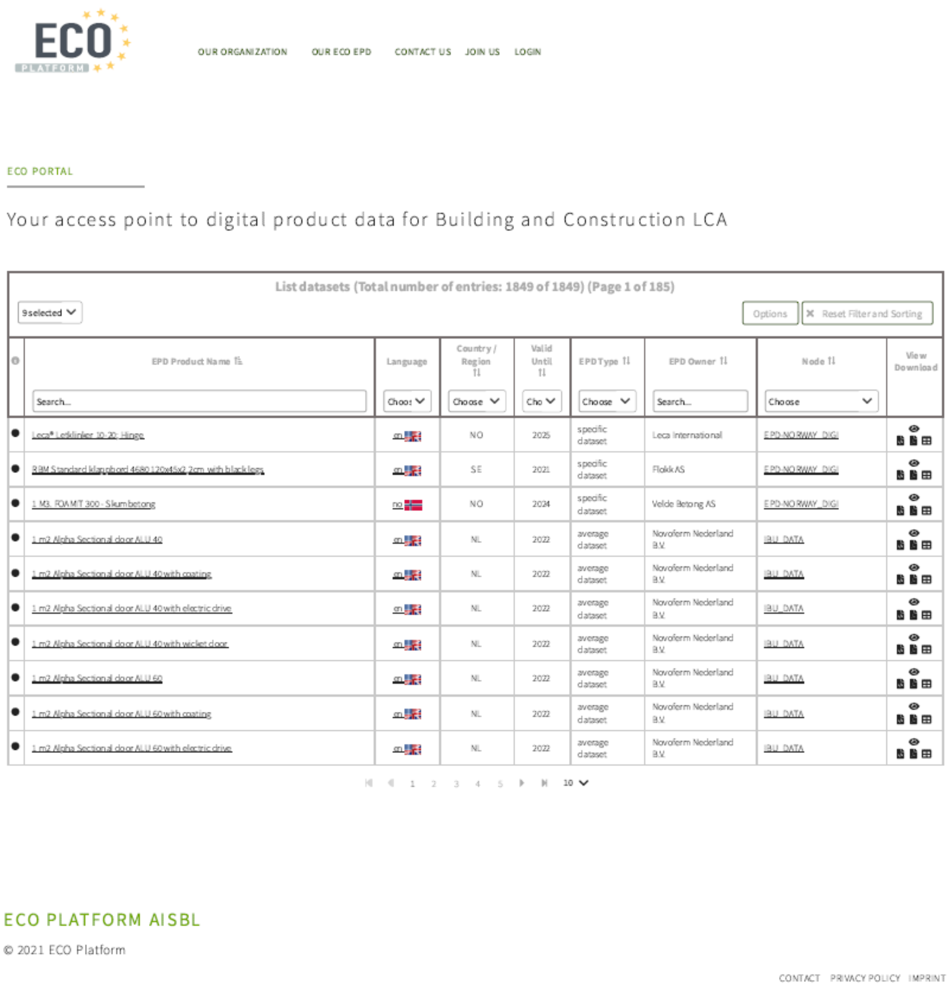

Figure 25. https://www.eco-platform.org/epd-data.html

c) Life Cycle Assessment (LCA) tools

The environmental assessment of the single components or of the entire equipment can be conducted with the use of LCA tools. The operational process for LCA software for construction is consisting of the introduction of input data by the user, namely the materials for construction (expressed in volume or weight) present in the project. To each of them are attributed the environmental performances according to the available databases, which are then added, weighed, and normalized according to the LCA methodology internal to the software itself.

As follow a list of some existing LCA tools specific to the assessment of constructions:

- http://www.handprintconsulting.ca/index.php/tools-publications/

A free plugin for the Passive House Planning Package that calculates the embodied greenhouse gas emissions of insulation as compared to the operational greenhouse gas emissions of a given project modelled in PHPP v9.6.

- https://www.branz.co.nz/environment-zero-carbon-research/framework/lcaquick/

A free tool that evaluates the carbon footprint and other environmental impacts of a building design.

- http://www.athenasmi.org/what-we-do/lca-data-software/
- https://legep.de/?lang=en
- https://www.oneclicklca.com/

5.2. REVERSIBLE TECHNOLOGIES AND CIRCULAR STRATEGIES

Sustainability can be also reached through other strategies, mainly oriented to avoiding as much as possible the end up of materials to a landfill and promoting circular strategies, giving upcycled and recycled building materials a new life.

a) Design for Assembly, Disassembly and Reassembly

Design for Assembly, Disassembly and Reassembly is an important tool to mitigate the volume and impact of construction waste. The Partners should design with the aim to facilitate future change and the eventual dismantlement (in part or whole) for recovery of systems, components, and materials (**Figure 26**). Moreover, this strategy could facilitate the transportation and movement of the equipment for nZEB Roadshow events, not to be underestimated.

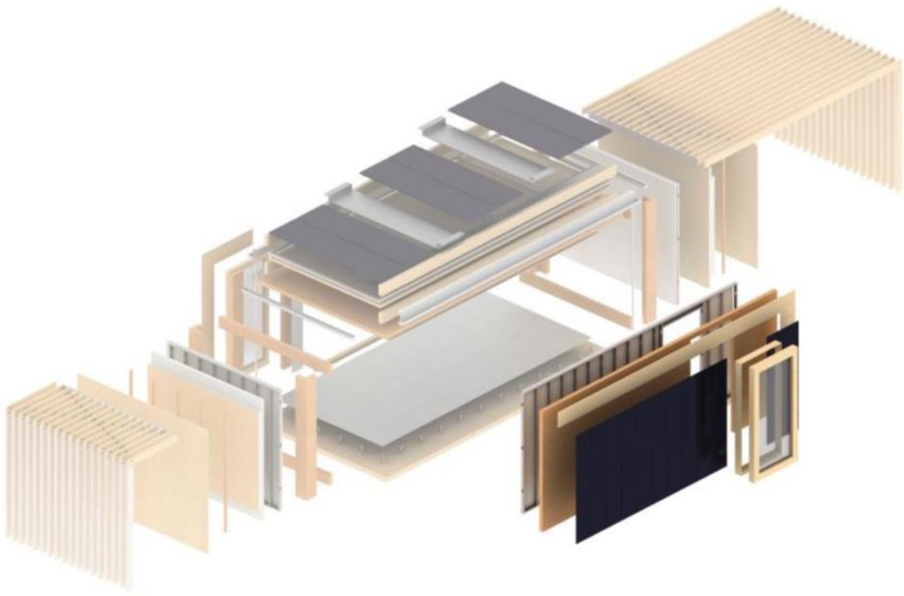

Figure 26. Decomposition of a wall. Soriano et al. (2014)

b) Recycle and re-use

The Partners are encouraged to use modular components, easy to assemble and disassemble, limiting the use of glues with the aim to facilitate the recovery of building materials and the recycle of most of them (**Figure 27**).

A re-use concept could be implemented by the Partners. For example, the devices could be used for training activities in other context (e.g., schools, technical institutes, etc.) or as mock-up model for companies or construction products manufacturers.

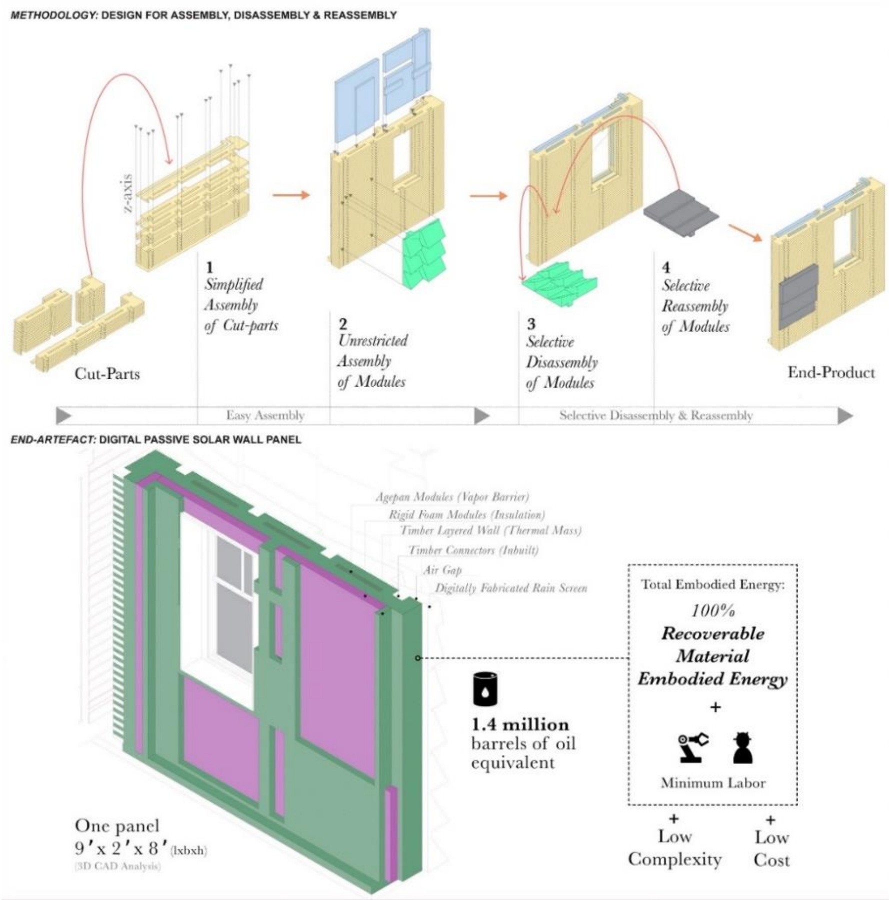

Figure 27. Podder, A. (2019)

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7. ANEXES

[A1] D3.1 – Annex 1-Checklist for demonstration equipment's design.

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