POLITECNICO di Milano

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CONVENZIONE TRA IL MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE ED IL POLITECNICO DI MILANO DEL 24 MARZO 2014 PER L'ATTUAZIONE DELLE METODOLOGIE DI CALCOLO DELL'IMPRONTA DI CARBONIO E DI COMPENSAZIONE DELLE EMISSIONI DI CO2 DI EXPO 2015

D.1.1.b Guidelines for the reduction of the environmental impact of temporary building and structures in mega events

Dipartimento di Energia

Indice:

1. Temporary buildings: case studies and technologies

di Marco Imperadori

Introduction

The current environmental urgency impose to face the design not from a linear but from a cycle point of view, integrating environmental criteria right from the conception stage, to make strategic choices aimed at containing the flows of energy and materials in and out from building, making the designer responsible, in a conscious way, at all stages of the life cycle.

The analysis of the issue of temporary buildings has led to the definition of three main categories to interpret temporariness and to define design strategies for temporary buildings: mobility, flexibility and reversibility.

Read in this order, they define a progressive increase in the level of temporariness of the building, passing from elements that are characterized by a few degrees of variability, in elements designed to accomplish the total reversibility of the construction.

Mobility – Temporary location

Concern the variability of the relationship between environment and building and refers to the mobile character of the building, to its capacity to be transferred in different places.

The building can be moved both by integrated handling organs and by means of transport.

The movement cannot leave out of consideration the dimensional control of the shape: it is possible to have 3D compact systems (possibly expandable) or buildings that can be disassembled and reassembled.

A well known and widely used three-dimensional system is the container technology used as a single body or as an aggregation of modules and sub-modules.

Flexibility – Temporary use

Linked to the activity housed in the building. Different ways to use the building can ensue even in very short timelines. It results in spatial and technological systems able to transform their layouts through works more or less heavy.

Reversibility – Temporary construction

It is strictly linked to the end of use of the building and its dismantling. The more the life of a building is short, the more it opens the problem of materials and building components which prematurely become waste. The use phase, in relation to its short duration, has a quite marginal role then the core of the design is strictly related to construction systems and technologies.

Reversibility is the capacity of a construction system to be de-constructed.

De-construction has several advantages over conventional demolition. It also faces several challenges.

Some of the advantages are:

- an increased rate of diversion of demolition waste from landfills;
- potential reuse of building components;
- increased ease of materials recycling;
- enhanced environmental protection, both locally and globally.

De-construction preserves the invested embodied energy of materials, thus reducing the input of new embodied energy in reprocessing or remanufacturing materials. A significant reduction of landfill space can also be a consequence.

As the dismantling of buildings generally requires more manpower and technical equipment than traditional demolition, the costs also tend to be higher but might be compensated by lower costs for the recycling or disposal of the materials, if dismantling and recycling are planned well.

Design for deconstruction – design for disassembly

The concept of Design for Deconstruction or Design for Disassembly (DfD) considers future demolition and disassembly of building elements at the design stage of new buildings promoting waste and resource-use reduction. The appropriate use of building technologies and their successful integration into the design process will facilitate an increased reuse of the building components. The difference between deconstruction and disassembly was debated at the “ Deconstruction — closing the loop” Conference held in 1999 at the Building Research Establishment (BRE): disassembly is a process of taking apart components without damaging them, but not necessarily to reuse them, while deconstruction is a process similar to disassembly but with thought towards reusing the components (Hurley et al 2001).

The complexity of the design process makes the development of any design tool or set of guidelines for de-construction difficult.

Crowther defines a pattern of performance standards and prescriptive guidelines grouped according to the specific and-of-life scenario:

- building reuse or relocation ;
- component reuse or relocation in a new building ;
- material reuse in the manufacture of new component;
- material recycling into new materials.

Such a distinction also highlights the hierarchical nature of reuse being environmentally preferable to recycling. The strategy of component reuse will generally require much less processing energy and material input than the strategy of remanufacturing which again in turn requires less energy and material than the strategy of recycling.

It is necessary to consider the technological context in which the dismantling will happen and then the attitude of a construction system or of a technological element to be separated whit the minimum quantity of work and energy.

Such a distinction highlights also the great importance to plan in advance the full life cycle of the building and therefore the use at the end of the first life, so as to direct the design choices.

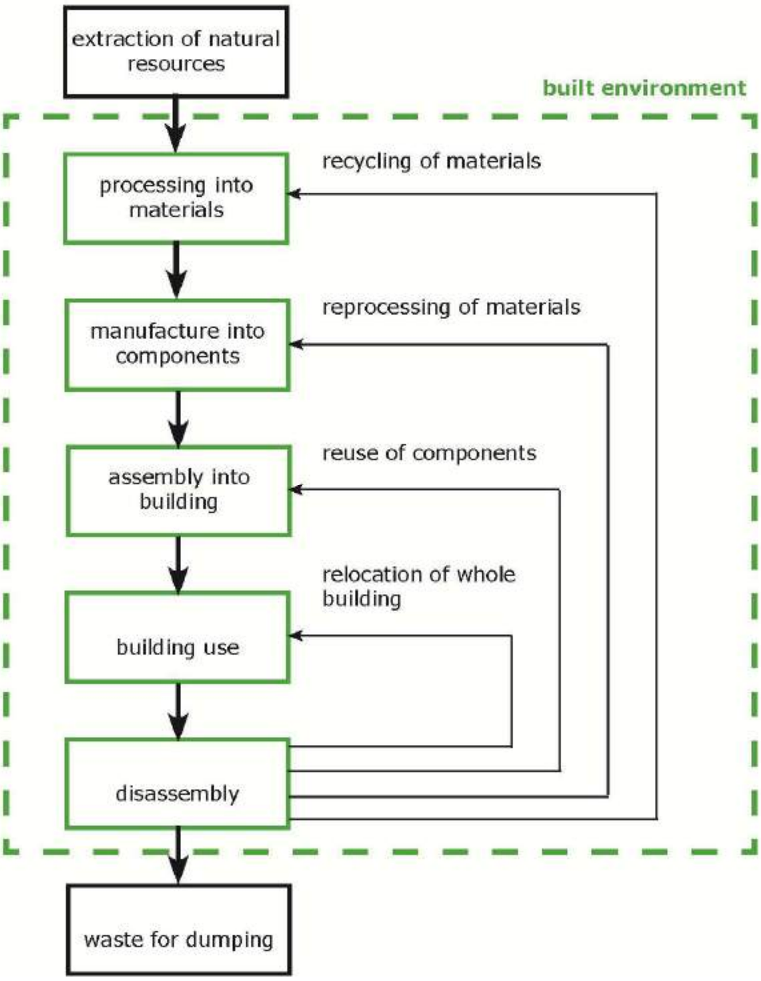


Figure 1. Life cycle of the building

Guidelines for technical design for de-construction

In the following tables are summarized the main guidelines useful to design and define a building following de-construction future possibilities.

Design for deconstruction for materials recycling	
n.	Guidelines
M1	Use recycled materials – increased use of recycled materials will encourage industry and government to develop new technologies for recycling, and to create a larger support network for future recycling and reuse
M2	Minimise the number of different types of material – this will simplify the process of sorting on site and reduce transport to separate reprocessing plants.
M3	Avoid toxic and hazardous materials – this will reduce the potential of contaminating materials that are being sorted for recycling and will also reduce the potential for human health risk during deconstruction.
M4	Make inseparable subassemblies from the same material – this means that large amounts of one material will not be contaminated by small amounts of a foreign materials that can not be separated.
M5	Avoid secondary finishes to materials – such coatings may contaminate the base material and make recycling more difficult, where possible use materials that provide their own suitable finish or use separable mechanically connected finishes (some protective finishes such as galvanising may still on balance be desirable for other reasons).
M6	Provide standard and permanent identification of material types – many materials such as plastics are not easily identifiable and should have some form of non removable and non contaminating identification mark to allow future sorting (ideally some form of bar code would be most suitable for fast identification, such a code could also provide information on place and date of production and structural capacity).

Design for deconstruction for component reprocessing	
n.	Guidelines
C7	Minimise the number of different types of components – this will simplify the process of sorting on site and make the potential for reprocess more attractive due to the larger quantities of same or similar items.
C8	Use a minimum number of wearing parts – this will reduce the number of parts that need

	to be removed in the remanufacturing process and thereby make reprocessing more efficient.
C9	Use mechanical connections rather than chemical ones – this will allow the easy separation of components and materials without force, and reduce contamination to materials and damage to components.
C10	Where appropriate, make chemical bonds weaker than the parts being connected – if chemical bonds are used they should be weaker than the components so that the bonds will break during disassembly rather than the components, for example mortar should be significantly weaker than the bricks.

Design for deconstruction for component reuse	
n.	Guidelines
R11	Use an open building system, a system where parts are more freely interchangeable and less unique to one application – this will allow alterations in the building layout through the relocation of components without significant construction work.
R12	Use modular design – use components that are compatible with other systems both dimensionally and functionally.
R13	Use assembly technologies that are compatible with standard building practice – specialist technologies will make disassembly difficult to perform and may require specialist labour and equipment that makes the option of reuse more difficult.
R14	Separate the structure from the cladding, the internal walls, and the services – to allow parallel disassembly where some parts of the building may be removed without affecting other parts.
R15	Provide access to all parts of the building and all components – ease of access will allow ease of disassembly, if possible allow for components to be recovered from within the building without the use of specialist plant equipment.
R16	Use components that are sized to suit the intended means of handling – allow for various possible handling options at all stages of assembly, disassembly, transport, reprocessing, and reassembly.
R17	Provide a means of handling components during disassembly – handling during disassembly may require points of connection for lifting equipment or temporary supporting devices.
R18	Provide realistic tolerances to allow for movement during disassembly – the disassembly

	process may require greater tolerances than the manufacture process or the initial assembly process.
R19	Use a minimum number of different types of connectors – standardisation of connectors will make disassembly quicker and require fewer types of tools, even if this result in the over sizing of some connections, it will save on assembly and disassembly time.
R20	Design joints and connectors to withstand repeated use – minimise damage and wear and tear from the assembly/disassembly procedure.
R21	Use a hierarchy of disassembly related to expected life span of the components – make components with a short life expectancy readily accessible and easy to disassemble, components with longer life expectancy may be less accessible or less easy to disassemble.
R22	Make the most reusable parts most accessible – to allow maximum advantage in reuse.
R23	Provide permanent identification of component type – similar to material identification, may use electronically readable information such as barcodes to international standards.

Design for deconstruction for building adaptability or relocation	
B24	Standardise the parts while allowing for an infinite variety of the building as a whole – this will allow minor alterations to the building without major building works.
B25	Use a standard structural grid – grid sizes should be related to the materials used such that structural spans are designed to make most efficient use of material type.
B26	Use a minimum number of different types of components – fewer types of component means fewer different disassembly operations that need to be known, learned or remembered – it also means more standardisation in the reassembly process which will make the option of relocation more attractive.
B27	Use lightweight materials and components – this will make handling easier, quicker, and less costly, thereby making reuse a more attractive option.
B28	Permanently identify point of disassembly – points of disassembly should be clearly identifiable and not be confused with other design features.
B29	Provide spare parts and on site storage for them (especially for custom built components) – both to replace damaged components and to facilitate minor alterations to the building.
B30	Sustain all information on the building manufacture and assembly process – measures should be taken to ensure the preservation of information such as ‘as built drawing’, information about disassembly process, material and component life expectancy, and maintenance requirements.

The Deconstruction Plan

Without a comprehensive Deconstruction Plan for the future, it is almost certain that designed re-usable building elements will be destroyed unnecessarily. The Plan should be issued to all parties at the outset of the contract to ensure a construction process that enables the deconstruction plan to operate.

For a successful Deconstruction Plan, which is a part of the overall Design for deconstruction (DfD) detailed plan, make sure the following tasks are undertaken:

Statement of strategy for DfD relating to the building:

- Demonstrate the strategy behind the designed re-usable elements and describe best practice to ensure they are handled in a way which preserves maximum re-usability.
- List building elements.
- Provide an inventory of all materials and components used in the project together with all full specifications and all war ranties, including details of manufacturers.
- Describe the design life and/or service life of materials and components.
- Identify best options for reuse, reclamation, recycling and waste to energy for all building element.

Provide instructions on how to deconstruct elements:

- Provide up-to-date location plans for identifying information on how to deconstruct buildings.
- Where necessary add additional information to the "as built" set of drawings to demonstrate the optimum technique for removal of specific elements.
- Describe the equipment required to dismantle the building, the sequential processes involved and the implications for health and safety as part of the CDM requirements.
- Ensure that the plan advises the future demolition contractor on the best means of categorising, recording and storing dismantled elements.

Distribution of DfD Plan:

- Revise the plan as necessary and re-issue to all parties at the handover stage, so that there is maximum awareness of the DfD requirements for the future, including building owner, architects and builder.
- Place copies of the revised Deconstruction Plan with the legal deeds of the building, the Health and Safety file and the maintenance file.

Construction technologies

Construction technology that best meets the principles of deconstruction is the lightweight dry stratification system.

This technology is different from Light Gauge Frame or Balloon Frame in steel or wood, typical of USA or Canadian housing, with notoriously poor performance. These technologies are known as Structure/Envelope (S/E) technology in France and United Kingdom, Trockenbau in Germany and S/R Struttura/Rivestimento in Italy.

The system is characterized by a complete separation between bearing structure and technical elements, with their own independent substructure and completed with lightweight layers, functionally specialized and dry assembled without dimensional or interface restrictions.

The tectonics of the system is clear and overall divisible into 5 distinct macro-entities:

1. Outside envelope
2. Outside interspace insulation layering
3. Bearing structure
4. Inside interspace insulation layering
5. Inside envelope.

The tectonics of Str/En systems is based on a mechanical process: the construction elements already exist, they were almost all industrially manufactured and at the worksite they have to be connected together using the dry-assembly method, according to the architectural/technological project. Panels and layers of various types are attached to each other mechanically, generally through straightforward screwing, and their use is not subject to specific constraints dictated by the atmospheric conditions at the location. The use of new materials, industrial panels, insulating mattresses, millimeter thick sheets and layers of insulation, semi-finished products and components, along with the possibility of finding prefabricated linear elements on the market for the construction of frames (in steel or wood), means projects can be tackled differently than before, restoring the true role of director of works, in this case the designer (architect-technologist or engineer-humanist), which unfortunately the system of formative specialization introduced over the last century had practically eliminated.

Within the limits of physical - chemical techniques S/E allows a designer to free assembly an almost indefinite variety of materials. The variability of the thickness and of the layers allow (theoretically) a punctual and specific response to each design situation. Election materials for sandwich construction are steel and wood, but also the massive concrete structures for hybrid solutions. The technique of “double-envelope” or “box in box” provides the best thermal and acoustic results and facilitates the building climate-sensitive behavior.

The ten cardinal points of the Str/En construction, building process and management paradigm are: diversification and performance improvement, optimisation of the material selection, the creation of technological packages, functional independence, high project definition, the possibility of assembling and dismantling, dynamic durability, dynamic functionality, sustainable environmental impact and the possibility of implementing advanced management.

To these it is now possible to add a number of extra element born out of additional theoretical and practical analysis, carried out directly on earlier Str/En projects and constructions, such as the performance verification, engineering flexibility and reliability, the optimisation of worksite procedures and the evolution of the building process, implementation of new technologies over time, the control over the operations cycle operations, and the reduction of construction system's entropy which leads to savings in terms of resources.

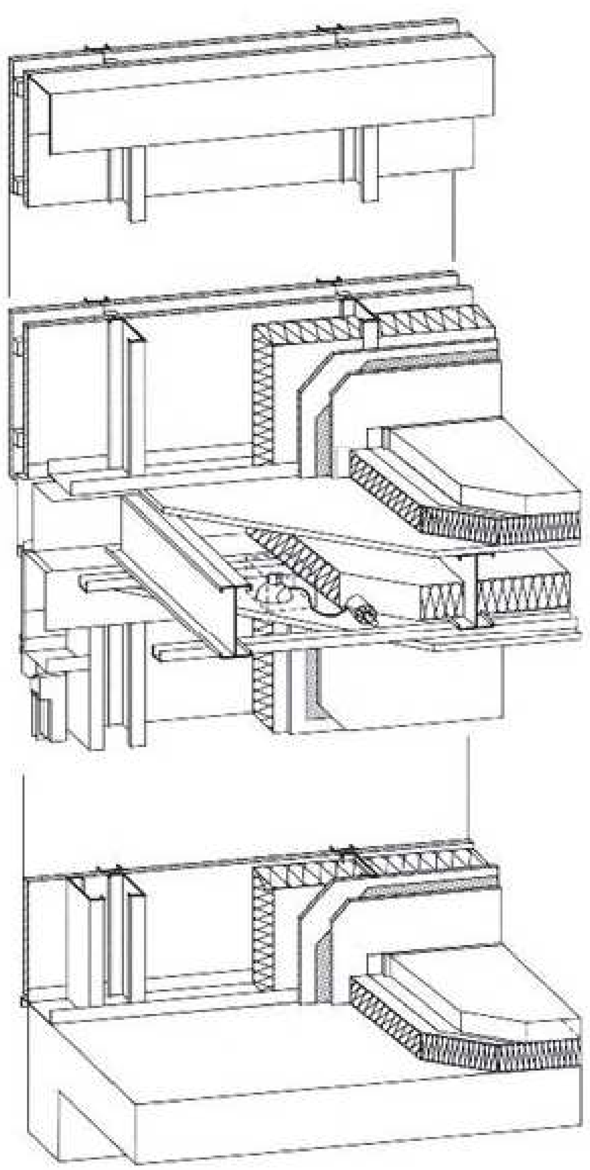


Figure 2. An example of lightweight dry stratification system

Case Studies of temporary buildings

In the following pages are dedicated to a collection of case studies illustrating possible solutions and criticalities in the design of temporary buildings, illustrating the application of the three, closely related, methodological levels: process, project and product. The case studies have been organized according to their size, as closely related to common problems.

In this selection the larger examples of temporary building is represented by Cluster pavilion designed and built for EXPO 2015.

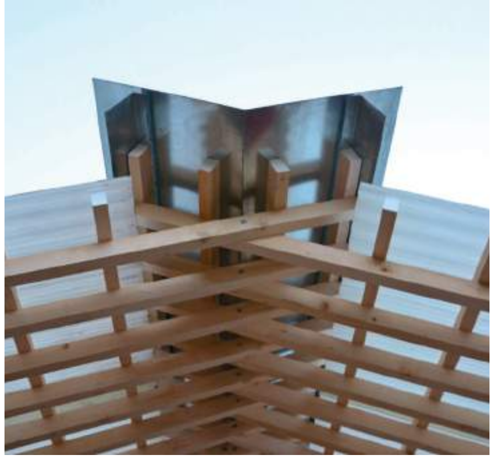
XS

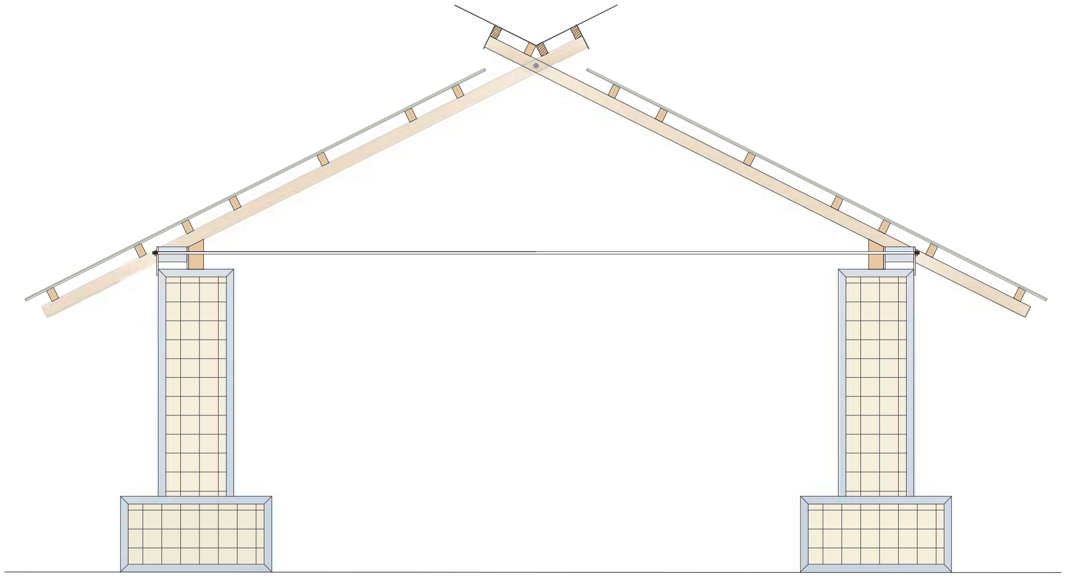
Akragashelter

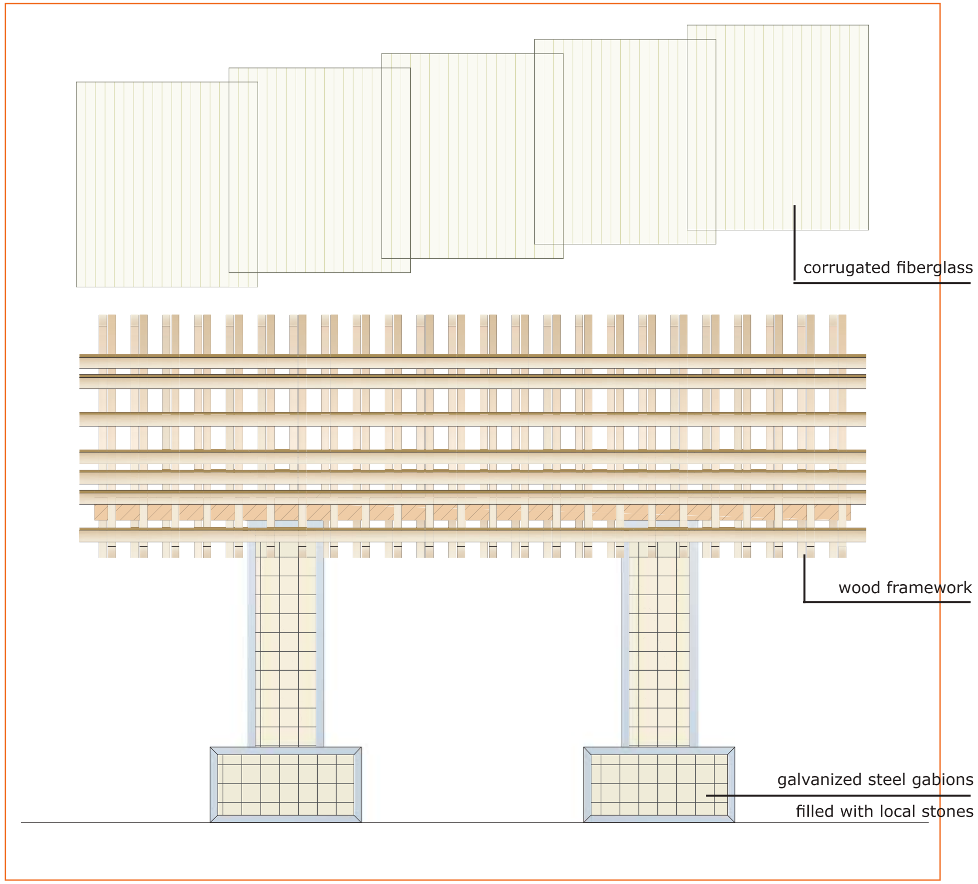
Agrigento - Valle dei Templi
International workshop “Architecture for acheological Sites”
Design: Politecnico di Milano - Prof. Imperadori - Prof. Vanossi
UTDA University of Tokyo - Salvator - John A. Liotta , Yuta Ito, Taichi Kuma
Università di Palermo - Prof. Occhipinti

The international workshop “Architecture for acheological Sites” offers the construction of a framework for the protection of testimonies sit in the Archaeological Park of the Valle dei Templi in Agrigento, with the sponsorship of Unesco, in order to identify new types modular and flexible, adaptable to different needs .
The workshop arised under the Director of the Park Arch. Giuseppe Parello and Arch. Carmelo Bennardo propose, in collaboration with JIA -Japan Institute of Architecture (National Chamber of Architects of Japan). Students from the University of Tokyo with the support of Toyo Ito Foundation, Polytechnic of Milan and the University of Palermo applied in the construction of temporary experimental prototypes for the protection of the archaeological excavations. It was requested that the prototypes were respectful of the landscape and trying to merge with it. For this reason all the projects are characterized by the use of natural materials.

Politecnico di Milano students, under the guide of Marco Imperadori and with the support of ATeler2 has realized the project AkragaShelter, which is sited at the rock temple of the sacred spring dedicated to Demeter, Zeus’s wife. A special and sacred place, where architecture and nature combine and join together in an empathetic way.
The small pavilion, about 20 square meters, was built to protect some portions of the temple, waiting for a possible relocation. However, this system could be used in the Park Valley of the Temples also for other achievements.
Due to the sacredness of the place and the impressive archaeological sit , it was decided a simple and elegant solution, both from the composition and the use of the natural materials. This solution had also a reasonable cost.
As the design work was shared with the University of Tokyo, Kengo Kuma Lab, which has, however, developed its own pavilion, the aim has been conjugating the Zen Eastern mysticism and the greek classicism. The massive columns of the Greek temples of Agrigento are retrieved from galvanized steel gabions, filled with local stone, honey-colored, which serve as an anchor. The slope of the roof, with an angle of 22.5°, like the Temple of Concordia, is another important reference. Finally, the wooden roof evokes the typical gable roof of greek temples. These are in addition to the most important tribute to the Japanese temple, the Temple of Ise, made of Inoki wood (cypress), both for its temporality (is disassembled and reassembled every 20 years), and the solution to the summit of three-hinged arches surmounted by a ventilation channel and collection of water V-shaped. AkragaShelter is a tribute to an ancient culture that fits well in the natural environment of the valley.
The roof is completed by a corrugated fiberglass, white like a milk, which gives vibration to the house and lit up at night. This remember a Japanese lamp made of rice paper .






corrugated fiberglass
wood framework
galvanized steel gabions
filled with local stones

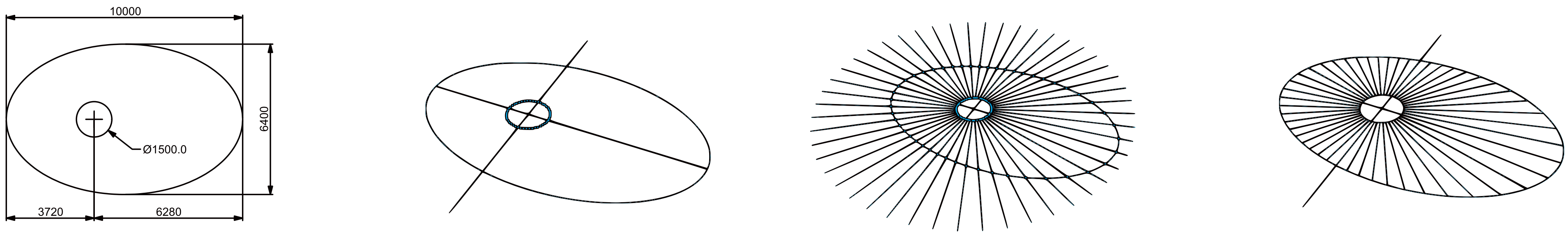
XS

Ongreening Pavilion

London - Ecobuild 2014
Design: Ongreening + Multienergy - Alfonso Senatore
Politecnico di Milano - Prof. Imperadori

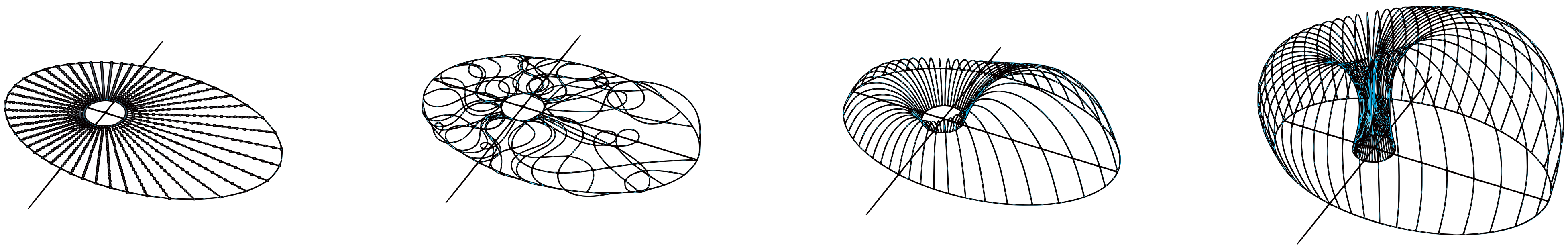
An innovative and sustainable timber structure created by Ongreening, Multienergy and the Politecnico di Milano to launch Ongreening.com, a new revolutionary online platform dedicated to green building. The look of the structure is intended to echo Ongreening's goal of capturing and filtering the world's knowledge of green data. The pavilion has already attracted a lot of attention.
The pavilion's egg-like geometry was generated using form-finding techniques pioneered on previous Ramboll Computational Design - RCD projects. The structure itself is unique in that it uses thin 6.5mm birch plywood timber laths which are bent into shape, creating a so-called 'bending active' structure which is incredibly stiff and acts like a monocoque, enabling the shell to carry most of the stresses.

The system is based on two input curves: an outer curve representing the extent of the structure and an inner circle for the central support tunnel.



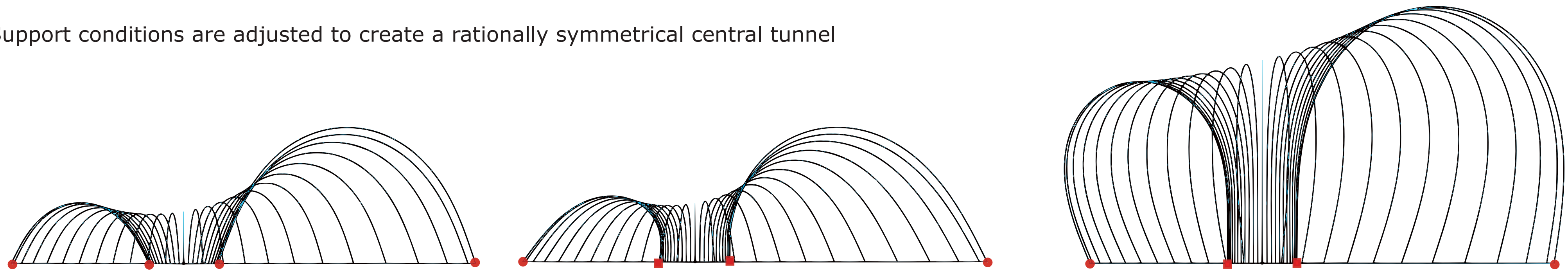
Approximate dimensions	Place points on central	Create radial lines from	Trim radial lines with

An iterative physics solver mimics axial and bending stiffness for the radial lines

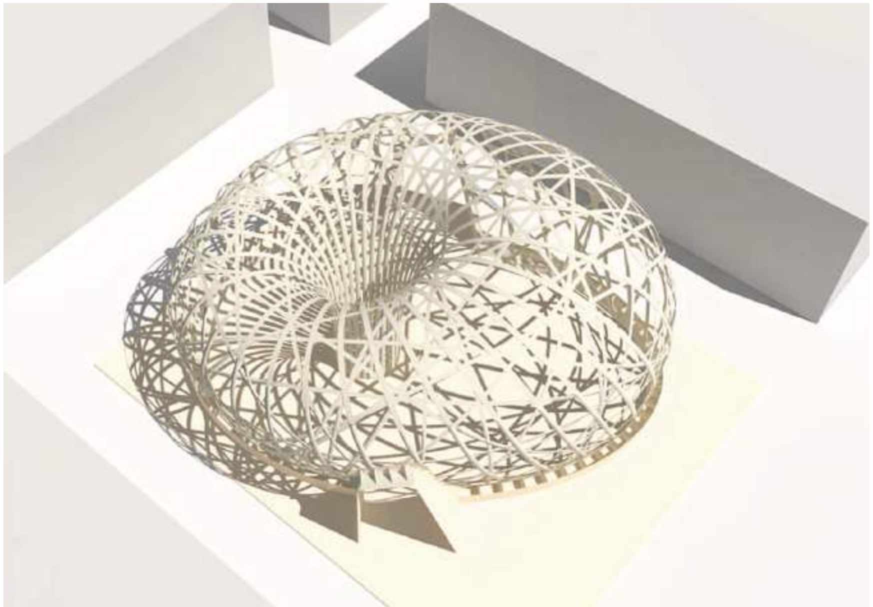


Each lines subdivided and	Natural lenght of springs	Buckle is constrained to	Natural lenght of springs

Support conditions are adjusted to create a rationally symmetrical central tunnel



Initial pinned condition - Members can	Updated support condition - members around the base of the tunnel may not	Natural lenghts set to previous levels to create final form - Vertical fixed supports

The timber laths are aligned along geodesic lines between pre-seeded generation points set out using a parametric model. The primary geodesic members are restrained by secondary laths of the same narrow and thin profile of plywood with a simple bolted connection. This method allowed the use of straight and short length pieces of timber, making it more practical to purchase and build compared with other similar looking structures.








from **Atika** to **VELUXlab**

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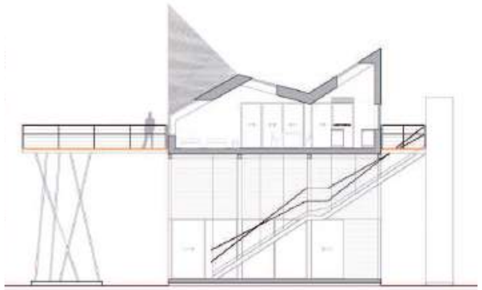
Bilbao - Rome - Milan Fair - Milan Bovisa Politecnico
Design: ACXT-IDOM
Restyling and energetic retrofitting: Politecnico di Milano



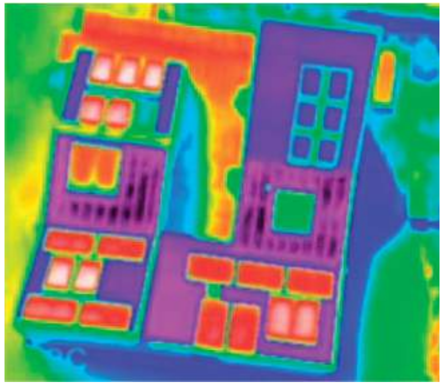
Arrived in Milan it is installed without the exhibition ground floor and it is simply laid on the ground on wooden beams, with no need of fixed foundations

Firstly known as demo-house Atika, it was presented in Bilbao in December 2006 and moved in Rome in July 2008. Finally it arrives also in Milan, installed near South Gate of Fiera di Milano in Rho-Pero (MI) between skyscrapers by Dominique Perrault and fair pavilions by Fuksas.
The experimental house, sponsored by VELUX, born inside an international project about sustainable buildings, keeps the same performances of energy efficiency both with hot and clod climate, thanks to an integrated solar cooling system connected to solar thermal panels Velux, reaching the A+ energetic class. Criteria of sustainability and volume addition, push today to consider Atika like a device for the extension and additional storey of existing buildings, but also for their re-design aiming the energy efficiency: some typological studies show the possibilities to apply the model-Atika seeing the volume bonus.

Atika was conceived as a prefabricated modular housing structure. The demo version was assembled for the first time in Bilbao, and was designed to travel through different countries over the next few years. It has therefore been built to be assembled and disassembled several times without decreasing the quality of its construction.

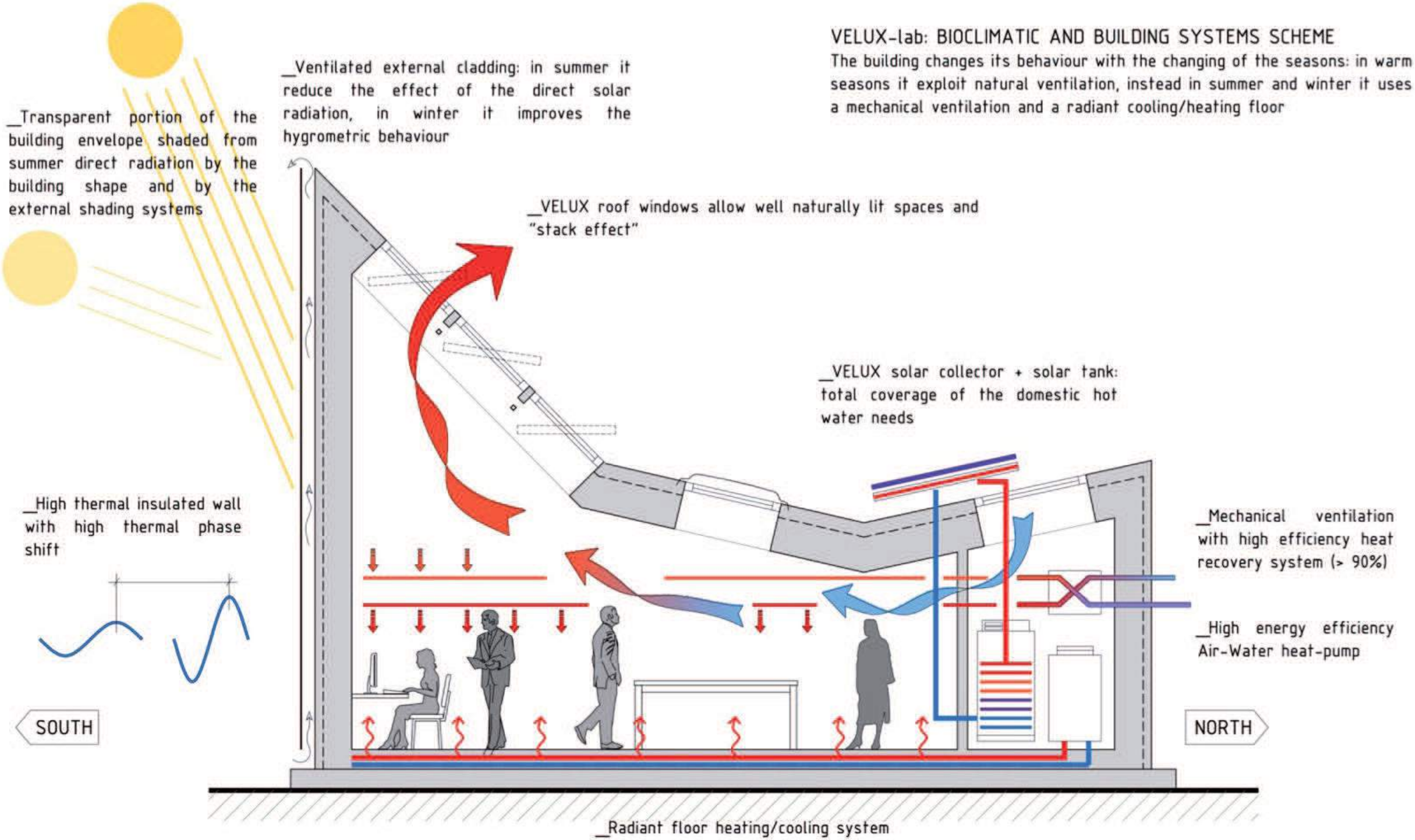
Atika is transported by road. So both the structures of the exhibition ground floor and the dwelling need to be self-bearing and able to resist the stress and crane of crane lifting. A convoy of four trucks is needed because of the dimension of the elements: 10x3.5x3.6m. The large dimension help to accelerate assembly and reduce critical construction weak points on site.

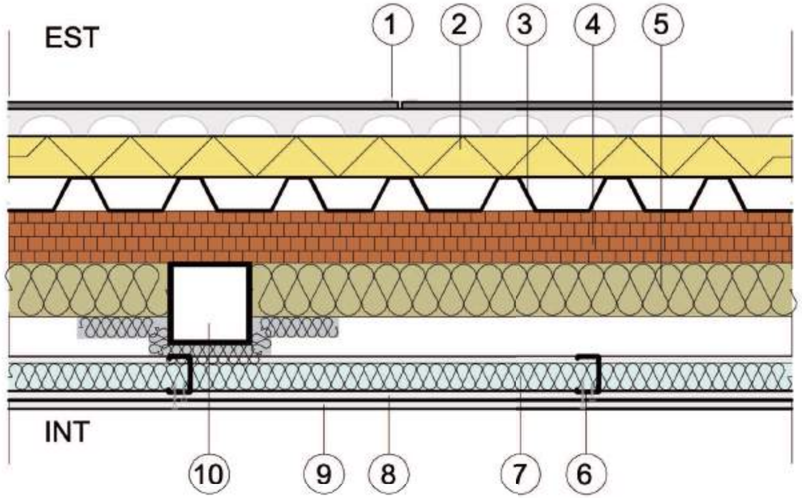
The main structure consists of perimeter steel frames for the floor and roof surfaces. Steel columns and diagonal braces stabilise the structure vertically. The floor is a reinforced concrete slab over a corrugated galvanised sheet. The 16cm thick thermal insulation panels are supported by a corrugated sheet on the roof and a lightweight galvanised steel frame at the exterior walls. Roofs and facades are both clad with high-pressure laminate plate on the outside and plasterboard panels on the inside. The interior partitions are also plasterboard double skin walls with interior acoustic insulation. The floor finishing's are ceramic tiles for the interior of the house and wood for the patio and terraces.
Atika was designed as a finished unit and requires hardly any foundation works. The undefined ground floor conditions of future sites lead to a conservative structural solution with very low weights per surface area to be absorbed by the building site grounds.
It is not only the construction that has to be durable enough to survive – the interior must last too. So it has been built with long lifetime materials, making the interior sober and aesy to maintain.
Due to the temporary nature of the construction and the need to assemble and disassemble quickly, the joints of the electrical and water ducts between the different modules are designed to be easily switched on and off, without stressing welds.



Atika is definitively moved in Politecnico di Milano – Bovisa Campus, becoming VELUXlab, a pilot case of construction with extremely high energy efficiency after a complete restyling and energetic retrofitting held by ATelier2. VELUXlab is the first NZEB – Nearly Zero Energy Building in Italy in a university campus. Promoted by Politecnico di Milano and completely sponsored by VELUX, the building is a laboratory of excellence, where searchers of Politecnico can experiment and text new technologies and materials for building energy efficiency and for the study of natural lighting and ventilation. Conceived as an experimental module, with a shape that gives "active" answers to external climatic changes, VELUXlab will be constantly monitored to evaluate not only real energy consumptions, but also envelope thermal behavior (even dynamic in summer) to validate adopted analytical models. It has been installed a system of temperature sensors (both superficial and in wall interspace) plus some more counters to calculate the final energy consumption of the building.

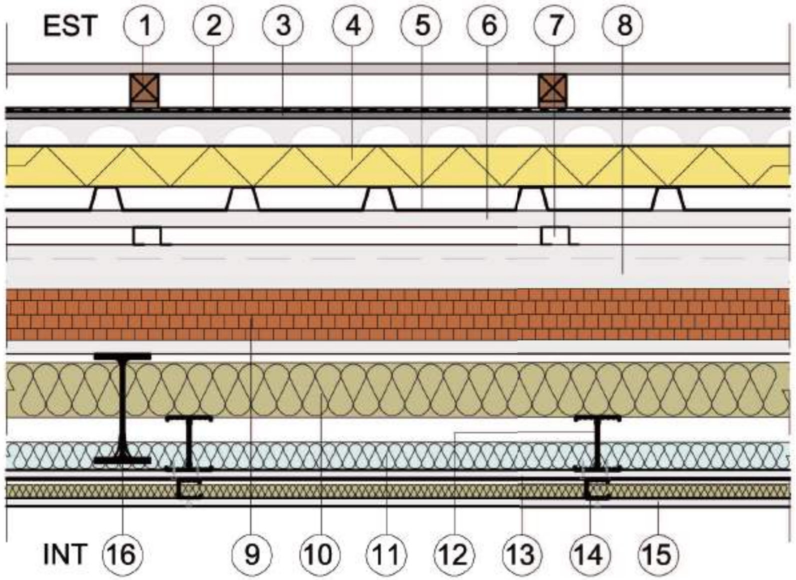
The whole project has deeply considered the environmental impact. Thermal insulation with wooden or synthetic root and easily recyclable, external cladding panels in recycled fiberglass, filling interspaces with crumbled polystyrene coming from grinded wastage resulting from manufacturing, external floor in reused iroko wood: these are all materials that contribute to reduce building environmental impact in its whole life cycle. The multi-layer dry stratified construction technology allows itself to disassemble and easily recycle the building in its components and to reach considerable


VELUX-lab: BIOCLIMATIC AND BUILDING SYSTEMS SCHEME
The building changes its behaviour with the changing of the seasons: in warm seasons it exploit natural ventilation, instead in summer and winter it uses a mechanical ventilation and a radiant cooling/heating floor
_Ventilated external cladding: in summer it reduce the effect of the direct solar radiation, in winter it improves the hygrometric behaviour
_Transparent portion of the building envelope shaded from summer direct radiation by the building shape and by the external shading systems
_VELUX roof windows allow well naturally lit spaces and "stack effect"
_VELUX solar collector + solar tank: total coverage of the domestic hot water needs
_High thermal insulated wall with high thermal phase shift
_Mechanical ventilation with high efficiency heat recovery system (> 90%)
_High energy efficiency Air-Water heat-pump
SOUTH
NORTH
_Radiant floor heating/cooling system



EXTERNAL WALL (U = 0.124 W/m2K)

1. Cladding in fiber-cement boards th. 10mm with mechanical fixing on view
2. ISOTEC PARETE sandwich panel in polyurethane th. 60mm with ventilation bar type XL
3. Corrugated metal sheet (cavities are filled with polystyrene powder coming from construction site waste)
4. Mineralised spruce wood-whole bound with portland concrete type CELENIT N th. 75mm
5. Rockwool semi-rigid panels dens. 40kg/mc th. 80mm
6. Vertical strut C shaped in galvanised steel type Knauf E 50x50mm
7. Glass fiber insulation dens. 15kg/mc th. 40mm
8. Plasterboard th. 12.5mm with aluminum vapor barrier
9. Wooden oriented strand board (OSB) th. 12mm
10. Existing metal structure



ROOF (U = 0.133 W/m2K)

1. Cladding in aluminum slats fixed on wooden profiles
2. Waterproofing membrane
3. Wooden oriented strand board (OSB) th. 12mm
4. ISOTEC PARETE sandwich panel in polyurethane th. 60mm with ventilation bar type XL
5. Corrugated metal sheet th. 35mm
6. Bent steel profile 25mm
7. Bent steel profile 25mm
8. Bent steel C-profile 160mm
9. Mineralised spruce wood-whole bound with portland concrete type CELENIT N th. 75mm tucked inside the C-profiles
10. Rockwool semi-rigid panels dens. 40kg/mc th. 80mm
11. Glass fiber insulation dens. 15kg/mc th. 40mm
12. Lightweight galvanised steel structure for self-bearing false-ceiling type Knaud D116, double U-profile 75x40mm, max. axle spacing 60cm
13. Plasterboard th. 12.5mm with aluminum vapor barrier
14. Lightweight galvanised steel structure type Knauf 50x27mm
15. Micro-perforated plasterboard th. 12.5mm type Knauf Cleaneo with sound-absorption felt in mineral wool
16. Existing steel bearing structure

S

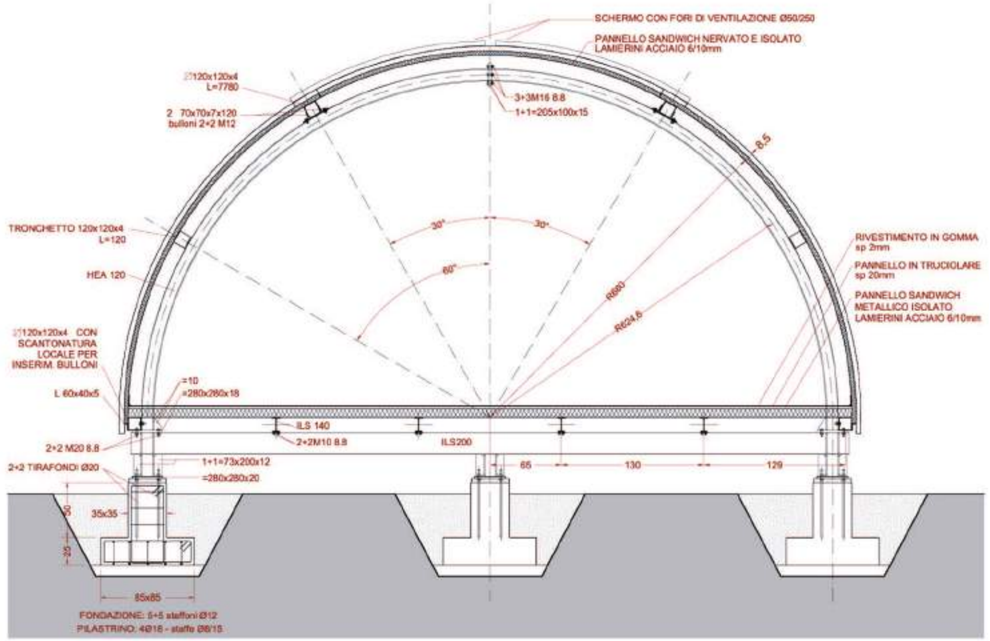
Armadillo - Casa a guscio prêt-à-porter

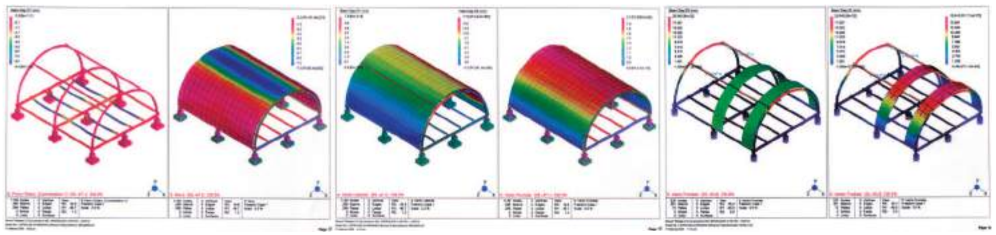
Brianza Plastica prototype
Design: ATelier2 with Dubosc & Landowski Architectes
Coordination and Management: Studio IdeaG

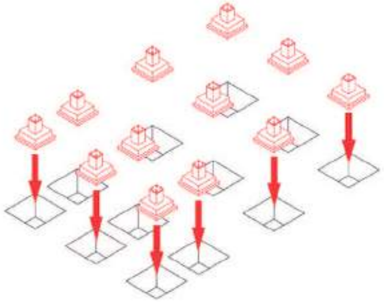
Prototype for a new industrialized house realized with curve panel Elycop – Brianza Plastica.

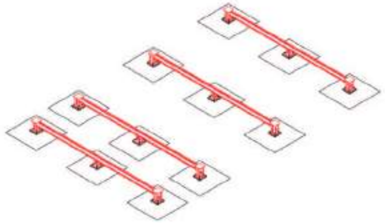
The project is based on the use of high-quality materials and devices easily available on the market which was assembled through a continuous integrated design between architects, by the executive and applied ergonomics design, engineers, by calculation and testing, and manufacturers, thanks to products use optimisation, logistics and stocking for transportation till the prototype’s installation phase.
The aim was to study the design (both with Anglo-Saxon meaning of overall technological project and with Italian meaning of object with an aesthetical characterisation) of an industrialized architecture, modular (base module 60 m2) but conceived with different sizes (and therefore targets), extremely flexible in inner free spatial organisation and, starting from the concept of base components, implementable with the addition of further functional layers (and therefore performances) as they were optionals.

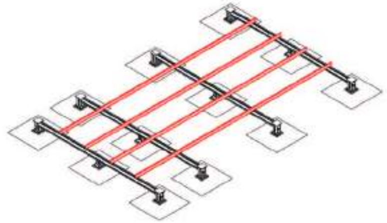
The structure, implemented both in the all metal version and the mixed metal-wood version, is an tube architecture based on the use of metal sandwich panels used for the shell, for vertical facades and also for the floor slab.

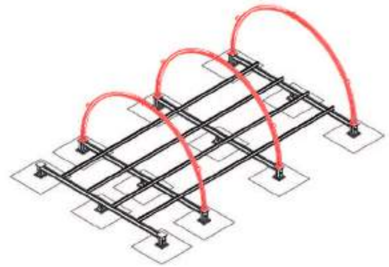





1. Concrete plinths


2. Primary beams


3. Secondary beams


4. Arches


5. Lateral tubular beams + L profiles


6. Top tubular beams


7. Floor sandwich panels

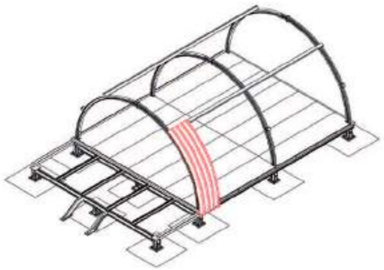

8. Floor sandwich panels

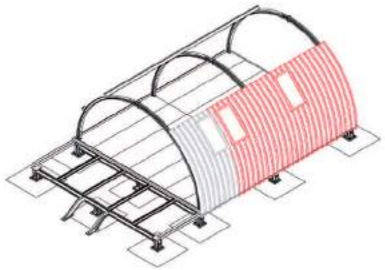



9. Orthogonal plywood panels


10. Orthogonal plywood panels




11. Curved sandwich panels Elycop


12. Curved sandwich panels Elycop

13. Curved sandwich panels Elycop

14. Curved sandwich panels Elycop

15. Curved sandwich panels Elycop

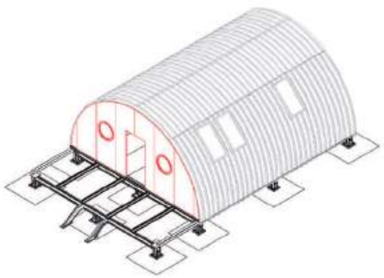
16. Polycarbonate corrugate sheet for ventilation

17. Polycarbonate corrugate sheet

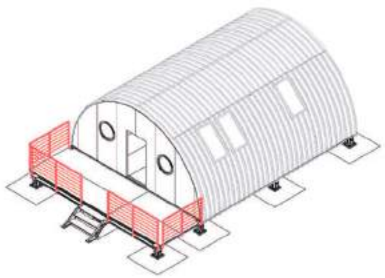
18. L-profiles for walls fixing

19. Extenal wall in sandwich panels

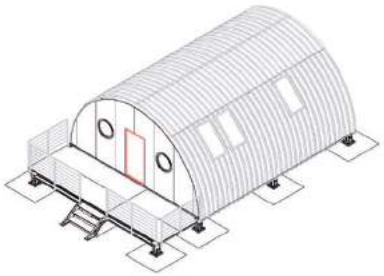
20. Inside plasterboard walls



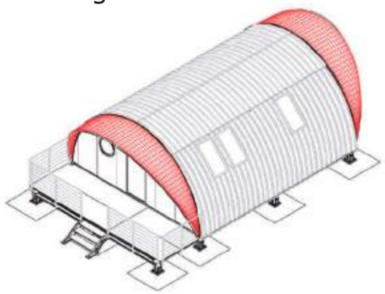
21. External wall in sandwich panels



22. Outside floor in metal grid + metal railing

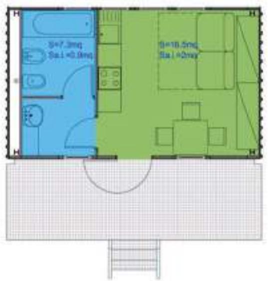


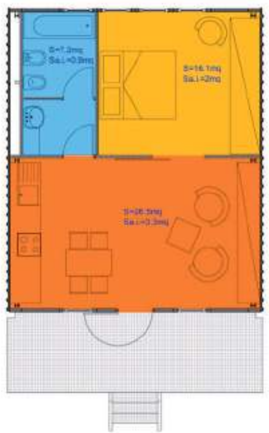
23. Windows

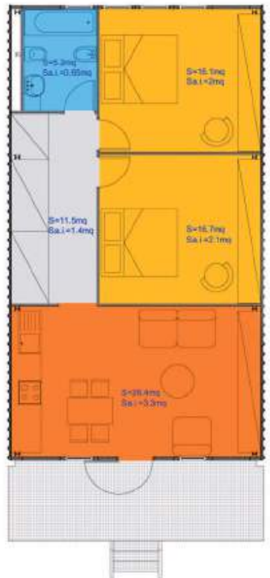


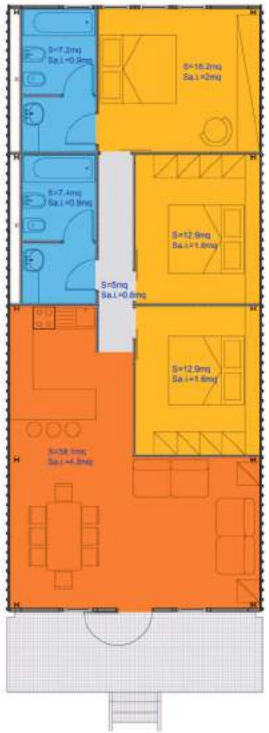
24. Awnings and inside finishings (rubber floor)

Modularity and flexibility



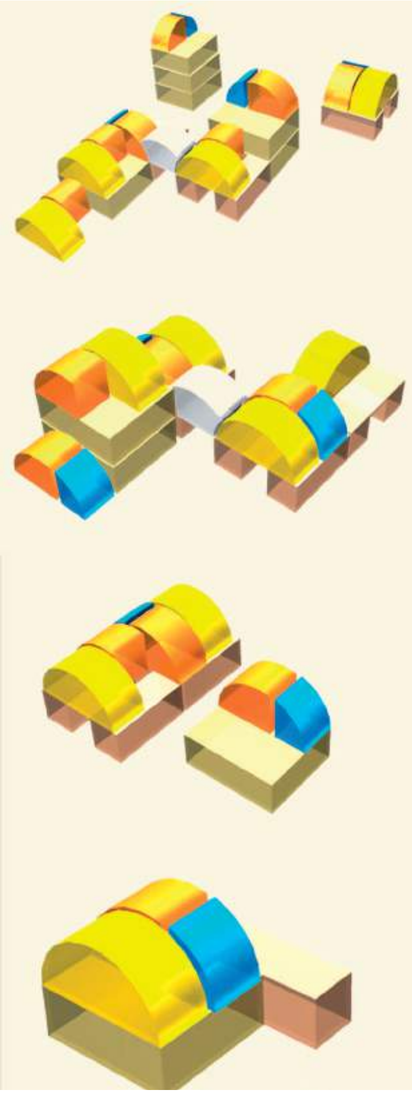


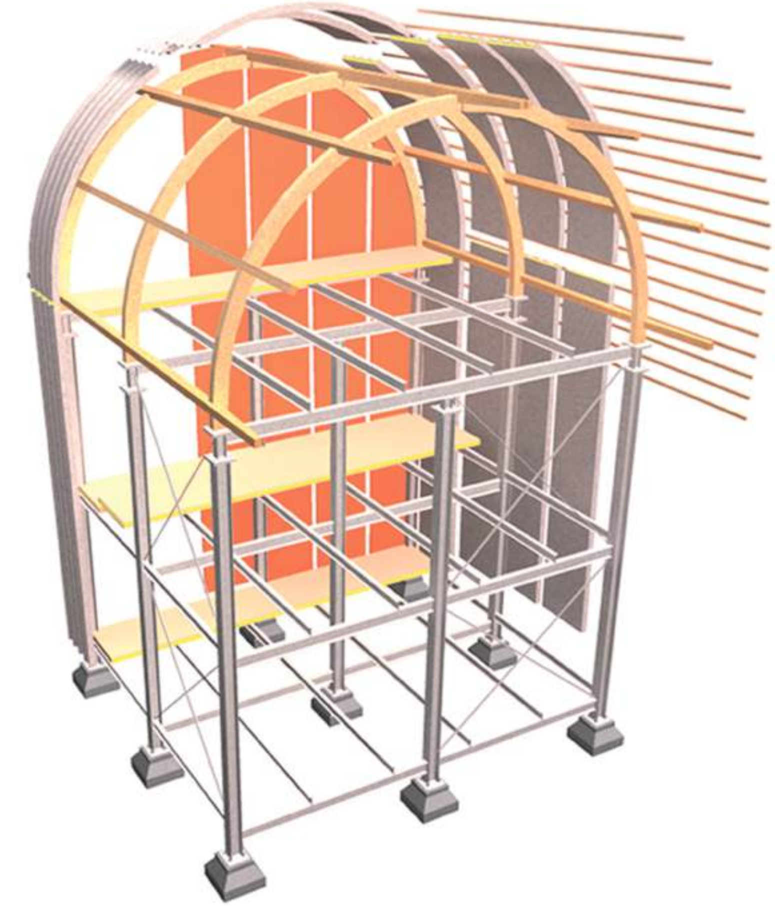


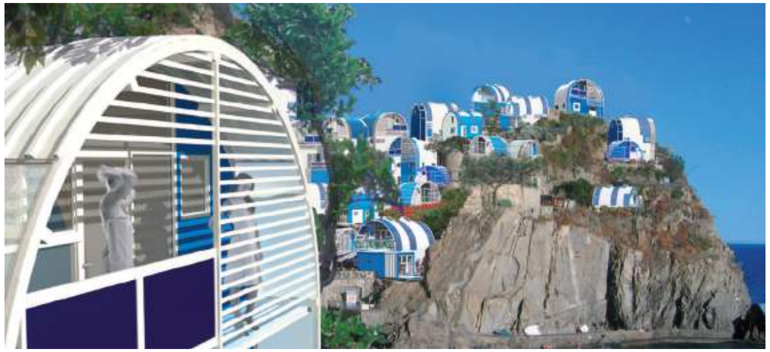


The structure is characterized by a great flexibility and and we can assume a variety of uses, some already realized as first aid post in emergency situations, temporary structures for schools etc, kiosks, bungalows for camping, shelters at high altitude.

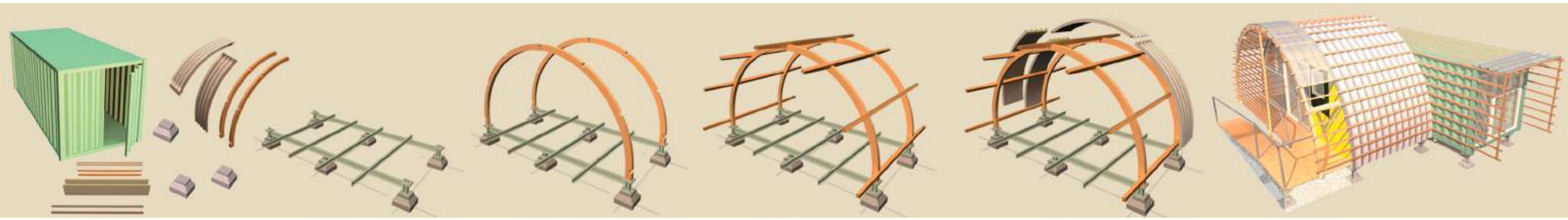
Aggregability

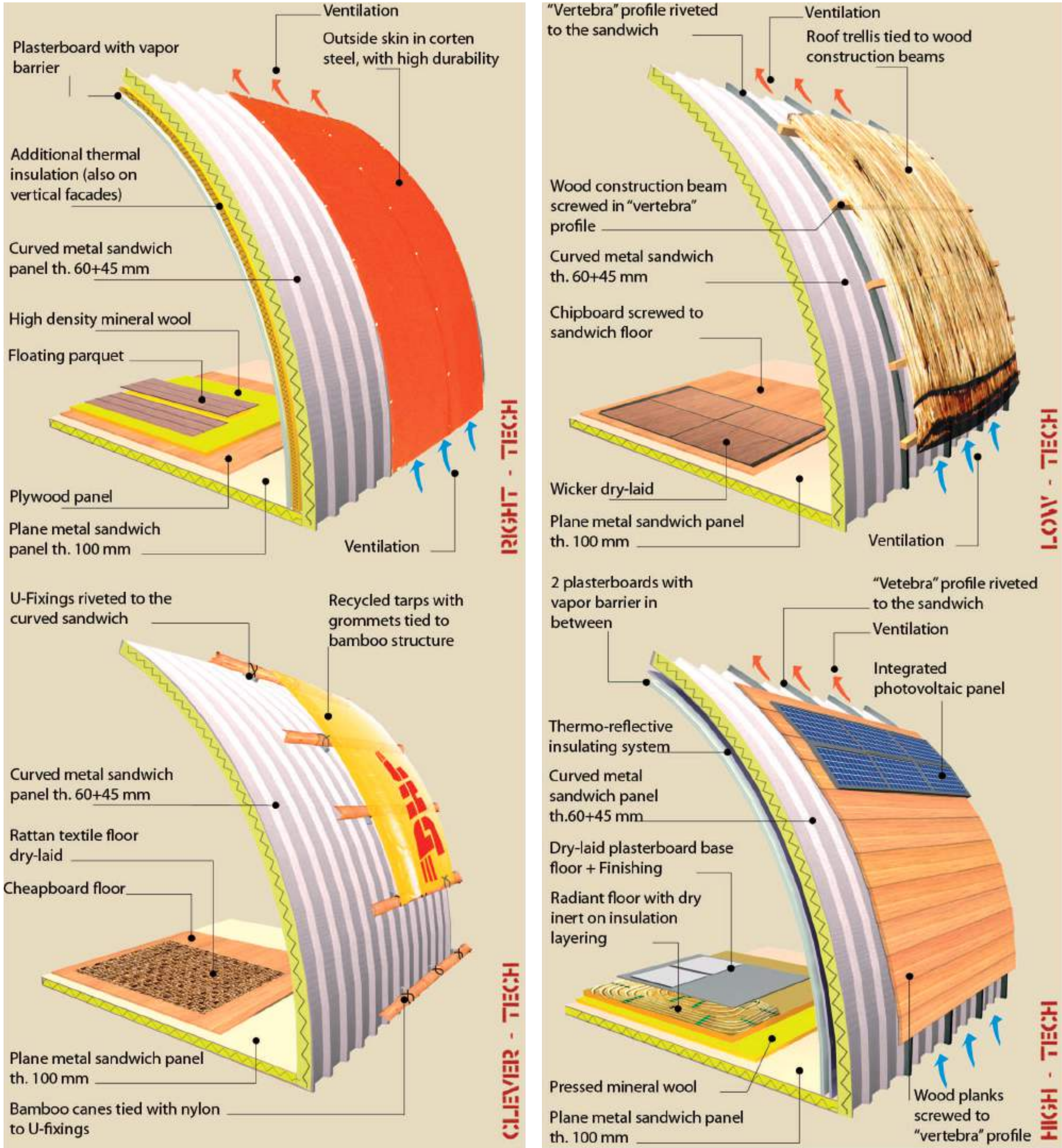






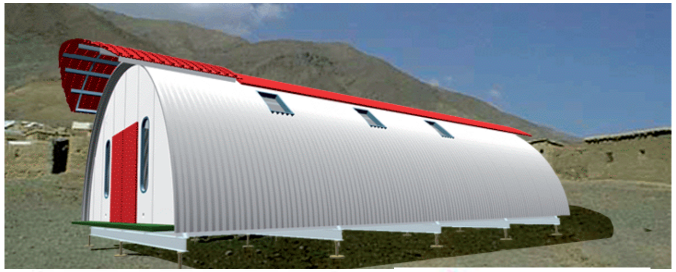
Modularity allows easy implementation in line but the system provides additional possibilities for spatial aggregation and implementation also in vertical.
The building can be easy mounted and dismantled, being carried in container that can also become part of the final layout.





Basic structure and envelope can be implemented with different technologies, more or less evolved, adapting to the local building construction reality, depending on availability of materials and skilled labor.

Built examples



Emergency First Aid Post

The project was initially destined to become a FAP for Iraq or Afghanistan, where Emergency is one of the few medical realities helping population and war victims. Security problems didn't allow the realization of the prototype in these areas and so Emergency has decided, with designers, to assign the building (already mounted and disassembled three times) to Gruppo 29 Maggio, a linked association.

Children Village

Niculesti - Romania

The building has been used first to house workers during the construction of village houses, after transformed in a small school "doposcuola" for the whole complex, that in the meantime expanded with other semi-cylindrical structures (a greenhouse and a machine store) and now dominates a wide agricultural space, cultivated, giving new hope to unlucky people, non victims of war, but of ruthless or absent societies often forgetting them.

Borboleta

Farim - Guinea Bissau

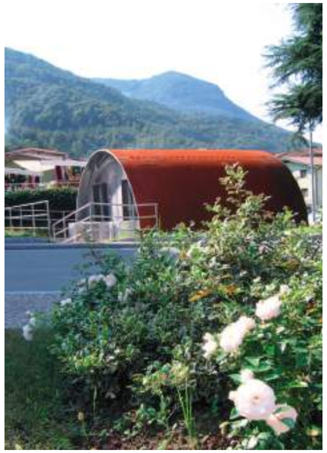
Borboleta, that means butterfly in Portugues, is a small infirmary of 50 square meters that will fly up from Italy to Guinea Bissau.

The project was conceived by the Gruppo 29 Maggio, an ONG Association: a space for medical assistance for children of a village of Farim (Guinea Bissau), since this need of a mission of the Carmelitani Fathers.

Built examples



APE TAU
Coppito - L'Aquila
The nursery school APE TAU originates from the idea to realize something useful for a L'Aquila after the earthquake arrived on April 6th 2009. A "constructive" and positive idea after the damages caused by the earthquake, for the most young and for their mothers who can, this way, come back to a work.
APE TAU is technically formed of three covered bodies (using the concept L'Armadillo by Atelier2 / Brianza Plastica) and a technological cantilever roof leading to the main pedestrian entrance.


Pian Café
Piancamuno - Brescia
The industrialized module "L'Armadillo – Brianza Plastica" is readapted to house a new different public function, a bar-stall for the market place. Outside the architecture finds its character in the envelope, paneled with a second skin in corten steel sheets, in a dialogue of matter and shape with the curved walls bounding Piazza Verdi, designed by ATelier2.


Forest Armadillo
Bergamo
A photo agency on Bergamo hills. The module has been installed in its essential line. The white color underlines this essentiality. The space obtained is bright and flexible and it perfectly matches the professional photographer exigencies. The suspended base floor solves the problems linked to the moisture of the soil.

S

Rhome for denCity

Solar Decathlon Europe 2014
Design: Università di Roma TRE - Facoltà di Architettura
Team leader: Prof. Chiara Tonelli
Active House validation: Politecnico di Milano

Rome, towards a smart city with RhOME. The italian project of University of Roma TRE participating to Solar Decathlon Europe 2014 in Versailles

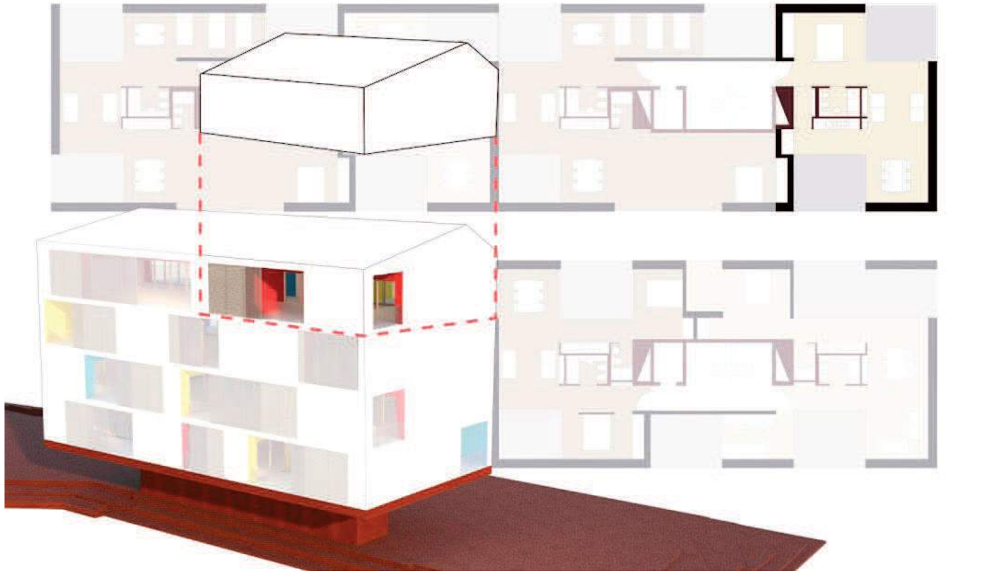
Solar Decathlon

The international competition Solar Decathlon was born in 1999 in America, promoted by the Department of Energy of the Government of the United States of America. From 2010 the competition also takes place in Europe, in 2014 is going to be organized in Versailles, France. Twenty selected university teams from all over the world will face each other in a sort of "Olympic Games of Sustainable Architecture" with the aim of design, build and simulate a real domestic life in a high energetic efficiency residential building, exclusively powered by solar energy.

Main themes of SDE 2014:

- sobriety
- density
- transportability
- affordability

The project designed for the roman urban areas is taken as an opportunity to deal with the global condition, that is easier to explain with the description of a local action. "Thinking globally by acting locally". That's the reason of the birth of RhOME, "a home for ROME" that represents a systematic plan of interventions replayable in many other contexts to materialize the idea of "Smart City".



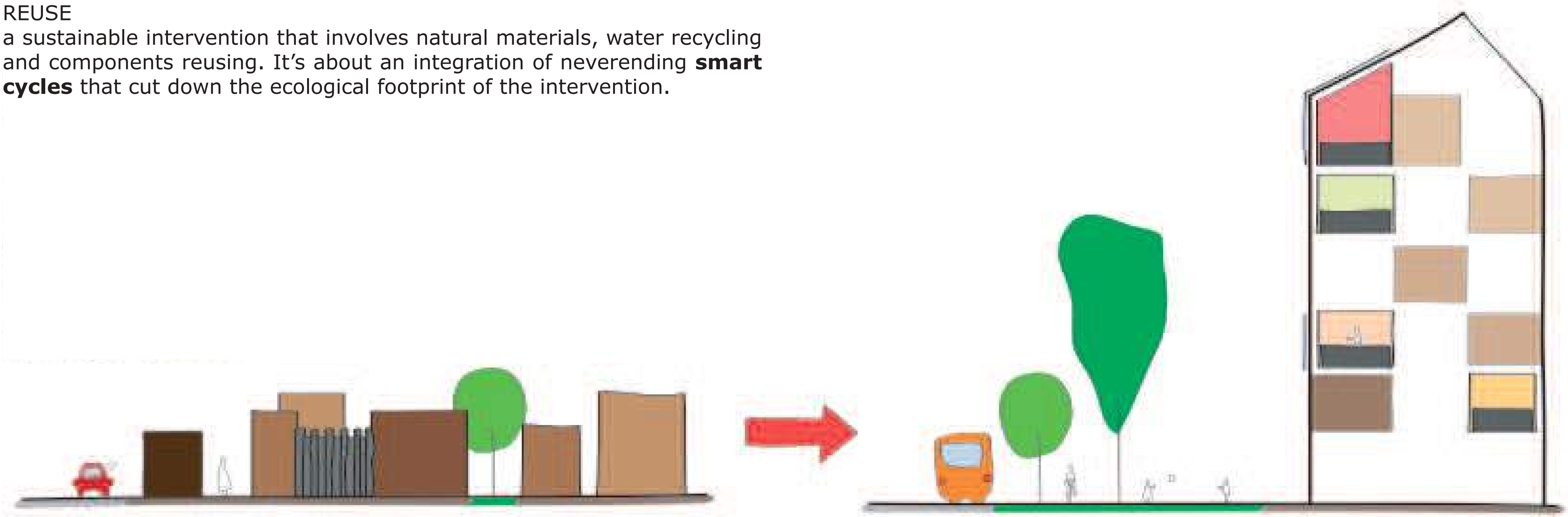
REGENERATION
Urban regeneration through densification that requalifies the land use. The densification of the buildings frees land converting
it in public use, returning the population lost urban spaces, that arrange an active and productive **smart area** with increased resources and reduced mobility coexist.

RELATIONSHIP
a developed territory creates for its population new opportunities and it allows to find a local identity. The population could, in that way, drive the management and the dynamic activities, **smart citizens** who gained a new lifestyle fitting the new living standards.

RAPIDITY
innovative and dynamic constructive solutions that involve industrialization practice. Clear timing and affordable pricing for **smart buildings** and an easy and long run maintenance avoiding degradation.

REDUCE
the impact of the project decrease considering every intervention view under
the energy efficiency and affordability perspectives. It's a **smart integration** of different technologies that work in a synergic system.

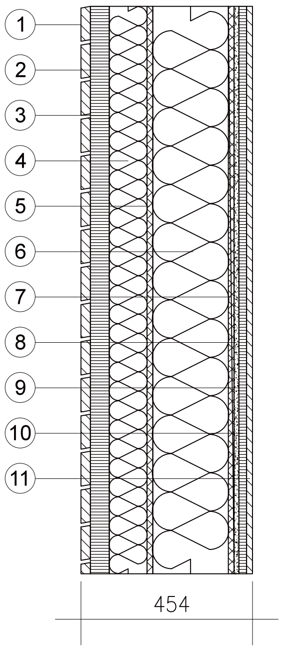
REUSE
a sustainable intervention that involves natural materials, water recycling and components reusing. It's about an integration of neverending **smart cycles** that cut down the ecological footprint of the intervention.



The prototype for Versailles is the 60 m2 top floor of the urban compound. Here the intention to describe the architectural features and technological innovations that would not appear in a common floor or in the ground floor, where the focus is on the integration with the urban environment. The space is articulated around the 3d core which is the plant and structural center of the house. This element hierarchizes and characterizes the space, defining the various areas of which the house is composed. The presence of the loggias in the two opposite corners ensures a versatile plan scheme, of which the Versailles prototype is only one possible configuration.

The Rhome for denCity project takes into account the global quantity of primary energy embodied and global warming potential in all materials, components and processes included in manufacturing, transportation and erection of the building. According to this information, during the design process alternatives are evaluated with the aim of reaching the highest level of global sustainability of the construction. Materials were selected in order to reduce enerfgy consumption in all their life, from manufaturing to disposal: renewable, recyclable, reusable materials are used.

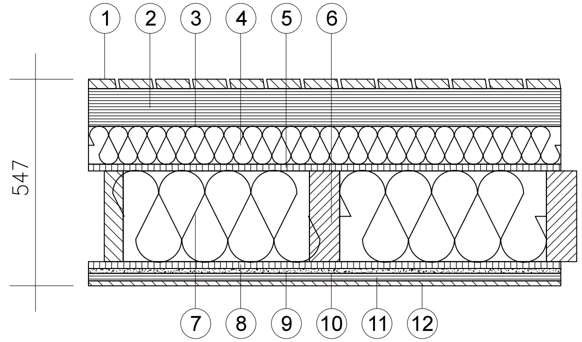
The building has a wood based constructive system: prefabricated elements with wooden lattice structure filled with insulating natural materials and completed with concrete panels, plasterboards and wood cladding.
Everything is completely prefabricated in factory and then simply assembled on site, with a high timeline reduction and a total control of dimensions, details, performances and costs.
The system is completely dry assembled and this allows to easy disassemble the building, to be moved and replaced in other sites.



Standard outside wall

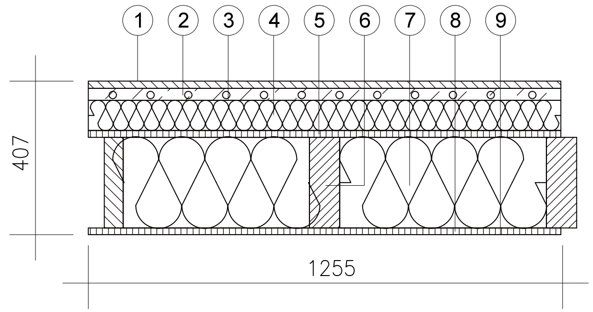
1. Larch cladding th. 25mm
2. Wooden laths th. 50mm
3. Breathable membrane
4. Wood fiber insulating panels th. 100mm
5. Fermacell gypsum fiberboard th. 15mm
6. Wood fiber insulating panels th. 200mm between wooden structure
7. Fermacell gypsum fiberboard th. 15mm
8. Plasterboard th. 12.5mm
9. Vapor barrier
10. Wooden laths th. 20mm
11. 3 layers plywood fir panel th. 16mm

Basement floor



1. Larch cladding th. 40+25mm
2. Wooden lath / aluminum sheet th. 100mm
3. Breathable membrane
4. Wood fiber insulating panels th. 100mm
5. Superpan concrete formwork panel th. 18mm
6. Wooden beams 80x240mm
7. Wood fiber insulating panels th. 240mm
8. Superpan concrete formwork panel th. 13mm
9. Fermacell gypsum fiberboard th. 15mm
10. Plasterboard th. 12.5mm
11. Vapor barrier
12. Wooden laths th. 20mm
13. 3 layers plywood fir panel th. 13mm

Roof



1. 3 layers lywood larch panel th. 19mm
2. Radiant floor panel th. 32mm
3. Vapor Barrier
4. Insulating kork panel th. 80mm
5. Superpan concrete formwork panel th. 18mm
6. Wooden beams 80x240mm
7. Wood fiber insulating panels th. 240mm
8. Superpan concrete formwork panel th. 18mm
9. Breathable membrane

FACTORY PREFABRICATION

ON SITE ASSEMBLY

S

Tintero - floating pavilion

Verona

Design: Marco Imperadori - Politecnico di Milano

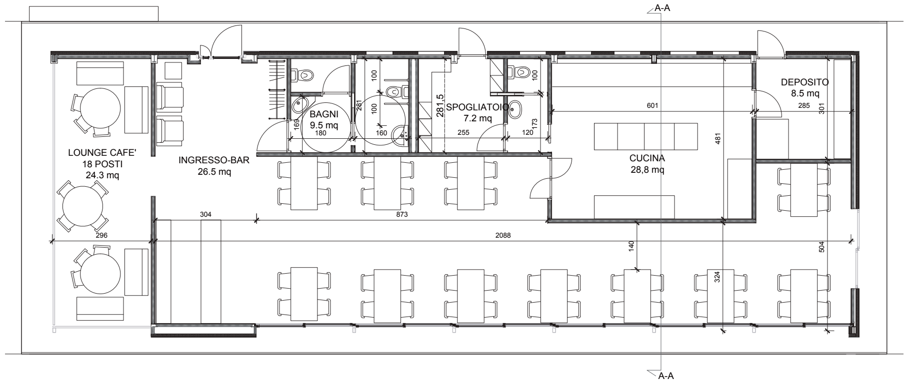
Tintero is a small floating pavilion designed as a first hypothesis to accommodate a restaurant.

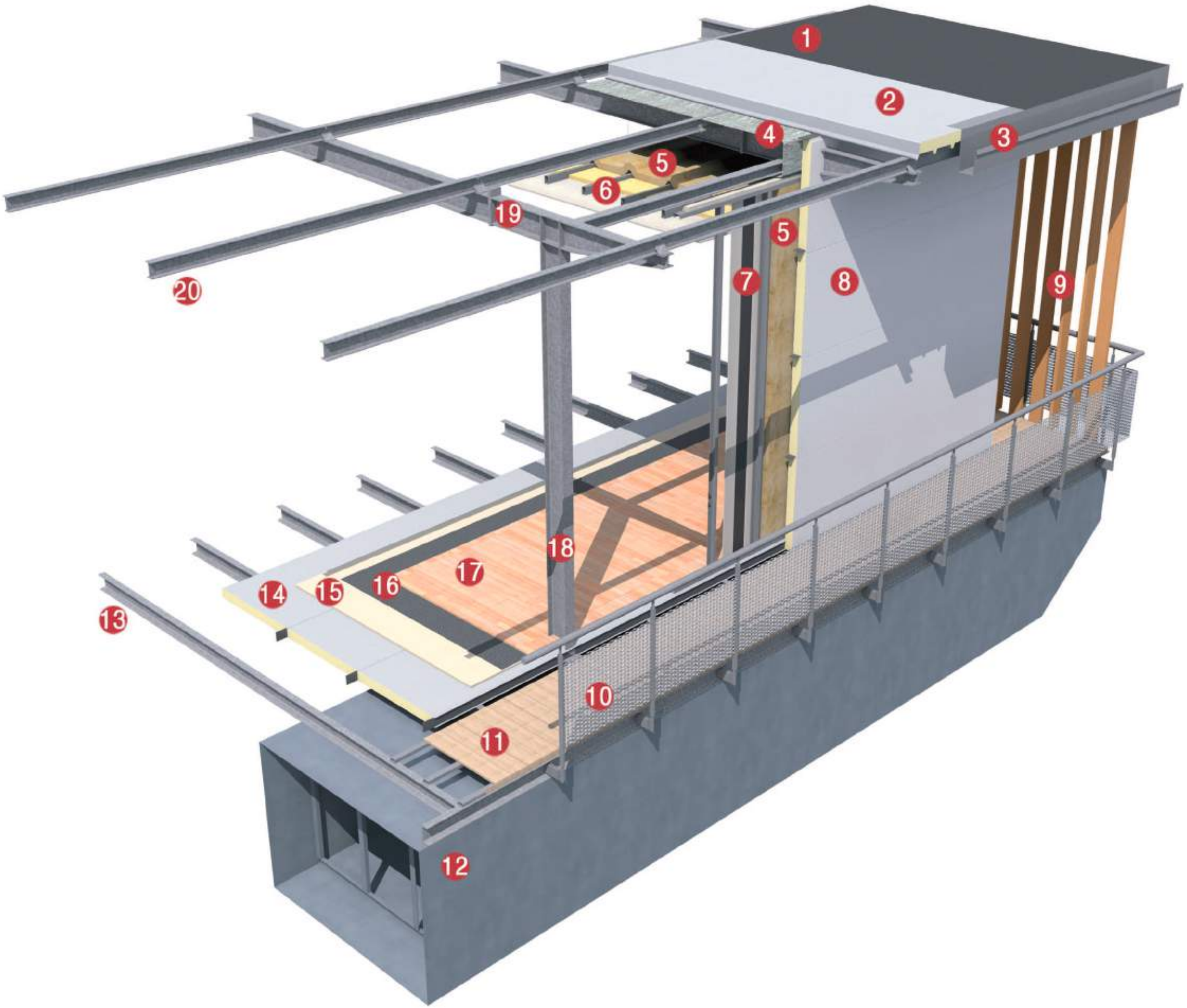
The galvanized steel structure consists essentially of two floating caissons on which rest a horizontal planking and frames in standard metal laminated profiles.

The completion envelopes are all dry-built and exploit as a basic component polyurethane sandwich panels which are added with several and differentiated layers (counter-walls and ceilings with independent lightweight structure, plasterboards, insulation and finishings) to complete the technical elements as floor, ceiling and roof.

The structure is characterized by a linear modularity that allows the extension of the building length, while the width is fixed by the initial structural dimensioning .

The caissons are sealed empty rooms that can be exploited for to house the plant and for the accumulation of waste water, so that the connection to the sewer system can be discontinuous in time.





1. Bituminous waterproofing
2. Polyurethane sandwich panel Isodeck Isopan (simple skin panel with the second face made of asphalted paper) th. 100mm
3. Gutter in natural aluminum
4. Thermo-reflective insulating system type Actis with vapor barrier function th. 1.5cm
5. Insulating mineal wool t. 70mm
6. False-ceiling wide-span with bearing double box-shaped profiles, sound-absorbing glas wool th. 40mm and perforated plasterboard type Knauf Cleaneo with sound-absorbing high performance th. 12.5mm
7. False wall with lightweight structure th. 75mm and double plasterboard with vapor barrier th. 12.5+12.5mm
8. Polyurethane sandwich panel type Plissé Isopan th. 100mm
9. Sunscreen in reconstituted wood slabs type Woodn 150x41mm
10. Expanded metal railing
11. Outdoor flooring system made up of reconstituted wooden planks type "Greenwood" laid on aluminum spars
12. Floating system with airtight caissons
13. UPN 160
14. Polyurethane sandwich panel type Isorighe Isopan th. 100mm
15. Insulating polyurethane panel high density th. 20mm
16. Subflooring panel made of granules of polystyrene foam th. 3mm
17. Floating floor in strips of solid bamboo
18. IPE 220
19. IPE 220 reconstituted
20. IPE 120

S

Scaffold House

Thesis by: Elisabetta Azzolini, Elisa Beretta, Fabiola Cerri - Politecnico di Milano
Tutor: Prof. Marco Imperadori - Politecnico di Milano

Scaffold House is an emergency temporary accommodation made using products existing on the market, not specifically intended to the emergency issue. This system was initially designed for a thesis and subsequently the project was developed in collaboration with Marcegaglia Group. The aim of this project was to implement and innovate standard products, or transfer technologies from other sectors, designing units ensuring an adequate and quality space and not merely a temporary shelter. The goal was to design an adaptable and flexible system, able to be integrated and changed according to the real different needs, also characterized by a low production cost. The idea is to use simple constructive and technological solutions, locally available, also in view of the self-construction processes involving local populations. The project is also designed according to a dynamic cycle, temporarily providing a service and then returning its parts. Even the assembly sequence is designed to ensure the lowest number of operations and a certain practicality and speed of implementation.
The main structure of the building, realized in metal scaffolding , is modular, allowing an internal adaptable layout. The result is an inner surface of around 22 square meters for the standard unit. The inner confort has been carefully studied : the envelope was created using polyurethane sandwich panels to provide thermal performance and stiffen the whole structure.

RESIDENTIAL UNIT A

Total useful surface: 40 m²
Inside useful surface: 24 m²
Outside useful surface: 16 m²
Structure: 6 portals (5 modules)

RESIDENTIAL UNIT B

Total useful surface: 72 m²
Inside useful surface: 48 m²
Outside useful surface: 24 m²
Structure: 10 portals (9 modules)

+1

RESIDENTIAL UNIT C

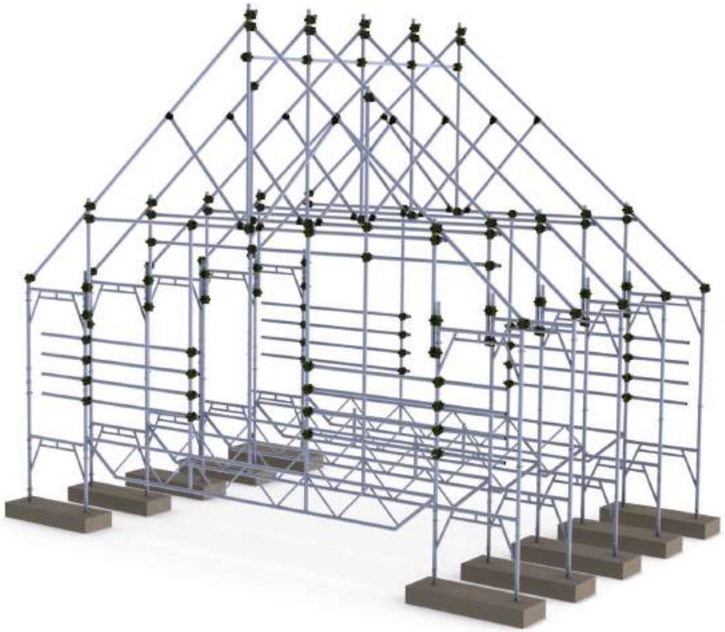
Total useful surface: 96 m²
Inside useful surface: 64 m²
Outside useful surface: 32 m²
Structure: 13 portals (12 modules)

+2

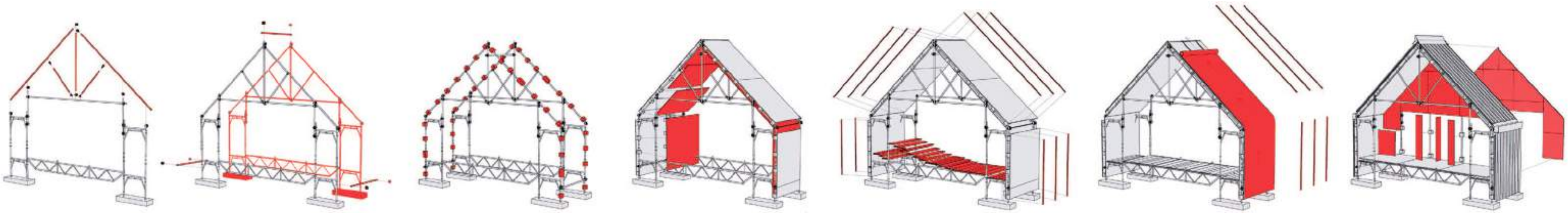
FIRST AID POST - HOSPITAL

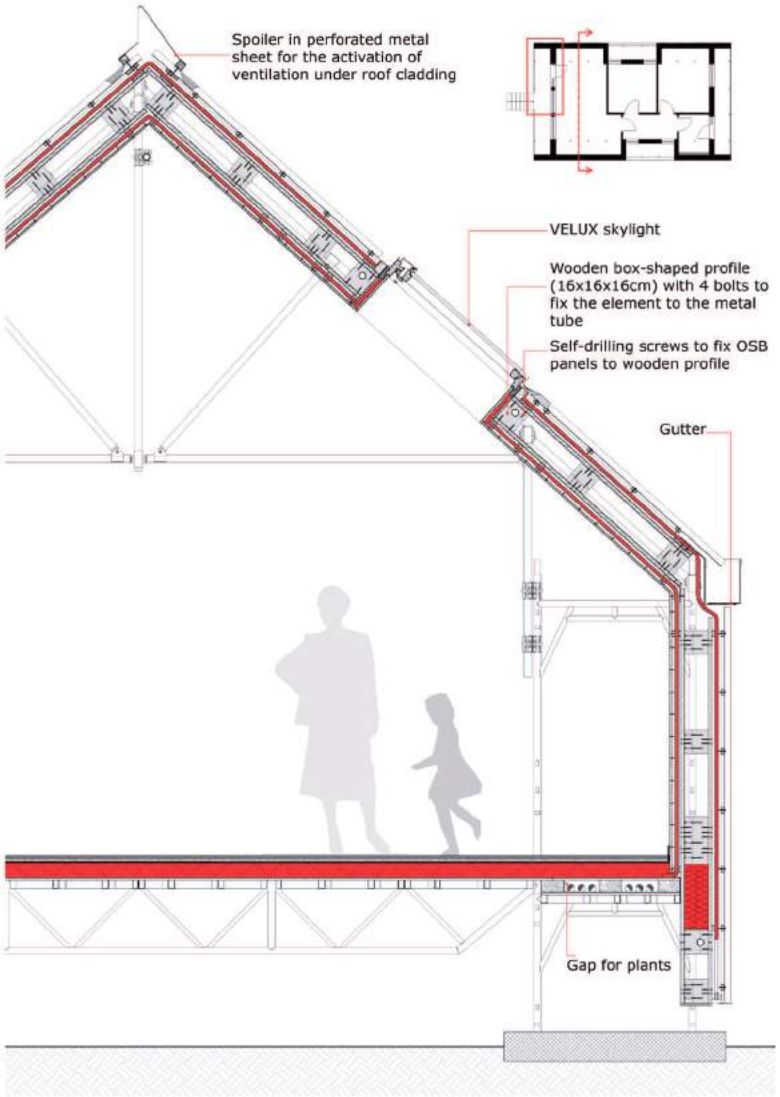
Total useful surface: 170 m²
Inside useful surface: 139 m²
Outside useful surface: 56 m²
Structure: 24 portals (23 modules)

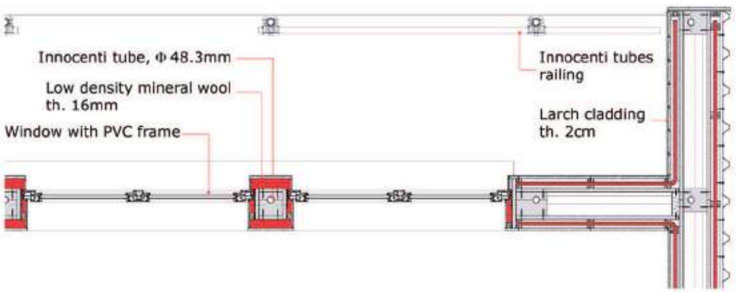
The system is modular and allows completely adaptable layouts and offers the possibility to house different functions: residences, hospitals, schools etc.

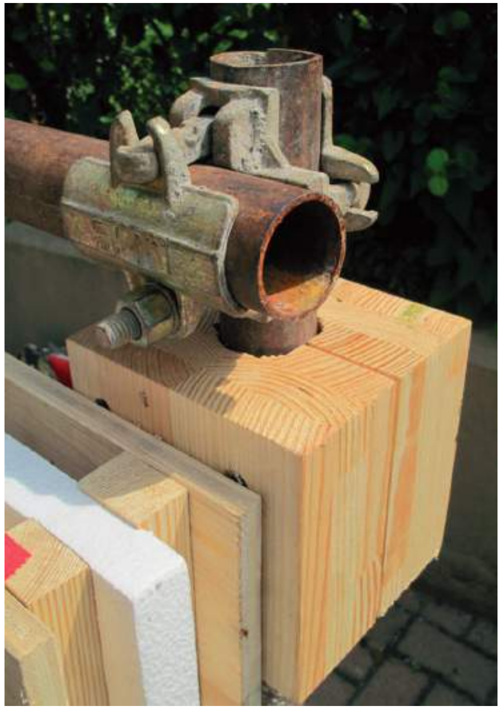


On October 4, 2013, in Lecco, near the local school building ESPE, it took place the " Scaffold House & Cardboard Wall Workshop" and a full-scale prototype was built.









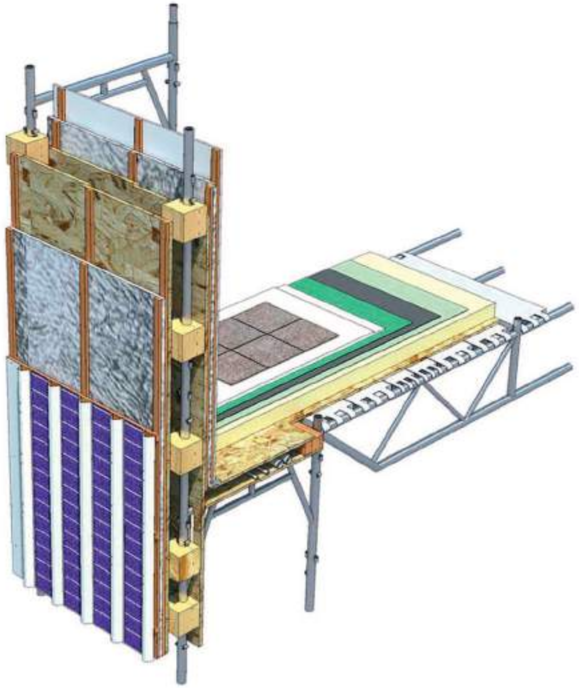
ROOF AND WALLS

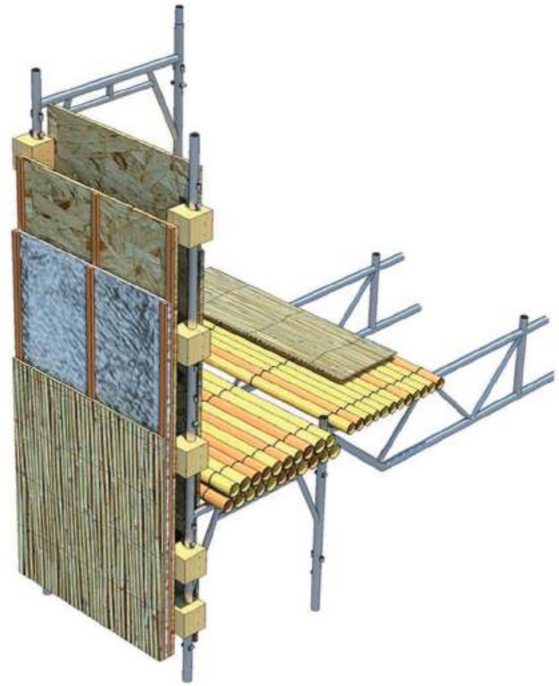
- cladding with fiberglass corugated sheets
- wooden strips for ventilation th. 4cm
- insulating thermo reflective system Triso-protect Actis th. 2.2cm
- wooden strips for air gap th. 2cm
- OSB panel th. 20mm
- air gap th. 16cm
- OSB panel th. 20mm
- wooden strips for air gap th. 2cm
- insulating thermo reflective system Triso-protect Actis th. 2.2cm
- wooden strips for air gap th. 2cm
- plasterboard th. 12.5mm

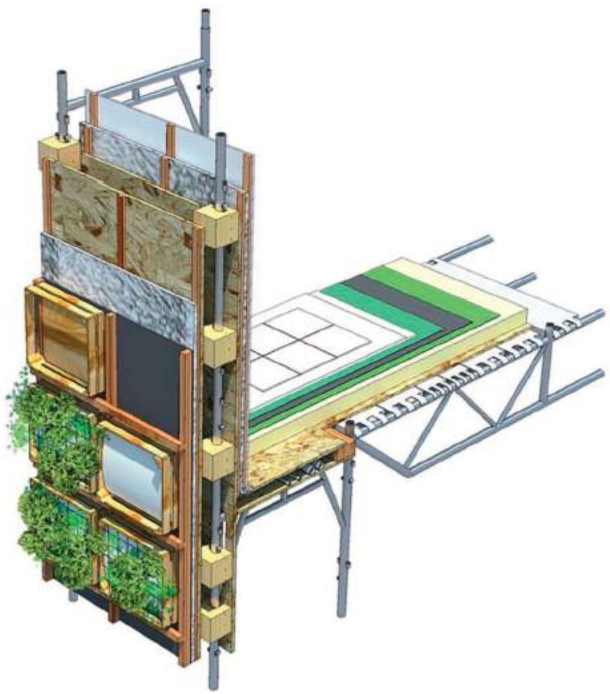
FLOOR

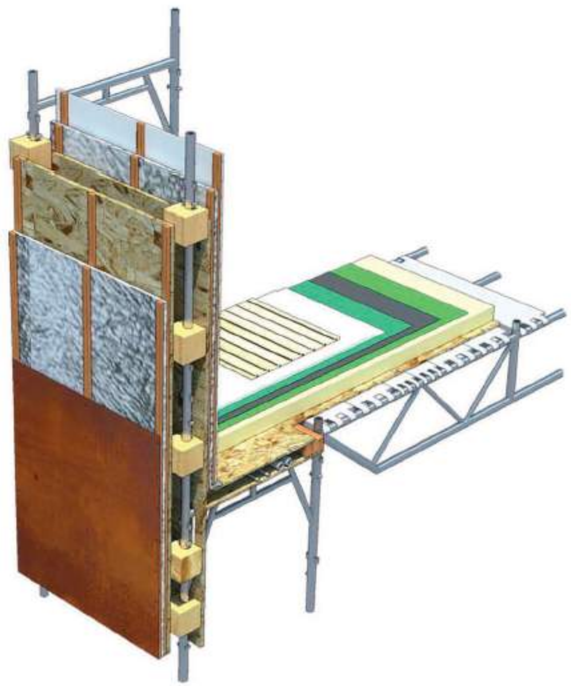
- floor finishing
- double layer of plasterboards for dry subflooring th. 2x12.5mm
- vapor barrier
- hemp felt th. 0.5mm
- polyurethane panel th. 100mm
- OSB panel th. 18mm
- steel plate scaffolding platform lenght 120cm

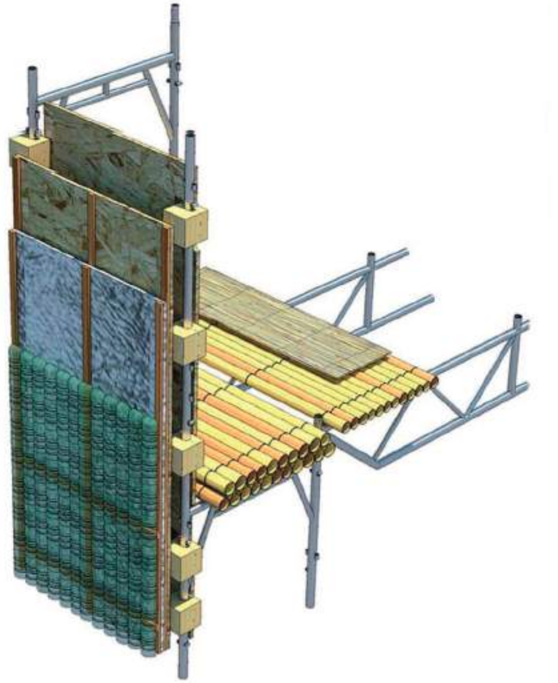
Layering customization is also possible in order to adapt the system to the context and to the constructive knowledge of the place where it is set up.











M

Campus Point
Lecco
Design: Arturo Montanelli - Studio Ardea - Lecco
Consultants: Politecnico di Milano - Prof. Imperadori e Prof. Zambelli

The project, conceived by Professor Riccardo Pietrabissa , deputy vice-rector of the Politecnico di Milano - Regional Centre of Lecco , was born from the desire to not wait for completion of the new campus under construction at the former hospital of the city, but to have quickly and cost-content areas whose realization should be itself cause for research and experimentation. A temporary architectural structure, designed specifically for the purpose, highly innovative, experimental and technological, not affecting the refurbishment of the hospital and that could be easily disassembled at the end of its using period. A "container" for the research made of many containers open to the city to allow the whole community to live together with the university this experiment, to follow its progress and enjoy the results.
The structure consists of 27 containers , industrial prefabricated in steel and glass, size 2.90m x 8.11m x 2.70m in height placed close to the facade of the building under renovation.
Designed and developed entirely with dry construction technologies, the individual elements came pre-wired and equipped with all facilities and pipes for water and drainage . The on-site assembly was completed in a few days, putting the individual cells on top of each other as to form a modern hive of large red semi-transparent pixels .
To achieve the effect of activities in progress and dynamism of the facade is not continuous but the individual elements are placed embossed, with different depth, to create vibrant amazing light and shadows effects.





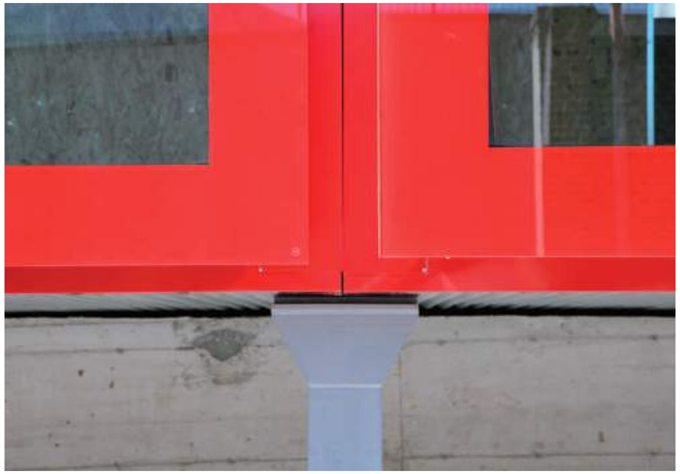






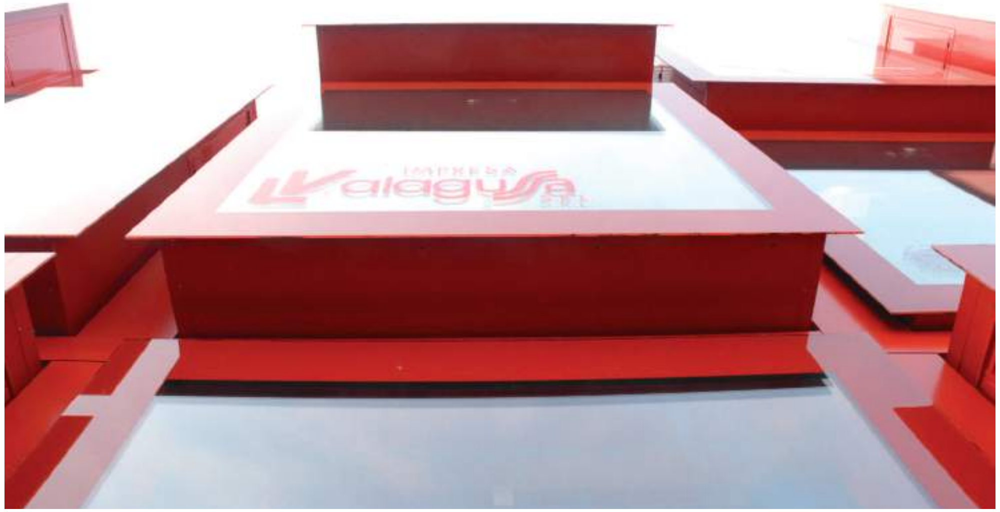






The building could be de-constructed and re-used on another site. Reuse is not, however, been designed and planned in advance, so for economic reasons and procurement, and for a lack of interest on the part of the executing company, the contractor decided not to reuse the building but to demolish it, conveying materials to the recycling chains.
It should however be considered that a technological detail, purely formal, such as the placement of large embossed glass facade, overhanging from the support frame, would have also increased the degree of difficulty of handling blocks and increased the costs of de-construction.

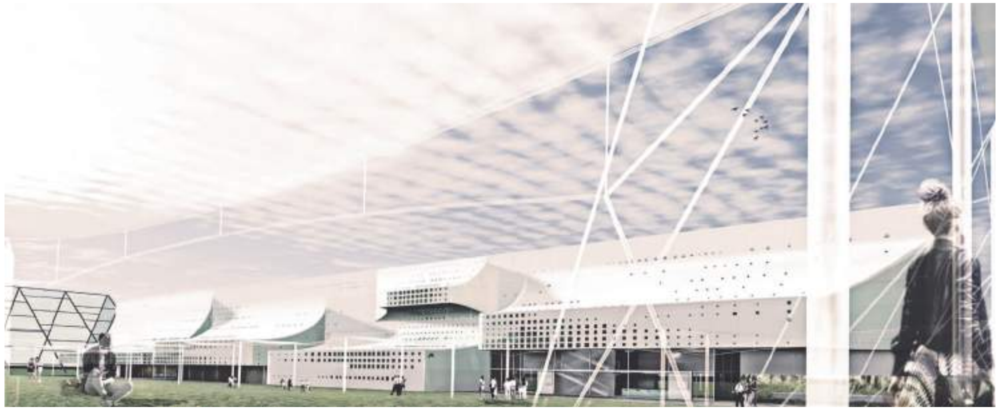


L

FABRIC - 5th prize **-** International competition of ideas for service areas Milano EXPO 2015

Design: Salvatore Musarò, Fabio Prada, Paola Trivini

Energy consultant: Michele Sauchelli

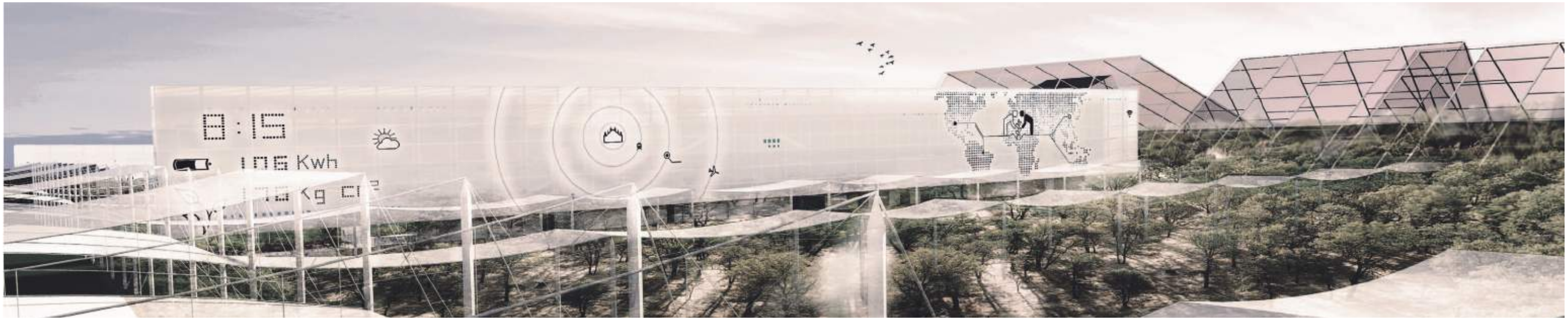


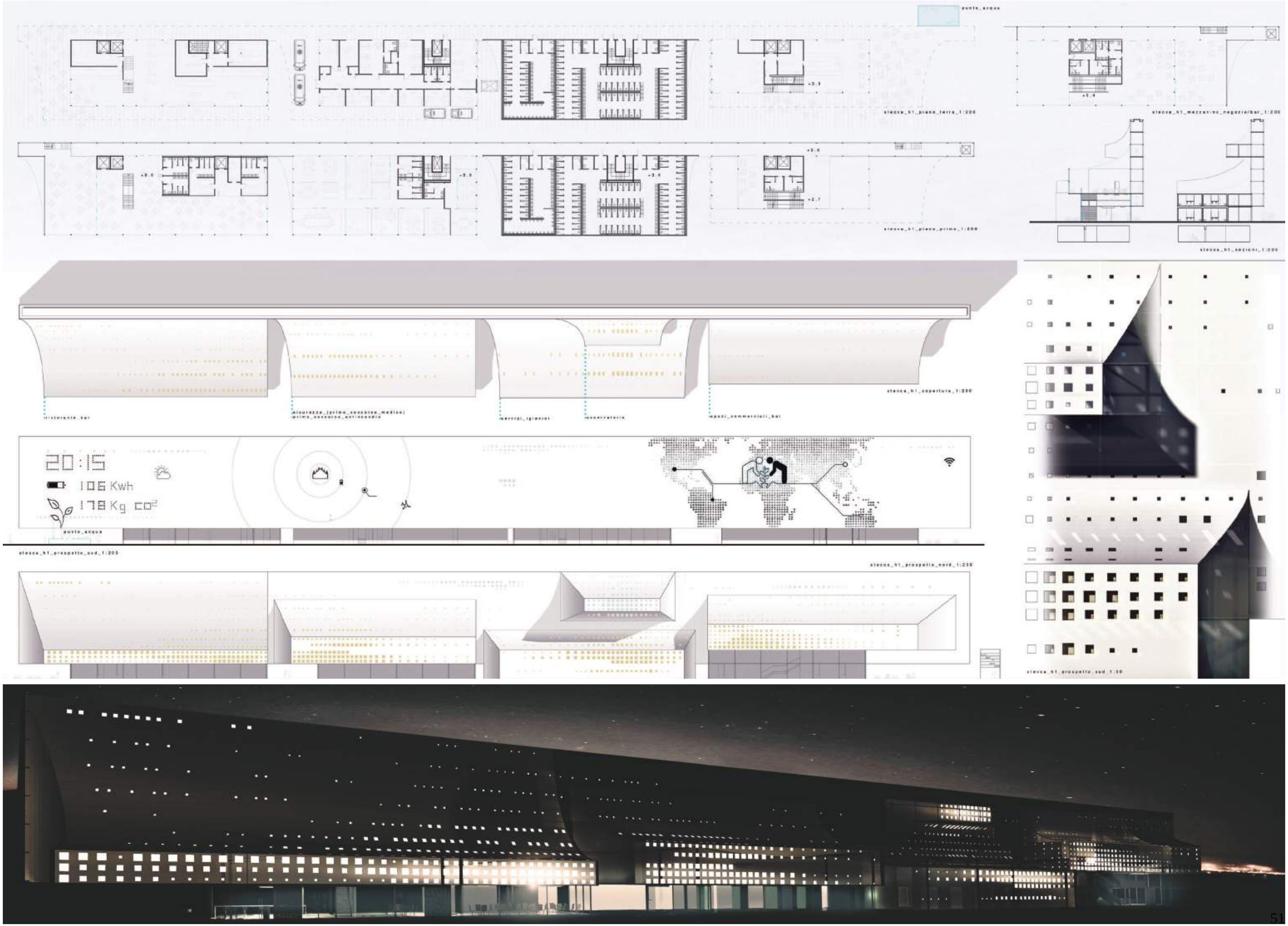
Simplicity is the guiding principle of the concept of service architectures and results in an architecture simple to build, to identify, understand, and communicate, to live and operate. Despite its simplicity, the project encompasses very strong themes such as environmental sustainability and energy efficiency and a high quality of space, inside and in relationship with the landscape. The resulting image is a blank sheet, milestone and engine of the architecture.

The service buildings are huge white sheets billowing out of a shadow line, becoming the backdrop to the open spaces: the two-dimensional image then becomes architecture and the paper turns to the wall, the shadow into functional blocks lined up to anchor the structure to the ground.

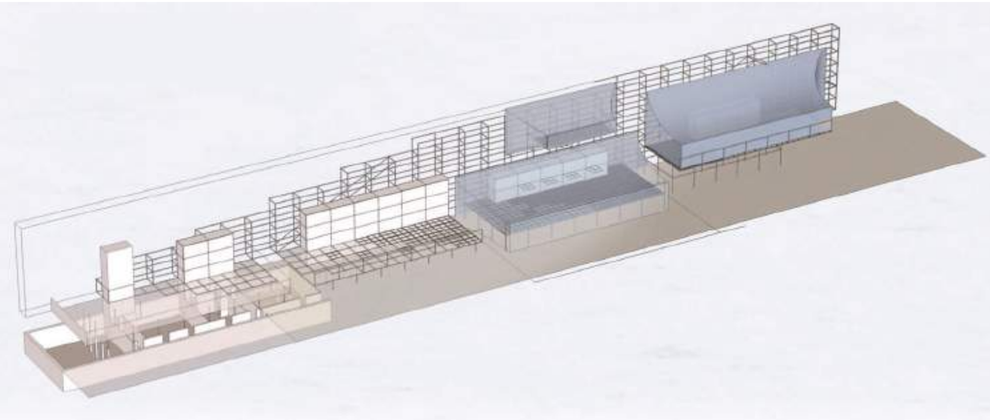
The wall is the unifying element combining shape, functions, technologies and energy.

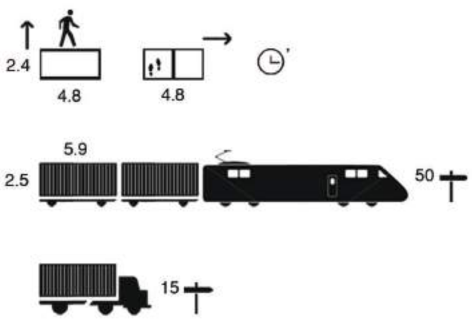
The aboveground structure of the service area is assembled using completely dry construction techniques. It is based on the repetition in three dimensions of modular two-dimensional metal frames which are then covered with a textile skin. The system is characterized by total offsite prefabrication with only simple assembly operations taking place onsite.

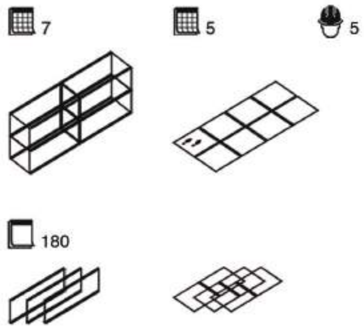


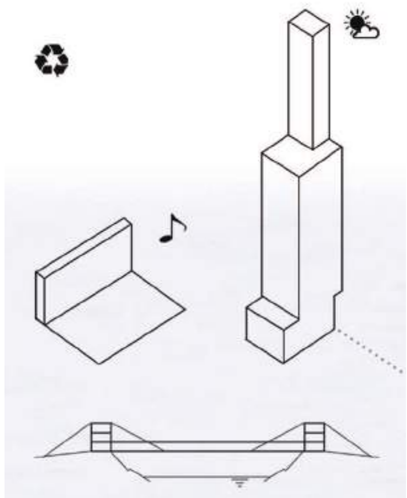

20:15
106 Kwh
178 Kg CO2

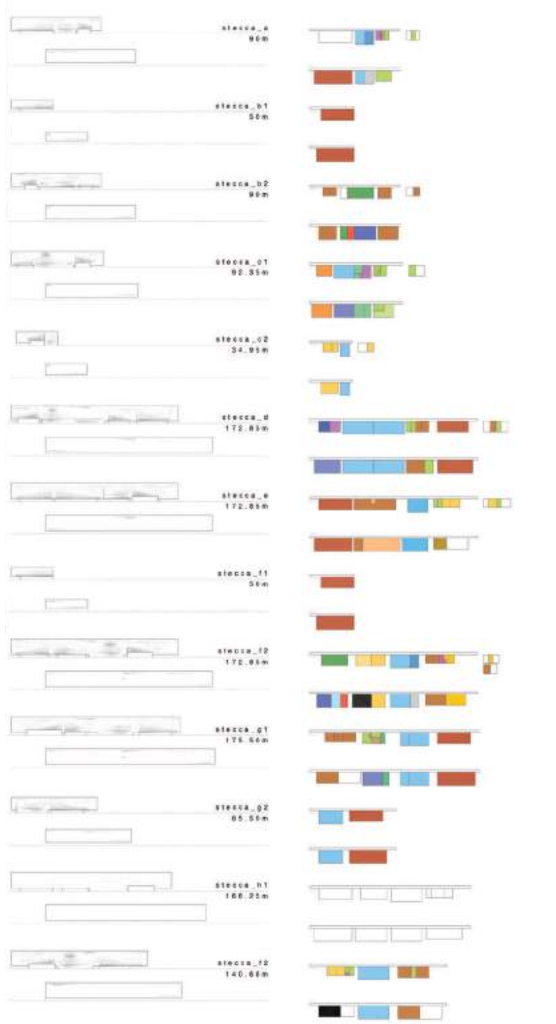
2.40 m. These dimensions were chosen to optimize transport without requiring special means (oversized loads). These standard section tube profiles are assembled and interlocked using mechanical connectors. Dry assembly techniques are also used for the external glass elements, the textile "skins", the textile membranes characterizing the interior floors and walls, and the sanitary facilities.
The modular buildings, built entirely using dry assembly techniques, can easily be disassembled and the individual materials separated into the proper channels for reusing, recycling or disposal. The modularity and simplicity make the system very flexible and easily convertible into other types of urban installations: concert stage, pedestrian walkways, towers as few exemples.
The choice of materials is oriented toward those with a high content of recyclable elements and light weight in order to reduce environmental impact in all phases of production, transport, construction, and disassembly, minimizing the amount of embodied energy (it has been calculated that over the 60% of the embodied energy is represented by concrete foundations). Textile architecture represents the synthesis of this choice.



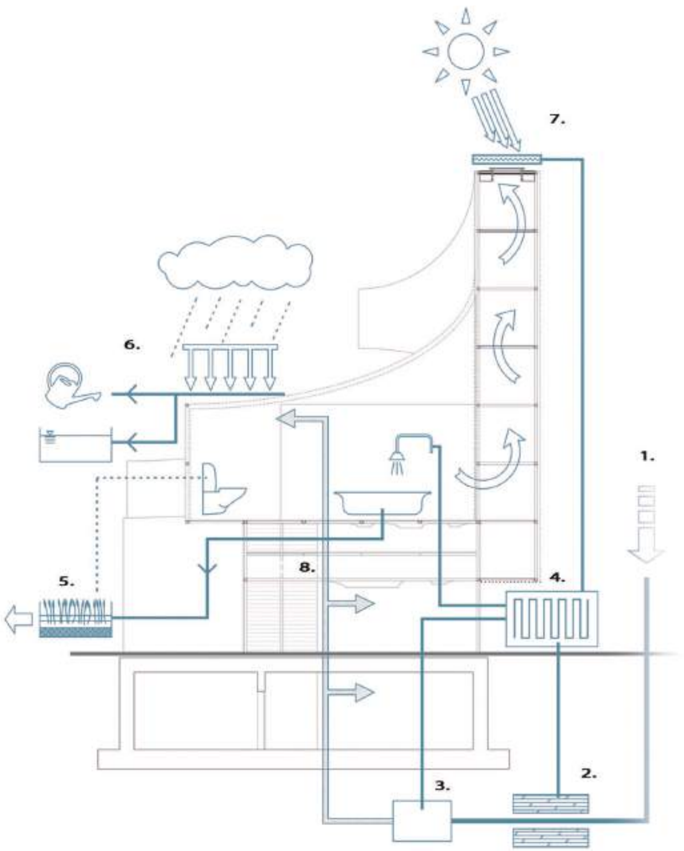






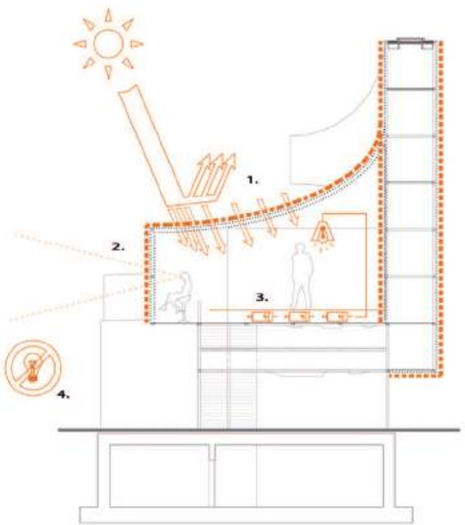


Despite the temporarity of the building, according to the guide lines by EXPO, the architecture has been designed to achieve almost zero energy demand. Initial simulation results using Trnsys software indicate an energy density for summer air conditioning, artificial illumination, hot sanitary water production, and heating (in October) of 7.99 kWh/m2/year.
The wall represents the energy driver and distributor for the building, delivering natural ventilation and interior air exchange. There are no plans to install an AHU. Incoming fresh air is naturally cooled by passing through a buried network of horizontal pipes and dehumidified using a desiccant which is regenerated by the solar thermal system. The solar thermal system also feeds into the downstream reheat coils designed for use only during cold autumn days and supplies all necessary hot sanitary water.
Air extraction in the sanitary facilities will be accomplished exclusively by means of natural ventilation and the solar chimney effect. Temperature peaks on particularly hot days will be buffered by the installation of phase-change materials (PCM) in the dropped ceiling.



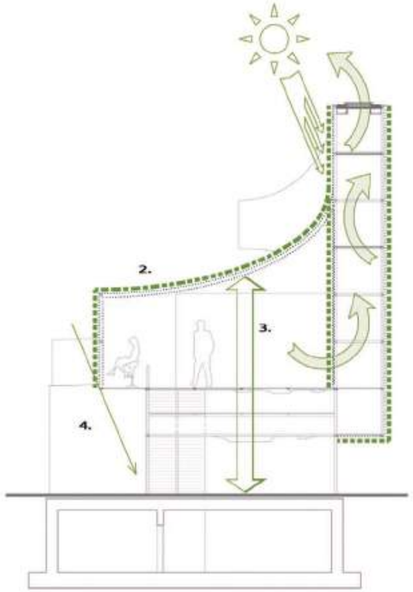
Energy and plant system

1. natural cooling of the fresh air through underground pipes
2. dehumidification of the inlet air through drying salts, regenerated by the thermal solar circuit
3. post-heating battery powered by thermal solar circuit for cold days
4. storage tank of the thermal solar circuit for the total demand coverage of domestic hot water (reserve for overcast days)
5. filtering through phytoremediation of gray water to be reused within the site
6. rainwater harvesting for irrigation of outdoor spaces and tanks for fire fighting
7. solar thermal and photovoltaic field integrated in the roof
8. integration in the ceiling of the toilets of phase change materials (PCM) to moderate summer heat peaks and avoid the installation of an air conditioning system



Natural lighting

1. the outer skin acts as a filter and protection against excessive radiation, spreading the light in space
2. visual comfort and view open to the outside
3. piezoelectrical floor to generate the electricity needed to illuminate the spaces in the evening hours
4. reduction of operating hours of artificial lighting



Bio-climatic strategies

1. solar chimney for natural ventilation
2. textile skin able to filter out the incident solar radiation and diffuse sunlight
3. double-height spaces and changes of geometry to facilitate natural ventilation of the premises
4. glazing on the ground floor protected from direct solar radiation

Cluster pavilion for EXPO 2015

Traditionally, the Organizer will group together those Countries taking part in the Exposition who do not intend or desire to participate with a stand-alone Self-Built Exhibition Space in common exhibition areas or Joint Pavilions. However, since the idea of the whole project of Expo Milano 2015 is to look at the Theme from every point of view, the Organizer has decided also to apply this idea to the Countries. So Countries will not be grouped according to geographical region but by themes. Once again, Expo Milano 2015 will make the Theme “Feeding the Planet, Energy for Life” central to everything.

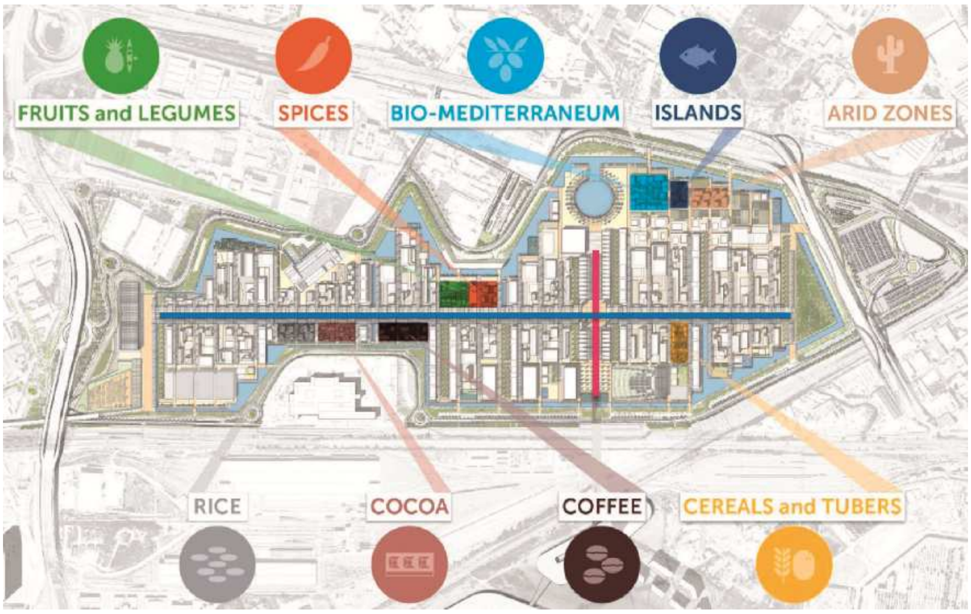


Figure 3. Clusters identification in EXPO site

The Organizer has decided to organize the Clusters according to two basic criteria on the basis of which the Countries will be distributed around the Site:

- Food chains: Countries in these Clusters will be grouped according to the role they play in a particular food chain;
- Thematic Identity: in these Clusters, Countries will be grouped according to the particular aspect or interpretation of the Expo Theme that they want to develop.

The themes of the Clusters have been decided through close discussion with the participating Countries themselves and with the Faculty of Agriculture of the Università degli Studi di Milano in order to develop exhibition content. The Organizer has, therefore, chosen to adopt a collaborative approach to the development of each Cluster.

Each of the Clusters will be located in a prime site. The Clusters that belong to the group of Thematic Identity are the only ones to be put inside the big Biodiversity Park since this is a Thematic Area with such a strong profile within the Expo program. Instead, the Clusters addressing Food Chains will be located along the Decumanus, and these will alternate with the Self-Built Exhibition Spaces.

Finally, every Cluster will represent the start of a thematic Itinerary. This is so other Countries who have chosen to participate with a Self-Built Exhibition Space but who are interested in the Cluster concept can contribute to it and help develop its theme. This also means that these Countries can become part of the itinerary thus adding extra weight to the interpretation of the Theme within the Cluster.

The concepts of clusters have been developed within the framework of the Cluster International Workshop 2012 in commitment with the professors and students of universities from all over the world. After that phase, the concepts have been deeply developed and updated by Politecnico di Milano, with professors previously involved.

According to the Cluster model, each Country will have its own individual exhibition space around a common area.

This space will be used for joint initiatives with the Countries who make up the rest of the Cluster. At the same time, the personal identity of every Country will be respected while they can each choose how this should be best represented within the exhibition space allocated to them.

So every Country that becomes part of a Cluster can show the particular aspects of the Theme in which they excel:

- showing how each country interprets the Theme;
- developing their own contribution to the Cluster;
- bringing their identity to the fore in their own exhibition space.

While respecting the collective input, each Cluster will be characterized by a distinctive architectural design.

The multi-purpose common area will be integrated into this to fulfil a wide range of functions: refreshments, sales, events and exhibitions.

The common area will represent the heart of the Cluster. It will make up the most innovative element of this particular project in that it will promote the Theme as a narrative thread running right through the Expo, exemplify the participation of the various Countries and encourage them.

The Exhibition Spaces have been encouraged to develop environmentally sustainable through:

- An integrated design process that involves reuse, recycle and low carbon.
- Low-impact construction system enabling easy construction and dismantling.
- Use of sustainable materials (local, recycled, recyclable, certified as responsibly sourced, low-emitting) chosen also via an environmental assessment through a Life Cycle Assessment or an Embodied Energy/ Carbon methodology either via a country-of-origin system or a European system.
- Minimise the energy need and consumption optimizing passive strategies (shading, natural ventilation, massing) and efficient systems. Use dynamic energy modeling considering all energy sources including cooling, lighting, internal equipment and renewables.
- Minimise the water consumption by using low flow fixtures and native or adapted planting.
- Minimise the heat island effect choosing pavements (SRI > 30) and roofing materials (SRI>80) with a high albedo effect where shading is not provided or green roofs.
- Minimise light pollution.
- In the construction and dismantling phases, is require an environmental quality system or certification (ISO 14000 or EMAS compliant).
- Innovative environmental solutions.

The structure of the units consists of the construction of a varying number of frames in laminated wood (Class GL28h) for a basic 125-sqm module with maximum height of approximately 12 meters.

The height of the Covered part of the Exhibiton Space must be less than 12 meters. The height limit for buildings is 17 meters (including all architectural elements such as skylights, roof elements, vertical connections to the roof, sunscreen protections, signals...).

The option to have of an intermediate floor at a height of 5 m has been adopted in some cases.

The standard spacing for frame members is 2,75 m.

The structure system is composed as follows:

- laminated timber frame (20 cm width)
- X-lam dry-mounted floor structure (8.5 cm)
- wooden bracing
- prefabricated panel partitions

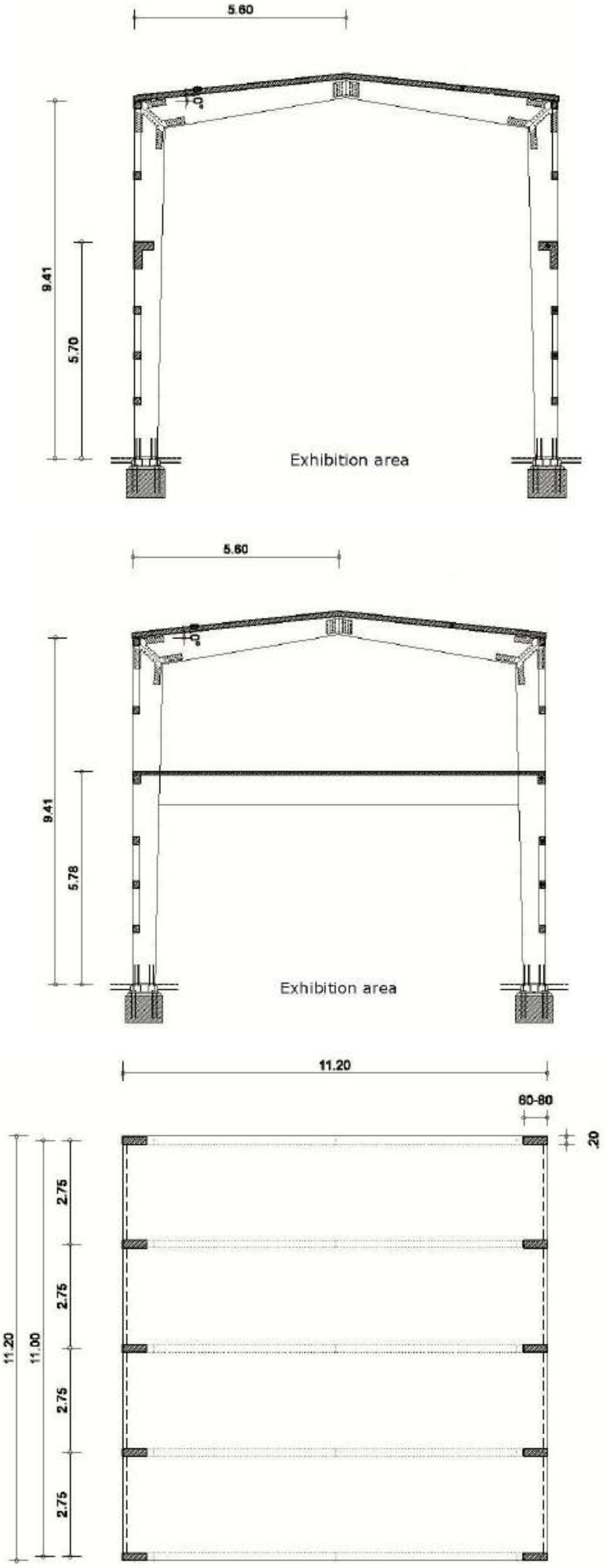


Figure 4. Three-hinged arch - Type 2

Floor slabs will be made of X-lam (thickness 8.5cm) installed without the use of adhesives.

Floors will be surfaced in wood or rubber or technical raised floors.

The ground level floor is designed with a load rating of 5 kN/m^2, whereas the 1st floor is designed with a load rating of 3 kN/m^2.

The sloping roof will be inclined at an angle of 6°. The rafters and purlins will be made of laminated wood on which self-supporting wooden sandwich insulated panels will be mounted.

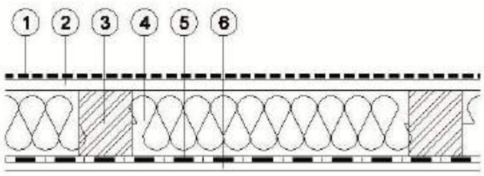
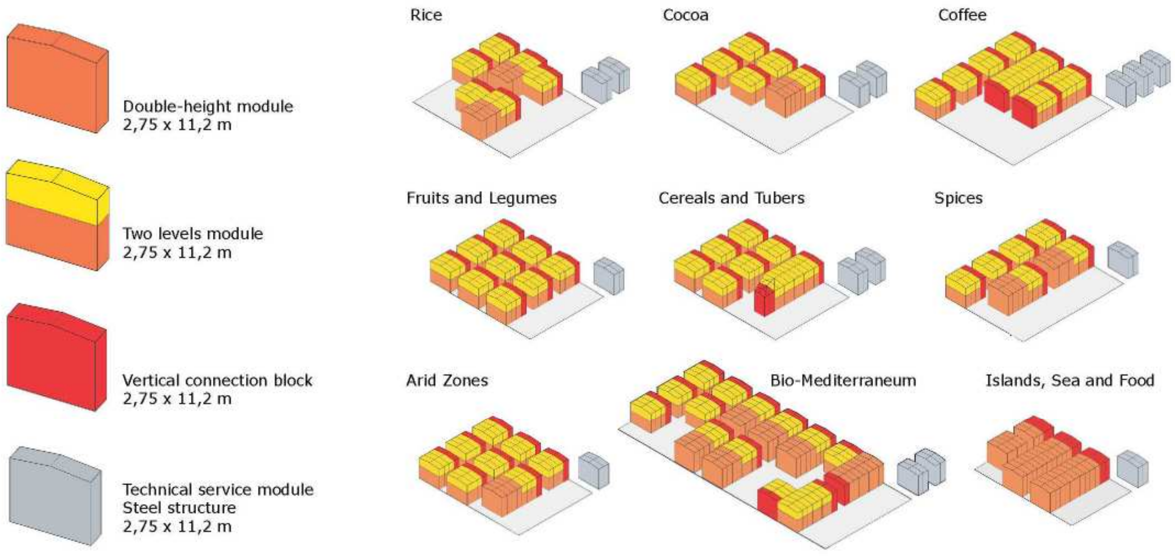


Figure 5. Typical composition of the wall

Here following Cluster are resumed in summary boards.

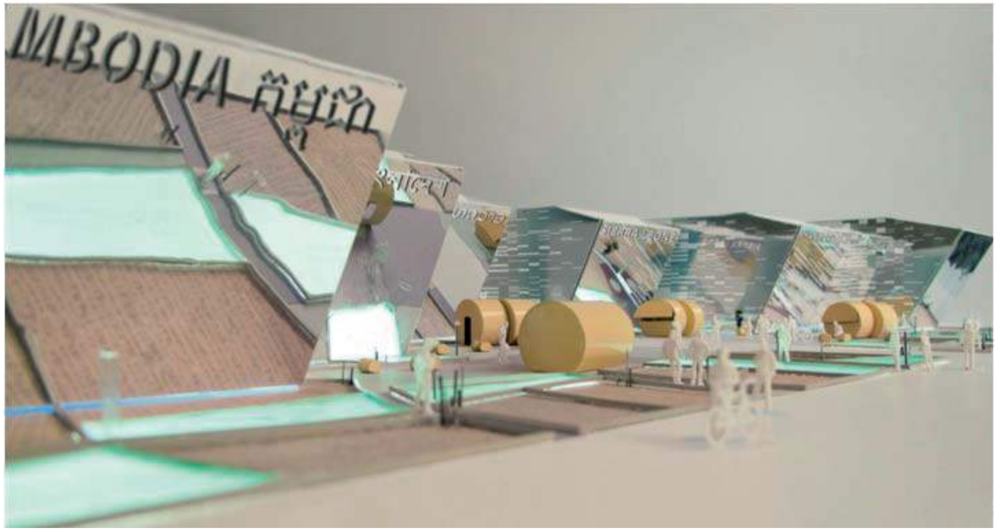


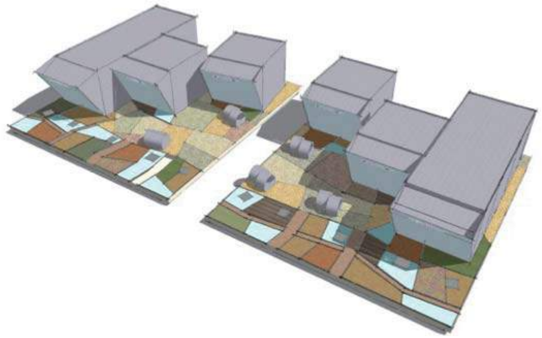
CLUSTER	UNITS (125sqm each)	1 LEVEL UNITS	2 LEVELS UNITS	SURFACE GROUD FLOOR (sqm)	SURFACE FIRST FLOOR (sqm)	SURFACE TOT ON 2 LEVELS (sqm)	FRAMES	CONNECTION BLOCKS	SURFACE TOT NET OF CONNECTION BLOCKS (sqm)	TECHNICAL SERVICES BLOCKS
Rice	8	2	6	1000	750	1750	38	6	1552	2
Cocoa	7	1	6	875	750	1625	34	6	1427	2
Coffee	10	0	10	1250	1250	2500	46	9	2203	3
Fruits and Legumes	9	0	9	1125	1125	2250	45	9	1953	1
Cereals and Tubers	8 (+1)	0	8	1000	1000	2000	39	7	1769	2
Spices	8	2	6	1000	750	1750	38	6	1552	1
Arid Zones	9	1	8	1125	1000	2125	44	8	1861	1
Bio-Mediterraneum	21	7	14	2625	1750	4375	98	14	3913	2
Islands, Sea and Food	8	0	8	1000	0	1000	36	3 (x2)	1808	1
TOTAL	88	13	75	11000	9375	20375	418	68	18038	15

Figure 6. Composition of Cluster

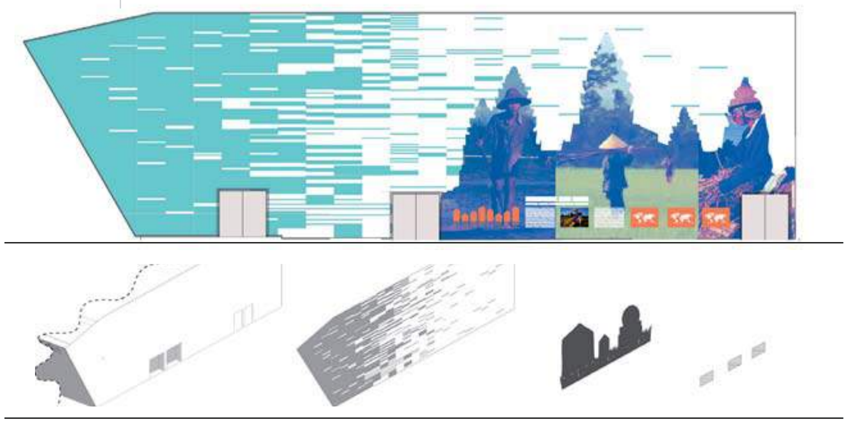
EXPO 2015 Cluster Pavilion
Rice

Design credits: Agnese Rebaglio, Davide Crippa, Barbara Di Prete, Lorenzo Loglio, Francesco Tosi





The atmosphere of the countryside, with the colors and scents of the rural world, welcomes the visitor to the rice cluster, with a landscape reminiscent of a vast rice paddy. The water covering the rice fields hides and reveals at the same time, and brings life. So the cluster conceals information and curiosities that are discovered, step by step, by the visitor.
In the thematic itinery, visitors can trace through the stages of the history of rice, intertwining stories fromdifferent countries and exploring the innovations introduced over time. With a spectacular sequence of reflecting pools, the pavilions are placed in an agricoltural landscape: entering the cluster, you are immediately immersed in a "miniature" rice field, a botanical exhibition of cultivated areas with different types of rice.



PAVILION

MIRRORING PATTERN
Rice DNA barcodes become graphic patterns to "represent" rice variety

GRAPHIC AREAS
Inspired by national monuments and fillen with photographs

EXHIBITION
Exhibition with texts, images and graphics

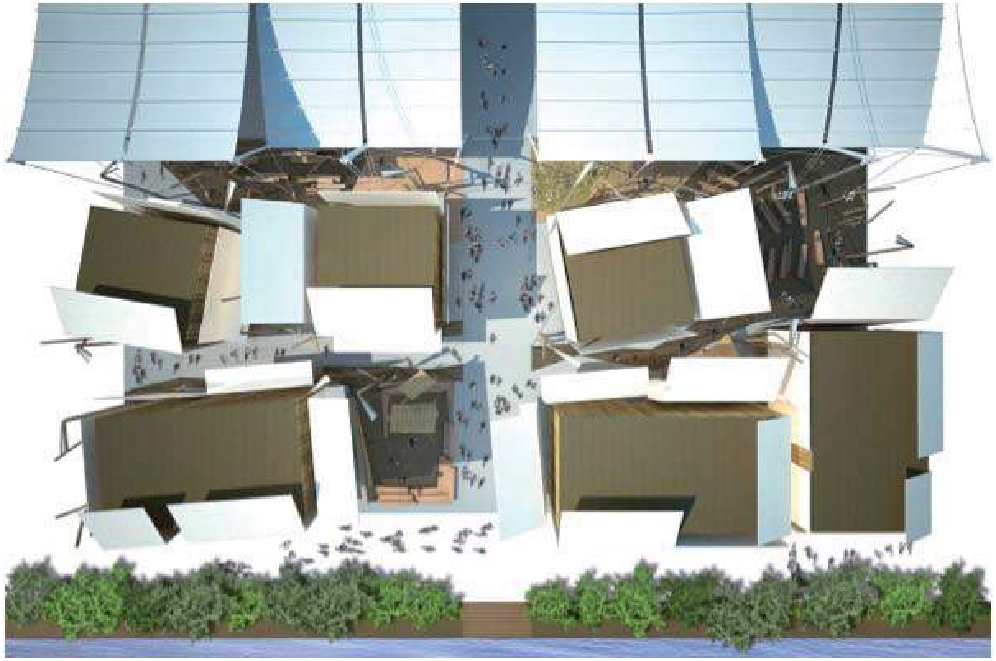
EXPO 2015 Cluster Pavilion
Cocoa

Design credits: Fabrizio Leoni, Mauricio Cardenas, Cesare Ventura

Entering the Cacao cluster, the visitor has the impression of entering a jungle. The concept draws inspiration from the places where cacao is cultivated: plantations in tropical and subtropical areas. The facades of the buildings are made of a lightweight pale fabric that opens to reveal the interior finishings: a metaphore for the need to protect a precious, aromatic product like cacao.

In the common area there are a number of poles of different heights and shapes, a metaphore of the trees under which cacao grows. The atmosphere is cozy and dense, like a forest, where light penetrates through the canopy of treetops, spreading through the pavilions.

The pavilions, similar in size and colors, identify the participating country with its flag and name on the facade.



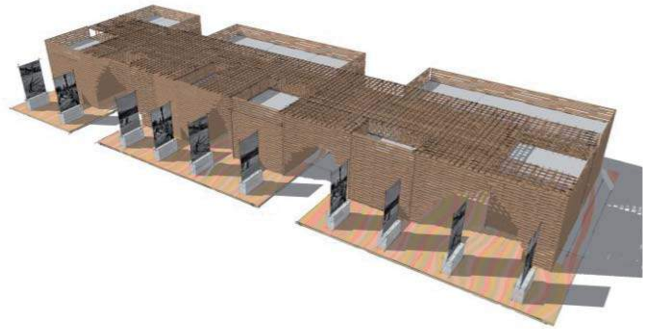
EXPO 2015 Cluster Pavilion
Coffee

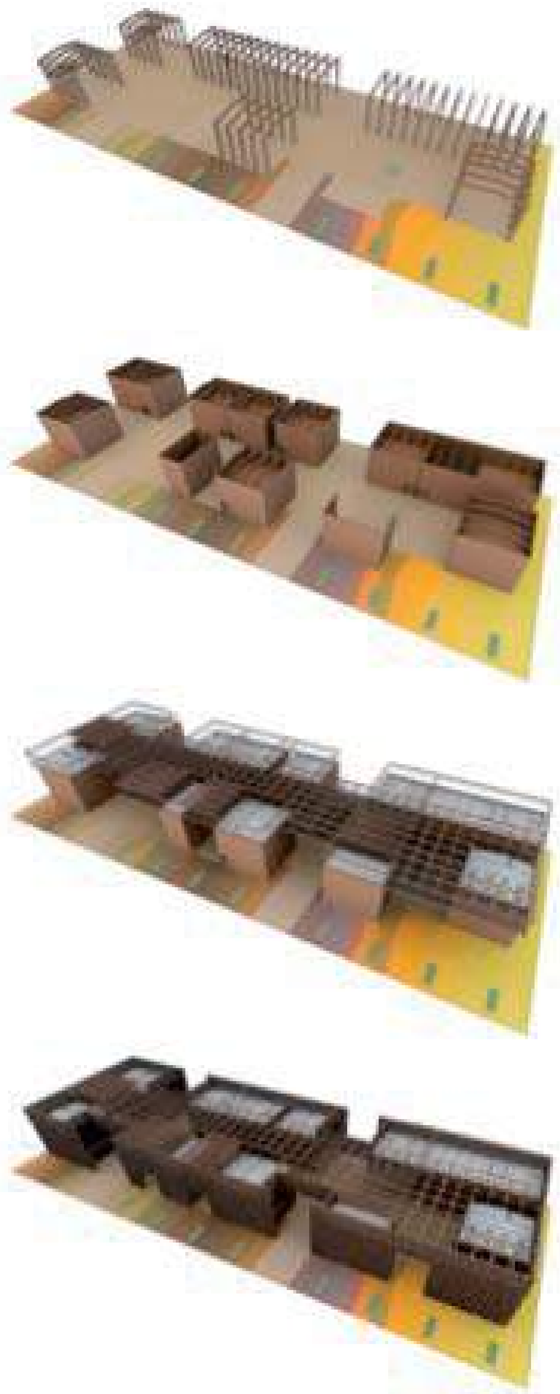
Design credits: Alessandro Colombo, Stefan Vieths
Contributors: Francesca Rapisarda, Alexandre Hepner, Maddalena Nakato Mainini, Silvia Pomodoro

The concept was developed within the International Cluster Workshop 2012, involving for this cluster Politecnico di Milano and FAU - Universidade de Sao Paulo (Prof. Francisco Spadoni).

The vast coffee plantations of tropical forests in Africa and Central America have inspired the design of coffee cluster. The architecture of the spaces references the highest branches of the trees that offer shade for the coffee plants, while the pavilions are a metaphore for their trunks.
The warm tones and natural colors that characterize the environment change depending on the light that filters through the roof from the outside, affecting the perception of space and giving the visitor the illusion of being right in a forest.
The coffee cluster offers an exhibition that accompanies the visitor "from the ground to the cup" and consists of five stops: greehouses, transportation (shipping containers are used as a metaphore), roasting, the café and an area for socializing. The route begins outside, in the green space set up with coffee plants, with the beautiful exhibition of photographs by Sebastiao Salgado.

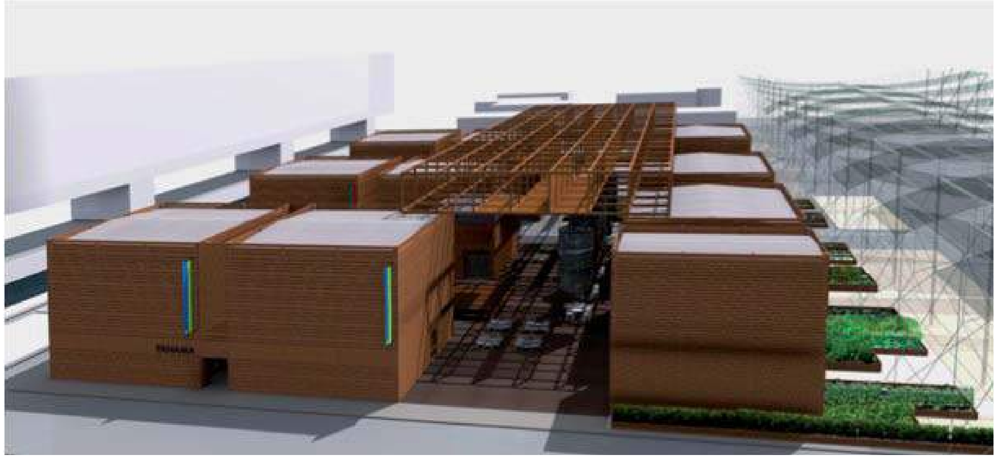
Entering the refreshment area, you can enjoy the fragrant and tasty drink. The event area is for encounters, presentations, performances. Between the café and he events area there is a market zone where you can buy prodcts from the world of coffee, from different countries: a way to store and carry with you the memory of the aromas and flavors encountered.





The facade composition is derived from the combination of modular elements.The panels were studied from strips of equal shape, mounted each time in a different position, so as to have more panels of the same type.

EXPO 2015 Cluster Pavilion
Fruits and legumes
Design credits: Massimo Ferrari , Matteo Vercelloni
Contributors: Stefano De Feudis, Stefano Sala, Claudia Tinazzi



In the spaces of fruits and legumes cluster there are areas plantes with fruit trees of different types. Around a cental square, inspired by the shapes, colors and scents, visitors can participate in events and admire the thematic displays. Above the square, designed to ideally join the pavilions, there is a wooden roof, like a pergola.
At the end of the visit visitor can stop to browse and purchase products at the market, which is an element of division between this cluster and the

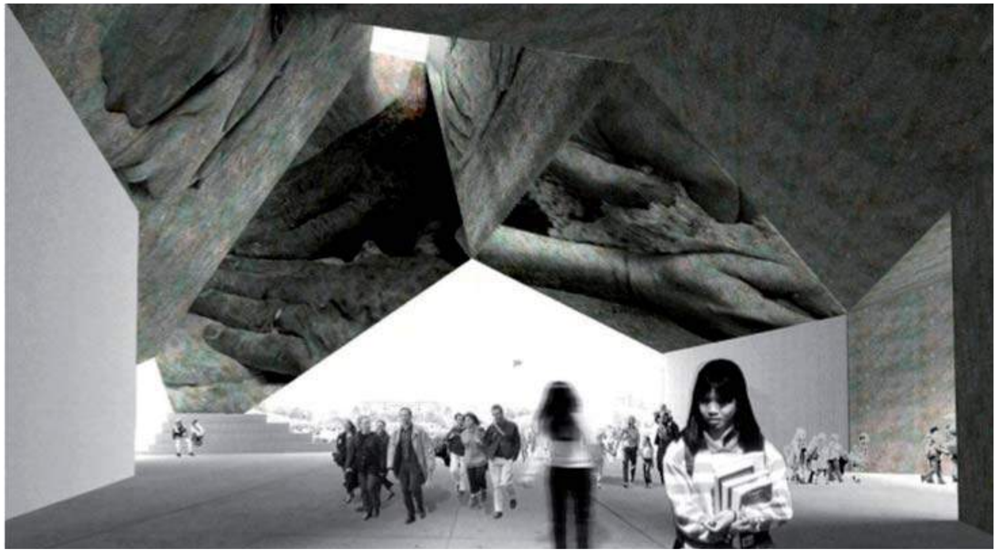
EXPO 2015 Cluster Pavilion
Cerelas and tubers

Design credits: Alessandro Rocca, Franco Tagliabue, Maria Feller, Marta Geroldi

The cluster elcomes and accompanies the visitors into a set of colors, surfaces, scents and feelings related to the cultivation of these foods. A path that, like a river, flows through the pavilions of various contries, issuing in a large indoor spae that hosts events and refreshments.

The architectural design includes a roof in the form of a large fireplace, containing an events area and a zone for distribution of thematically related foods.

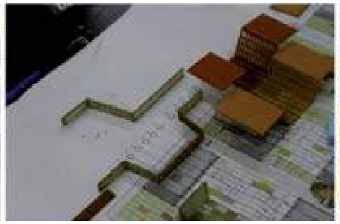
Pavilions have facades cladded alternatively with fiber cement panels finished in black painted jute fabric and matt alveolar polycarbonate. On the polycarbonate, high density adhesive films APA are printed with the graphics related to each participating country.

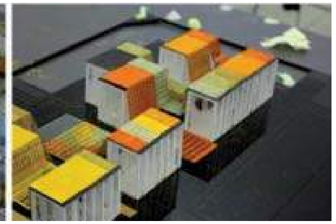


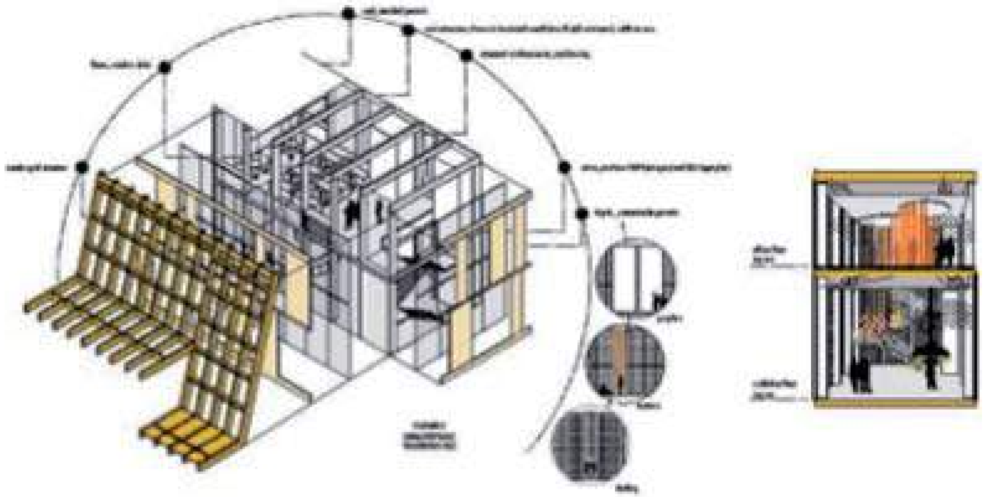
EXPO 2015 Cluster Pavilion
The world of spices

Design credits: Michele Brunello – DONTSTOP architettura, Silvia Bertolotti, Guadalupe Ciocoletto, Giulia Dogliotti, Corrado Longa, Monia Muraro, Massimiliano Savino, Pierluigi Salvadeo – studio Guidarini & Salvadeo

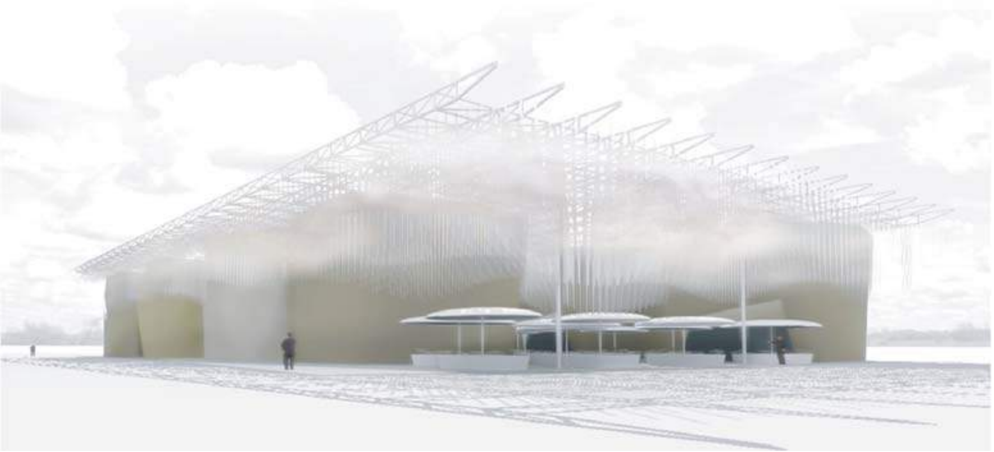
To follow the spce roads, crossing continents, ands and seas. To sense the aromas, to think of them as an ingredient in cooking, a medical remedy or a cosmetic product. All of this happens when you enter the spice cluster, which opens a sensory universe to the visitor. The visitor experience is transformed into a real journey. The exhibition displays the map that guided explorers, in history, to discover the world in search of spices, suggesting a journey between cultures triggered by a sequence of "sensory areas" that include tastings, installations and events.



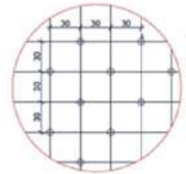




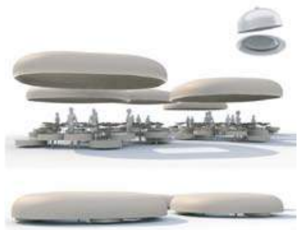
EXPO 2015 Cluster Pavilion
Agricolture and nutrition in arid zones
Design credits: Alessandro Biamonti, Barbara Camocini, ZPZ PARTNERS

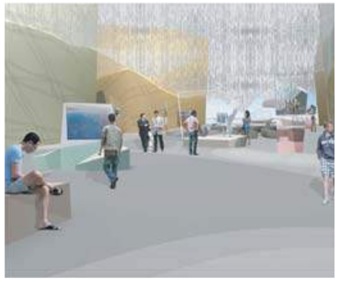


A desert sandstorm is the image that forms the basis for this cluster, the symbol of the difficulties of living and working the land in arid zones. A multitude of semi-transparent cylindres hanging from the ceiling evokes and recreates this unique atmosphere. The pavilions take on the appearence of stones that can be discovered by entering into this metaphorical sandstorm.



When the visitor enters the cluster, the pavilions are finally visible. Walking , they encounter, like an oasis, a water fountain in the common area. This area will also host events and performances, aimed at deepening our knowledge of arid zones, their problems and resources. At the end of the cluster is the arket, where you can buy and taste the products that, incredibly enough, are produced in these places.

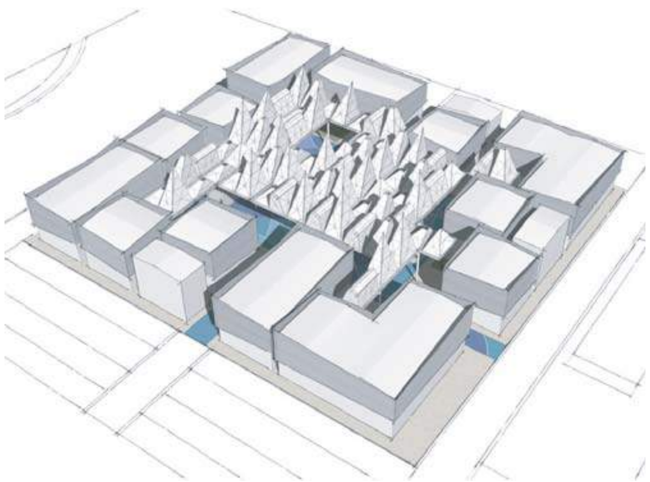


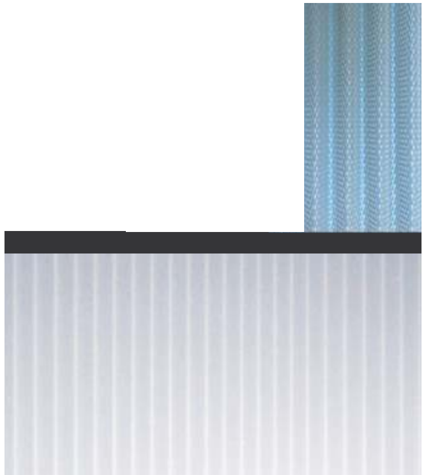


EXPO 2015 Cluster Pavilion Bio-mediterraneum

Design credits: Stefano Guidarini, Camillo Magni, Cherubino Gambardella, Lorenzo Capobianco, Simona Ottieri
Contributors: Vittorio Di Gioia, Gianluca Ferriero, Maria Gelvi, Concetta Tavoletta, Luca Varvello Francesco M.G. Vozza

The project is inspired by the image of the city in the Mediterranean and is built around a large partially sheltered square hosting four structures for the distribution of typical products. The variety of colors of the floor, made up of different shades of blue, evokes all the nuances of the sea borders of the nations contained in the cluster.





Places and foods are the central theme of the installation of an exhibition-narrative featuring the overlapping and intersection of three elements interpreted as parts of a single story: the story in pictures, the literary narrative and the filmed story.
Each pavilion has a coating that differs the upper part from the lower.
The upper part is conceived with a double coating: a wooden background panel, and a white metal mesh that will unify the overall image of the cluster.
The lower part is covered with polycarbonate’s opaque white slabs, and it’s the same for all the pavilions.

1.1 Focus design for deconstruction strategies and reuse: Island, sea and food cluster for Expo 2015

di Marco Imperadori

Design of Island, sea and food cluster

If you want to build a ship, don't drum up people together to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea … *Antoine di Saint-Exupery*

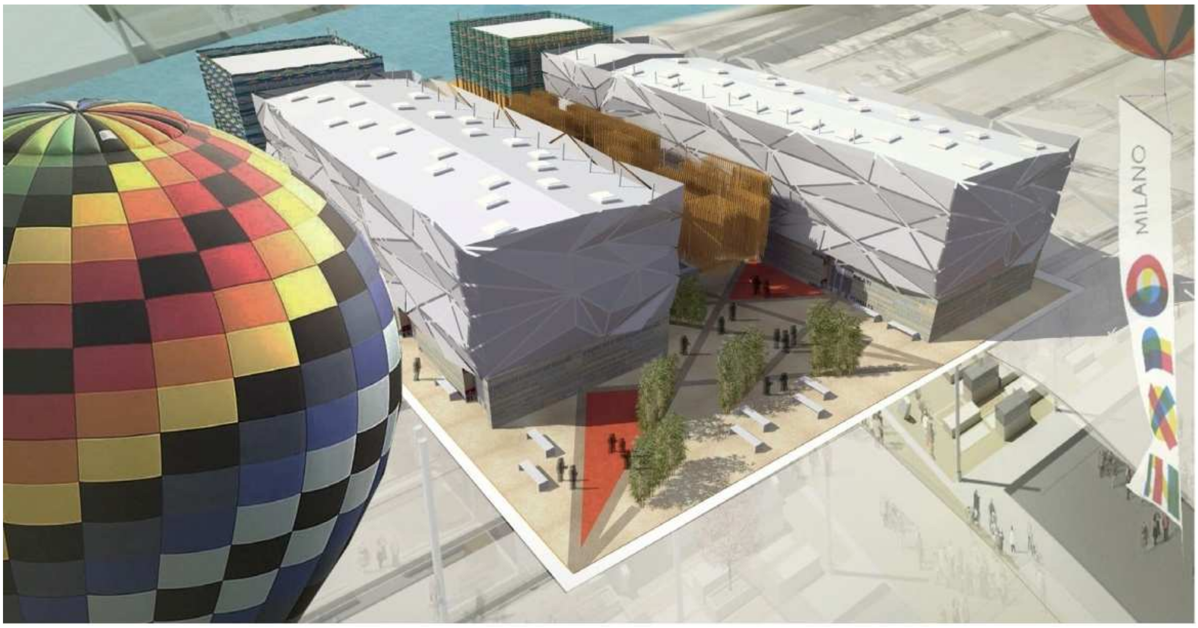


Figure 7. Aerial view of the cluster

The pavilion dedicated to the Cluster "Sea, Islands and Food" is a natural-anthropogenic peculiar situation that is immediately linked to the image of the exotic islands, located between the Tropic of Capricorn and Cancer and across the equatorial belt. It is composed of a series of architectural episodes, indoor or outdoor, that follow one another according to a rhythm clear and legible.

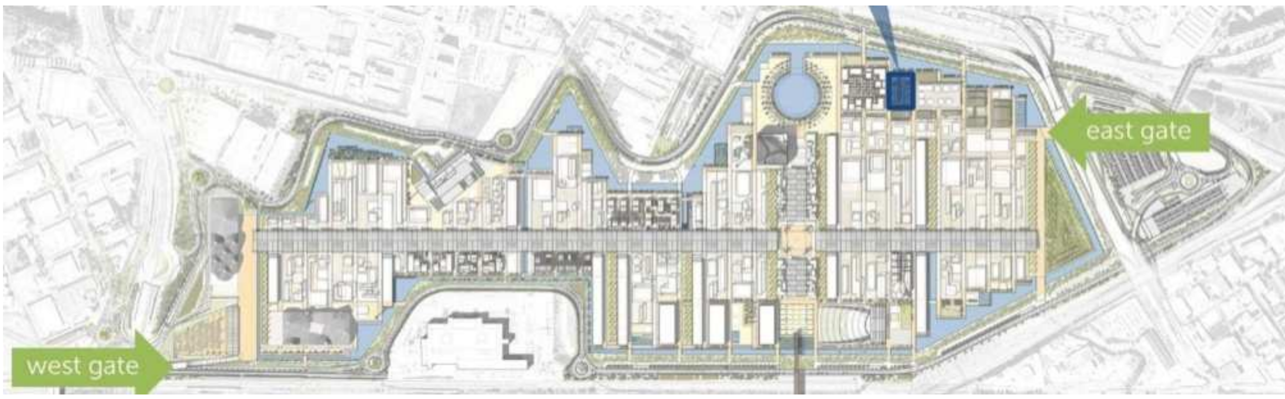


Figure 8. Cluster identification in EXPO site

The concept resulted from the workshop held in September 2012 is titled Rhythm of Discovery, since the idea is to abstract the exoticism both in plastic-geometric form and from the point of view of the sensations, in a total sense: music, indoor and outdoor lighting, tactile experience, surfaces and materials, food and drink tasting and olfactory experience. So a synaesthetic pavilion, able to engage all the senses.

Figure 9. View of the internal courtyard

Figure 10. View of the internal courtyard

The cluster differs from the others because of its size, it is the smaller one, and for the character of the participating countries, very small islands that often cannot afford the set up of their own individual space.

The architectural concept of the cluster “Islands sea and Food” follows the cluster architectural model with a layout tailored on these purposes:

- Joining International Organizations in one specific pavilion, guaranteeing an individual exhibition space for each country.
- Joining Countries requiring an autonomous individual exhibition space in one dedicated pavilion.
- All the individual exhibition spaces have independent accesses from the Common Area that contains the same functions of others clusters (exhibition, food, events, market).
- Every International Organization and Country participating in the Cluster has the name and the flag posted up on the facades of the pavilions, close to the accesses, guaranteeing the personal identity of each participant.
- Two open-space offices have been provided in each pavilion to be shared by the participants.

The parcel, small in size, has been optimized imagining a portion that exhort to enter, set on the main street, and two volumes narrow and elongated, articulated, which will host individual participating countries. At the end of the lot, on the opposite side, are then identified the areas of entertainment, shows and catering, imagined in a manner consistent to the theme and calibrated on culture and artistic culinary proposals of member countries. A technical space is designed near the pavilion dedicated to food service.

The access is from “decumano” and is a square / forest where bamboo plants in pots at the same level of the floor surface, emphasize paths and optical cones, which are marked on the ground by a network of lines inspired by the ancient nautical maps of Polynesia (mattang) and the Marshall Islands, which leads laterally to the accesses of covered exhibition spaces and to events space.

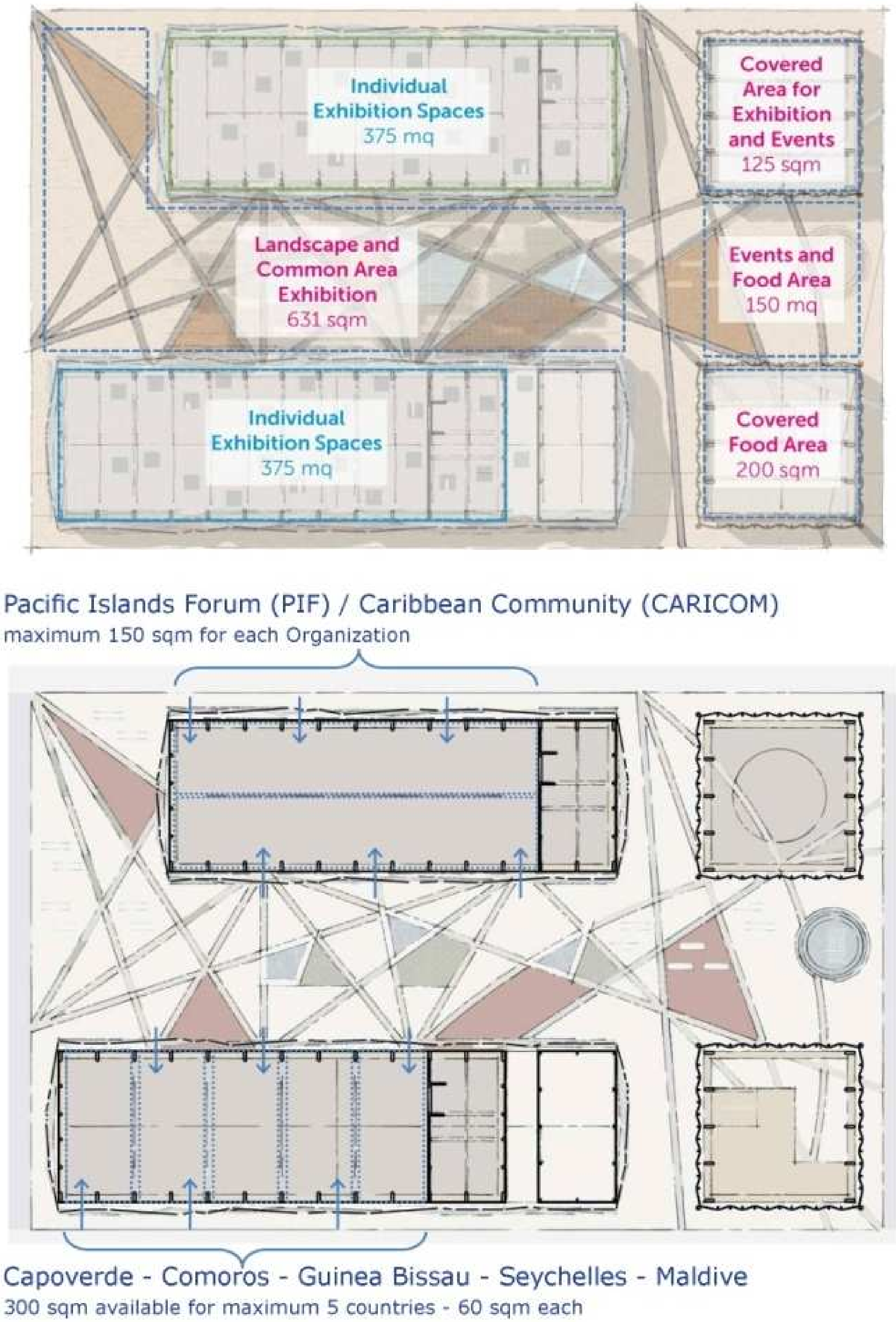


Figure 11. Site configuration

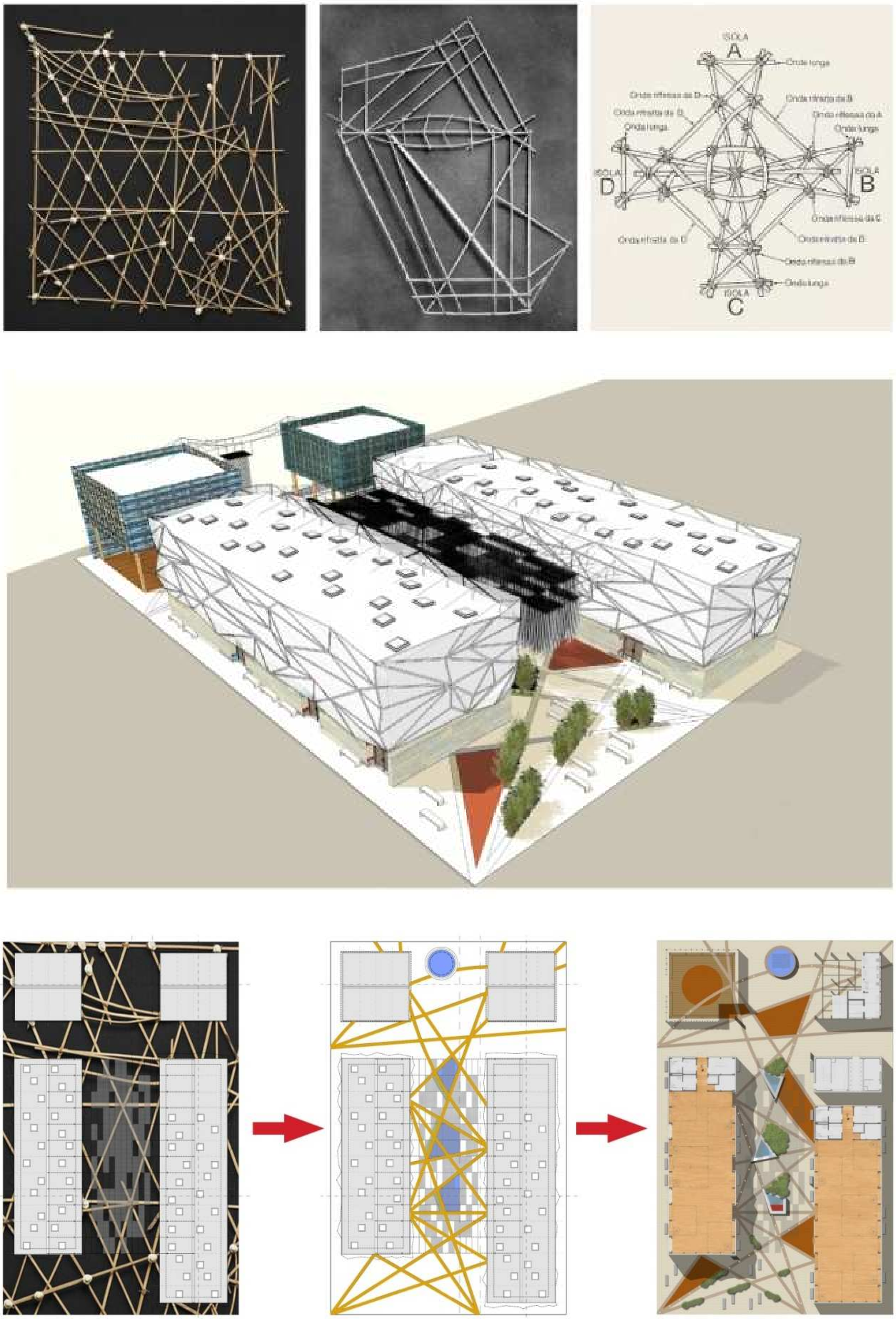


Figure 12. External paths design

The covered exhibition spaces clearly define the central public area. The two main buildings seem large clouds or sails inflated by the wind, or even translucent jellyfish that light up at night with LED lights between the enveloping skin (perforated) and the rear closure. The exterior skin consists of a system of PVC fabric with a micro-mesh (Serge Ferrari FT381) that allows a varied perception of surfaces, of different colours in a palette of light blues and sand tones, depending on the different incidence of the light on multiple inclinations of the sheets, as well as on the back-lighting by night. There will also be large writings near the entrances. The system is supported by a framework of steel rods and steel struts fixed to the structural portals in glulam behind.

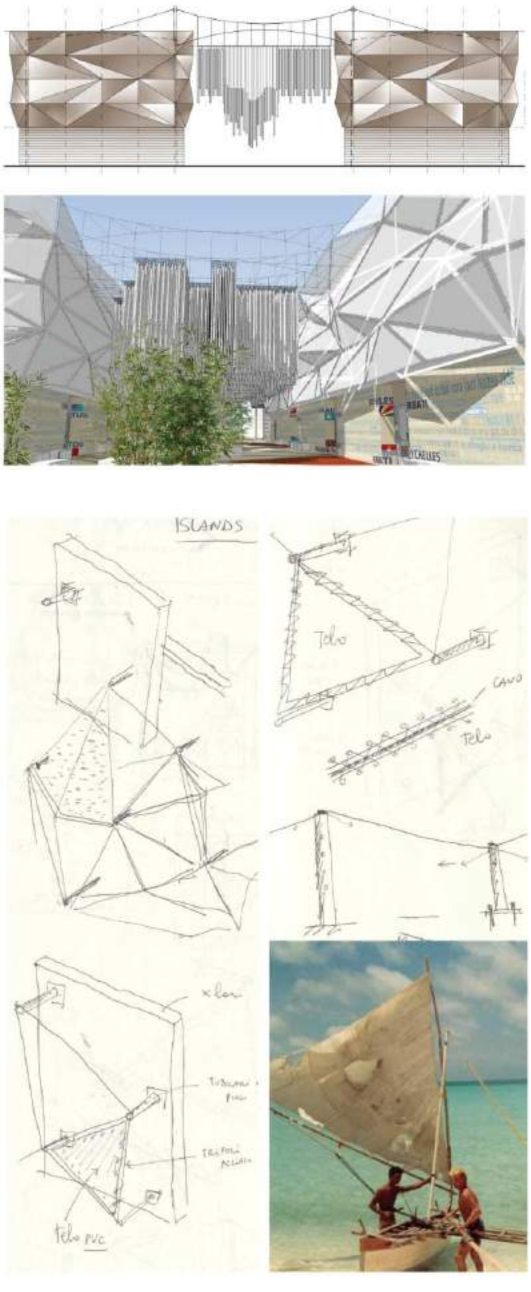


Figure 13. External skin concept

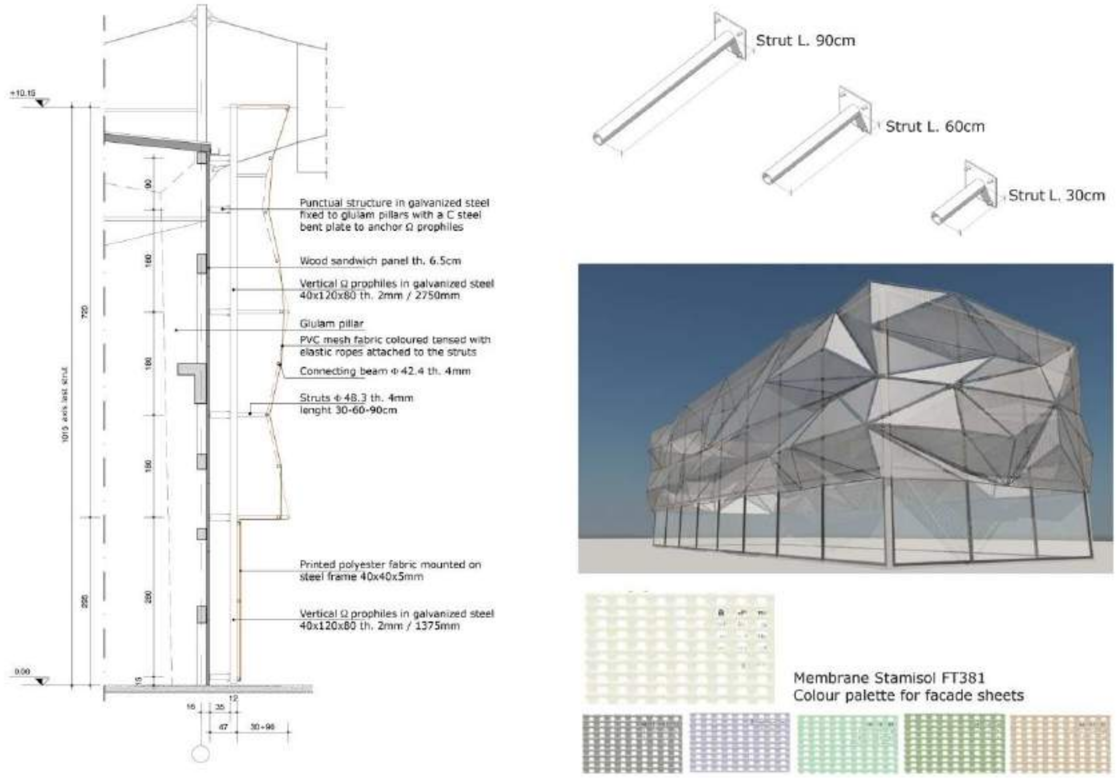


Figure 14. External skin final proposal

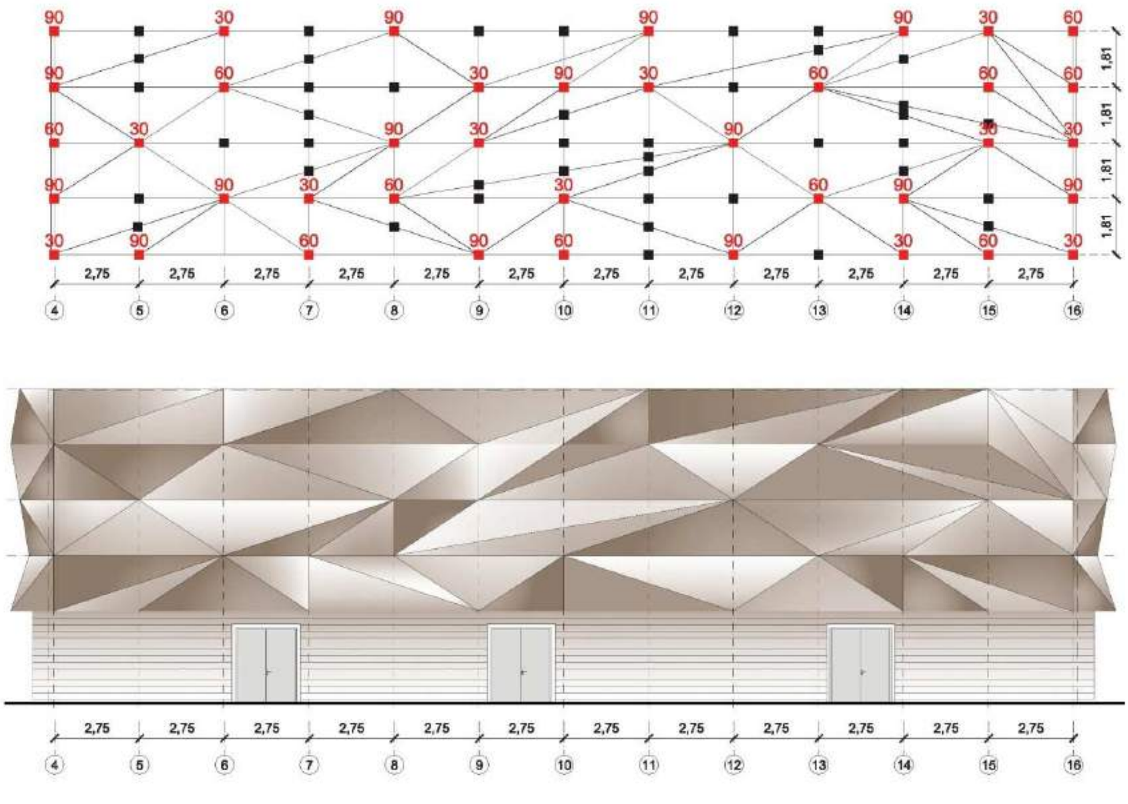


Figure 15. Façade design - structure and cladding

The interior is characterized by a plasterboard ceiling that leads the light (via “bright volcanoes” with portions finished with reflective strips) towards exhibition points, thanks to the zenithal light coming from the skylights. Entering the two pavilions, visitors will feel like “Pinocchio in the belly of the whale to return to the surface freed from a Tuna“ as in Collodi’s fairy tale. The artificial lighting will be both concentrated in areas dedicated to individual countries and diffuse: it could be integrated in the ceiling shaped in “volcanoes of light”, in the flat portions in contact with the outer walls but also in some of the “light chimneys”.

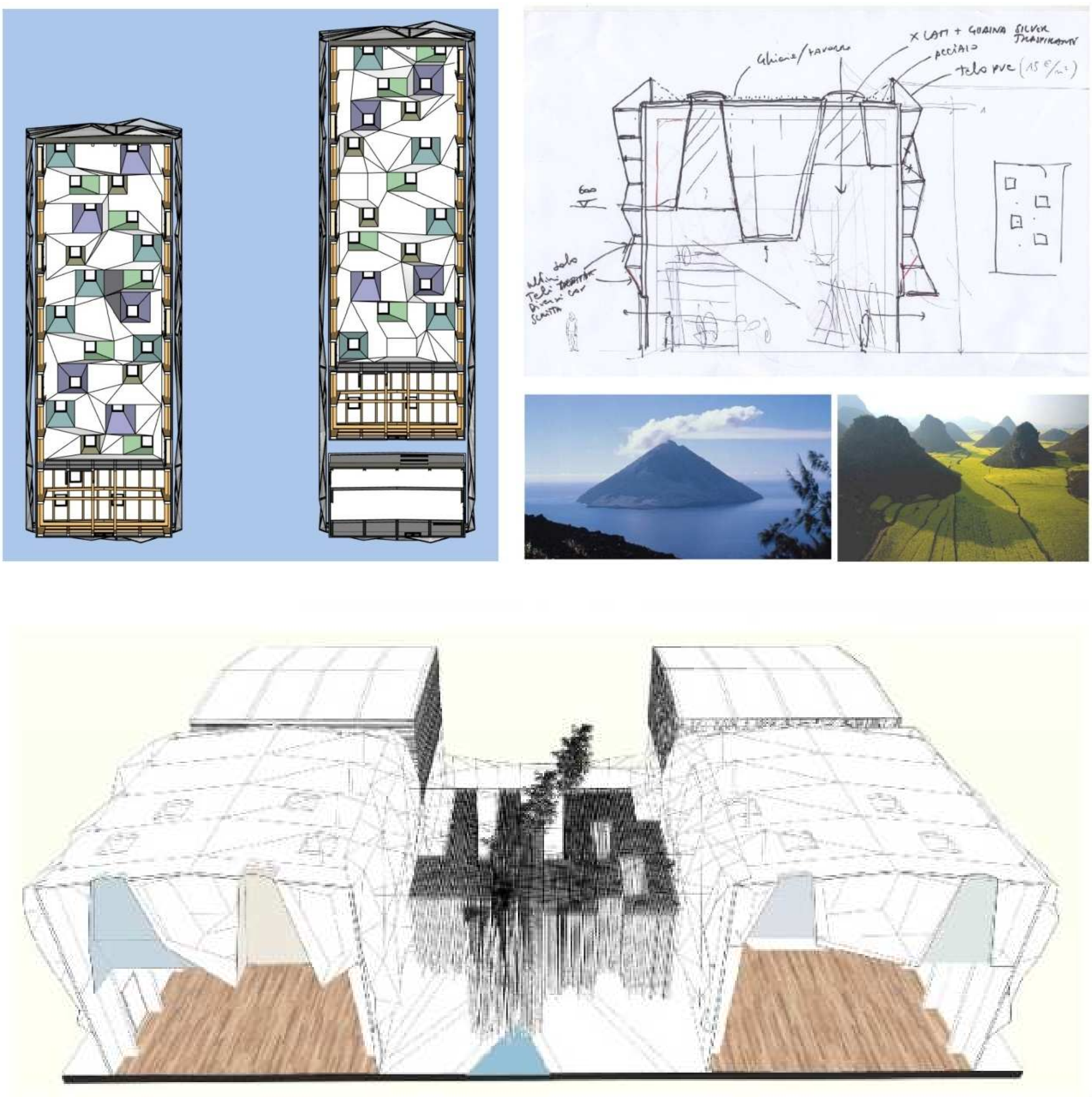


Figure 16. Volcanoes of light - Inspirations and design

Simulations were conducted to verify the effectiveness of the natural lighting system.

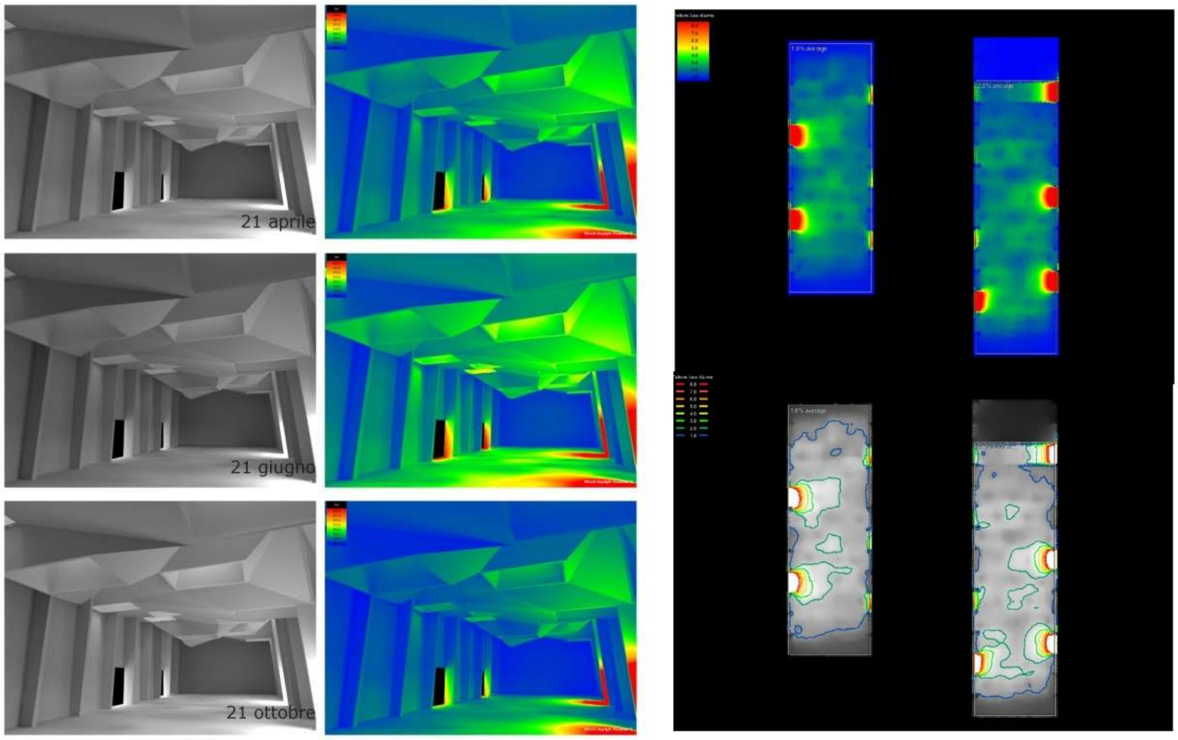


Figure 17. Daylighting - Pavilion EST Sky partly covered and Daylight factor (DLF)

In overcast conditions you may encounter high levels of illumination of the entire exhibition space with uniform illuminance values which are close to 250 lux. You can then verify the effectiveness of “Volcanoes of light” even in less favorable weather conditions.

The simulations allow to detect good values of fmld with a homogeneous distribution of the light below the “Volcanoes of light” even though these elements are punctual. It then verifies the correct operation of the false ceiling in spreading the direct light.

The two outdoor spaces dedicated to events (shows and restaurants) are inspired by the wicker baskets or by pots of natural woven fibres. The space devoted to the performances is characterized by a twine of fishing and aquaculture nets, variously coloured, which are fixed to a wooden structural system supported by the main load-bearing frames. Similarly for the restaurant, the twine is obtained using coloured fishing ropes.

Figure 18. External view of the cluster

All exterior floors are made of draining concrete (such as i.idro Drain by Italcementi), full-body coloured. Different colours will allow the design of the network of lines inspired by the bamboo Polynesian nautical maps. A system of recessed lights on the ground mark the paths leading the visitor to discover nocturnal cluster, as well as the constellations led sailors to their destinations.

Instead, the interior floors will be of bamboo strips, very durable, and dry-laid floating, with a finishing highlighting the culms.

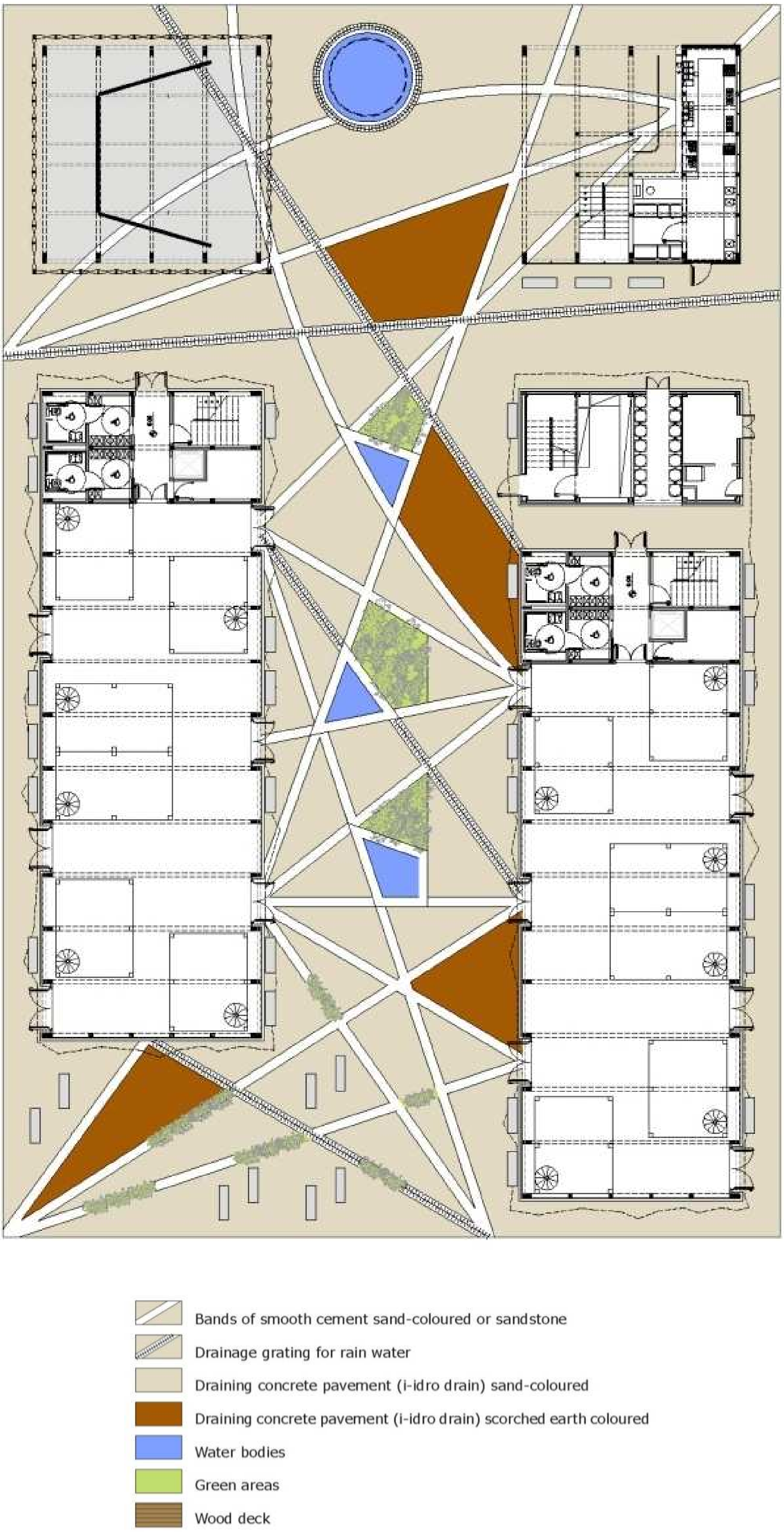


Figure 19. General plan of the cluster

Between the two pavilions is organized the space for the scenographic exhibition set-up. The real bamboo forest from the ground meets a “suspended forest of bamboo”, hanging on steel catenary collaborating with the main bearing frames of laminated wood of the buildings. This forest, metaphysical, is able to screen the solar rays creating a protected microclimate. The catenaries hang welded mesh in which nodes are suspended about 7,500 bamboo rods (diameter 5 cm, lenght 3,00 / 3,50 / 4,00 m). These may fluctuate and touch each other, creating an ancestral sound, a low frequency stroke, alternating with high frequency ringing of jangling metal fishes (BAM design) suspended in banks over bodies of water from which vaporize refreshing clouds. The pools are derived from the design of the ground floor at ground level (3 ponds) or rise (1 pond) as in the case of the circular fountain dedicated to aquaculture. Not being allowed to have live fish, some lights will light up intermittently at night (like the glow caused by the moon on the bellies of fishes) as a “ringing bank of fish” will be high above the bowl so as to ensure the dramatic effect during the day (accompanied by the tinkling) and the night by a dedicated lighting.

Between the two main pavilions, from above, at night, fall also bright LEDs “tentacles”, reminding jellyfish or squid, which make the space reminiscent of the mysterious and fascinating depths of the sea, the Nautilus, Captain Nemo …

Figure 20. View of the bright tentacles

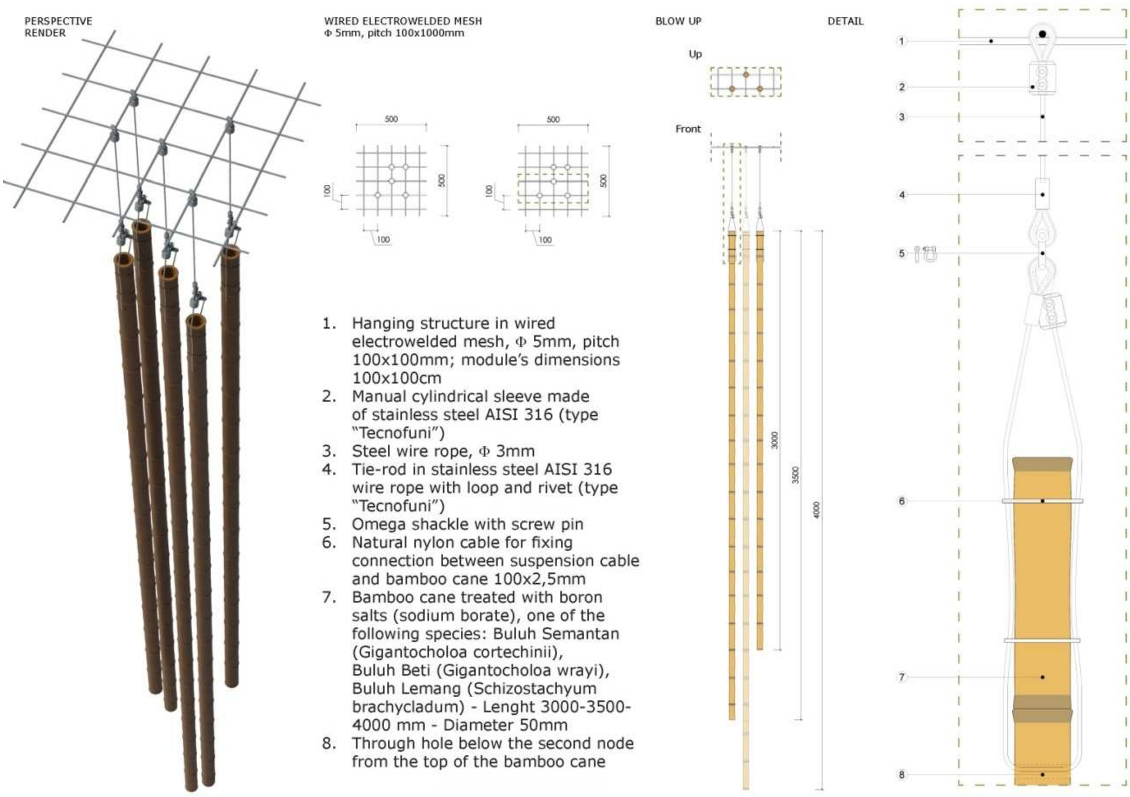


Figure 21. Detail of the suspended bamboo

A full-scale model was set-up to test different lighting layouts and effects with different types of LED lights

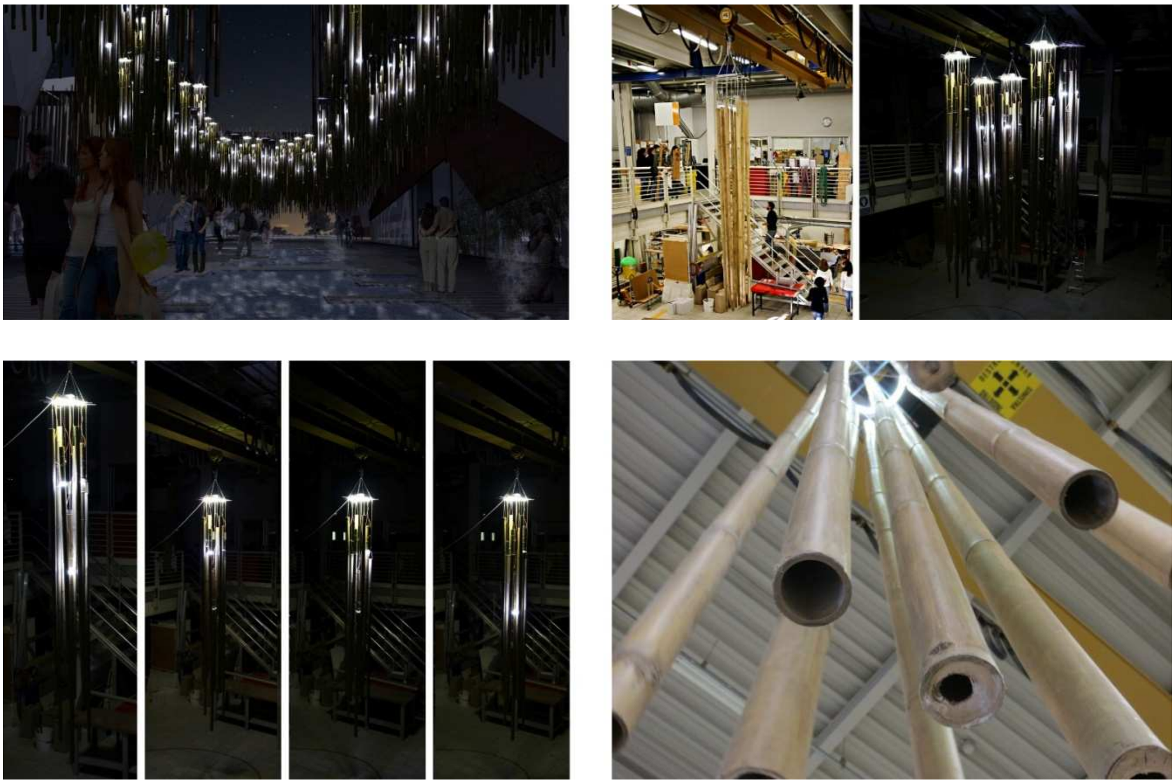


Figure 22. Full-scale model of the suspended bamboo

The outdoor area features benches and resting places along the entire perimeter close to the large pavilions. This allows to take advantage of the first three meters at the base of the facades for all the graphics and explanations of the contents of the cluster. With different fonts and different languages will be explained many concepts related to the topic of the cluster in the form of slogans, quotes, evocations, but also in a more narrative and argumentative way. The writing will be at various scales to be read by near or far and the colours will be in shades of white, blue and green water on sand-coloured background. This sort of “sea of information” will then alternate writings with a fish silhouettes (design Guido Scarabottolo).

The visitor can then choose to walk the Rhythm of Discovery being guided by the wonder and discovery, reading at a distance writings which emerge from the transparency of real bamboo and under the shade of suspended and resounding bamboo. Or get close to the pavilions and rest, and then read more carefully the small-scale writings and graphics explaining all the complexities and the opportunities and risks related to the delicate marine ecosystems, to human impact and to the equilibrium arisen over the centuries on the islands and on their livelihoods.

As required by EXPO, the entrances boxes will be marked by graphics displaying the name of the participating country and its flag. The name of the country will also be extended toward the front facade as well as in large-scale on the PVC sheets of the upper portion of the facade.

Given that the event space is equipped with power supply and sound amplification system, it will continuously transmit sounds to evoke the sea and the islands: the waves, the sound emitted by dolphins or whales, seagulls, the wind. These sounds of quiet and relaxation will alternate with musical moments with music typical of the host countries. This type of communication is different from the sound of life happening which will gradually be proposed in the event calendar of the pavilion.

Definitively the scenic and communicative design indissolubly unites architecture, construction, materials and functions so that the visitor is totally immersed in a unique experience, alienating and even relaxing in the hot and chaotic summer weather of EXPO in Milan. “An island of relaxation”, imagination and quiet in the great sea of the pavilions of EXPO 2015.

According to the design and to the guidelines of EXPO about the decommissioning of the area, different scenario of reuse “out of the site” or “on site” have been designed.

Re-use “out of site”: design proposals for re-using Clusters

Within the panorama of the possible re-use of the structures built for EXPO 2015 the possibility of a re-use “out of site”, shown in the previous section, led to develop different design solutions, producing a range of possible reuse of Clusters too. The Annex A) is the result of ipothesis made on functional re-use of Islands, sea and food cluster, developed by students of the course of “Innovazione e progettazione architettonica” and some undergraduate students of the Politecnico di Milano.

Figure 23. Building site of Islands Cluster: completion phases

Various design solutions have been developed without any constraints and they generated a lot of different solutions: from cold structure to passive building, from sports center to social housing. The choice of location, function and distributive or energetic-technological aspects have been produced by the study of the needs and demands of the territory.

The idea of the re-use “out of site” of the technological components of the Cluster was evaluated on the implementations that is necessary to achive the performance levels required. These levels concern structural, technological, energetic, lighting, sanitary, plans aspects etc.

From the functional point of view, the aim of the re-use of the eight moduls (125 sqm for each modul) that constitute Islands, sea and food cluster was reached in all the projects and just few solutions considered dimensional addition to the 1.000 sqm guaranteed re-using structure after the disassembly.

Structurally, the re-use of the 36 laminated wood frames implicated some adjustments related to the location and the functions. Stiffeners, bracing elements, reinforcements for the projection elements have been adopted in different shapes using various types of materials (wood and steel).

Figure 24. Cluster: laminated wood structure and standard modul

From the architectural point of view the total freedom of expression of the projects produced different solutions that use various technological solutions.

Technologically, to make an example about envelope, the idea of the re-use of the sandwich panels (OSB/PU/OSB) and increase, both internally and externally, their thermoigrometric performances asked to the envelope elements (roof and walls), or choosing to use only the structural frames and to design more technical walls, was originated by the function.

The technological aspect concerning the plant equipment, as well as having obvious implications on the constitution of the technological elements of transit, assuring the possibility of recycling the terminal devices, involved the renovation of the electrical systems and the integration of systems for the cold season.

The solutions for the second life “out of site” of clusters have been studied through holistic projects that don’t ignore real aspects of system or process organization that, in summary, are depending on function.

Since the latter depend adjustments in various fields of architectural and engineering design that can diversify the operation of re-use "out of site" in relation to the requests and needs, producing both an environmental and economic advantage of saving.

Re-use "on site": design proposals for "spaces" renovation

The configuration of the solutions post EXPO led to the formulation of different and evolving scenarios. But in particular, the idea of re-using in site a big part of the structures that are already on site could facilitate the process of re-occupation of the area dedicated to EXPO, even partially. As it was shown in the previuos sections, between the end of the event and the overall reorganization of the area, going though Fast Post scenarios that allow to not frustrate reached results (in terms of maintenance and construction), the progressive renovation of the area and the guidelines for possible development scenarios were hypothesized somehow from previous studies (see for example the document "ex-post - Converting, Recover, Reuse, guidelines for the preparation of the project proposal, Annex 2 - Masterplan and guide lines for preparation of the project proposal").

The site has been divided into areas that will be bequeathed to the city and left permanently, Cascina Triulza and garden, Italian Pavilion and water square, Collina Mediterranea and triangular square, Oper Air Theatre, Cardo and Italia square and West Access and inclined square. On remaining areas, as well as the development of the thematic park, are allowed functions related to the equipment and public services or general interest of the municipality also owned or managed by private, and tipical functions of the city, like residences, also in council or social housing, and similar functions including average sales structures.

The event area is divided in three executive areas: A, B e C.

Figure 25. Ambiti Esecutivi (source: Arexpo S.p.a. (2014), " Masterplan and guidelines for preparation of the project proposal".

For the area, that contains the West Access and inclined square and Cascina Triulza and the garden, and for the Area B, free from already identified areas, the real function is rather uncertain, instead

for Area C have already been drawn up proposals for action, primarily devoted to the theme park and "city of sport".
Starting from these last proposals, it has been developed, like a startup of some students' of Politecnico di Milano thesis project (mentor Prof. Marco Imperadori) a masterplan hypothesis to renovate area C.
This portion of area was designed considering the renovation of the spaces and buildings born to be re-used on site (Italian Pavilion and water square, Collina Mediterranea and triangular square, Open Air Theatre, Cardo and Italia square) and including in the general masterplan also the re-use of some Clusters in their actual location (Biomediterraneum, Islands, Arid Zones), services buildings and some Self-Built Pavilions (Israel, Japan, Brazil). For the last two categories of buildings it was be assumed both a renovation of the structure in the same actual position and through the disassembly and reassembly on construction site, giving the possibility to re-use structures located in some areas in B and C areas that have to be vacuated for future uses.
This solution was better analyzed in Annex B.
In summary, the proposed solutions aims to improve the services equipment (according to guidelines) already present in the spaces next to the Cardo, looking for a good balance between green/open and built spaces that could be be built to support the intended use residential developed on EXPO site (potentially in areas A and B) and in the neighboring areas of the municipalities of Rho and Milan.

1.2 Focus on technical textiles and membrane structures

di Alessandra Zanelli

In spite of tensile structures of the mid Fifties, we can refresh the meaning of *textile architecture* for those buildings where technical textiles play a significant role, both from a structural and esthetical point of view. Actually *textile architecture* can now rely upon a large variety of technological and constructive methods as well as a diversified range of fabric material and non-woven films. The nature of the definition of *textile architecture* aims at emphasizing the innovative properties of the applications of fabric materials in architecture and this is enhanced by a number of manufacturing technologies that are currently being tested as well as a renewed interest by the designers community towards light structures. In addition to the most common multi components membranes such as polyester/PVC and fibreglass/PTFE, the younger glass/silicone membrane is characterised by greater tensile resistance which is typical of fibreglass materials with the addition of properties typical of silicone such as waterproofing, fire resistance and malleability. This last quality facilitates the seam-welding of the fabric cloths at the manufacturing factory; the process consists in the application on the edges of the fabric of a sort of bi-adhesive strip with a silicon base; this makes the folding, storing and assembling process much less problematic.

The architecture made of textiles has born as temporary architecture, while currently it has been more and more assuming the form of permanent buildings. Technical textiles would be suitable for temporary buildings thanks to:

- their lightweight;
- the short chain from production to delivery and installation;
- as they are easy to handle and easy to dismantle,
- as they seem to be cost effective, if compared to other building systems.

Focusing on the end-of-life scenario, we can distingue the technical textiles used in architecture in two main groups.

In the first group each woven fabric is protected by a coating layer which has very different chemical characterization than the fabric itself: this means that the process to split them out at the end of their service life, is an high energy demanding process.

In the latter group, and one hand we can see the only one fabric on the market which is made of PTFE expanded filaments and then coated by PTFE itself; that means a membrane made of by

Tenara® is, in principle, 100% recyclable. The ETFE foils are not fabric, but films, which are produced through lamination process of ETFE pellet, and then they even are fully recyclable.

	Multi-component products			**Mono-component products**	
Coated/woven fabric	**PVC coated/ Polyester**	**PTFE coated/ fiberglass**	**Silicon coated/ fiberglass**	**PTFE coated /PTFE fabric (Tenara ®)**	**ETFE foil**
Resistance weft/warp [KN/m]	115/102	124/100	107/105	84/80	3/5
Fabric weight [g/m^2]	1200 [tipo 3]	1200[tipo 65]	1100	670 [tipo 1]	350
Trapezoidal Tear weft/warp [N]	800/950	400/400	960/700	925/925	450/600
Traslucency [%]	10-15	10-20	< 80	19-38	95
Folding Resistance	Alta	Bassa	Alta	Alta	Bassa
Fire resistance	M2 [NFP92503] B1 [DIN 4102]	M1 [NFP92503] B1/A2 [DIN 4102]	A [ASIM E-108] Nessuna tossicità dei fumi	M1 [NFP92503] B1/A2 [DIN 4102]	A[DIN 4102]
Dirt resistance	Low Medium (with PVDF top-coat)	High	medium	Medio-alta	Alta
Aging resistance	Low Medium (with PVDF o TiO_2 top-coat)	High	Medium-high	High	High
Average life (years)	10 15 (with PVDF)	30	20	30	30
Fabric panels conjunction method	High frequency welding	Hot bar	Hot bar with adhesive tape	Hot bar or high frequency welding	Hot bar
Recommanded use	Temporanee, Stagionali, Retrattili	Permanenti	Permanenti	Permanenti Retrattili	Permanenti
Structural systems compatible	Tensile structures Pneumatic structures	Tensile structures Pneumatic structures	Tensile structures Pneumatic structures	Tensile structures Pneumatic structures	Mono-layer framed film, Multi-layered cushions (façades, roofs)
Structural systems not compatible		Retractable, Seasonal systems	Retractable, Seasonal systems		Retractable, Seasonal systems
Cost	Basso	Alto	Alto	Alto	alto
Recyclability	100% of Poliester fabric through Texiloop process; 100% PVC coating through Vinyloop process			100%	100%

Table 1. Comparison of the most wide-spread technical textiles, their recommended use in architecture, their main performances and their life-span (elaboration by the author from: Bögner-Balz Heidrun, Zanelli Alessandra edited by, Ephemeral Architecture. Time and Textiles, Proceedings of Tensinet Symposium 2007, 16-18 April 2007, Politecnico di Milano, Clup, 2007, p. 42 and from: Zanelli Alessandra edited by, Progettare con le membrane, Maggioli, Rimini, 2007, p. 245).

In the field of membrane structures, since 2004 a significant role has been played by the TensiNet European Association, which is promoting the use of membrane structures to improve the quality of the built environment.

Another on-going networking instrument is the European COST Action TU1303, entitled *Novel structural skins: Improving sustainability and efficiency through new structural textile materials and designs* (2013-2016), of whom partners are developing new forms, new structures, new ways of use of technical textiles in architecture, taking into a special account the task of sustainability and LCA approach.

Other important tasks for managing temporary membrane structure in the best way are:

- updating on the development of a specific EuroCode for the design and installation of permanent membrane structure;
- weak points and some lack of knowledge in the current UNi-EN code on temporary membrane structures.
-

+ *Table*: Which kind of building systems we can effort by technical textiles, for which kind of application and for which kind of service life: emergency shelters, temporary buildings, free-form, large span covering systems, textile facades; fluoro-polimeric facades; pneumatic systems.

The challenge of the lightness and temporariness in membrane structures: it deals with two main aspects:

1. The way to design and build the foundation of the structural system; focus on temporary foundation elements;
2. the way to design the connections: easy to transport (design of packaging) and easy to install and dismantle more times (design for disassembling);
3. the way of trusting in the lightness of the materials; focus on the role of the sub-structures in textile facades.

Case study: Temporary as portable use

Figure 26. Frei Otto Design: two floors contemporary nomadic tent; aluminium structural frame and double layered transpirant fabrics.

Case study: Temporary as ephemeral use

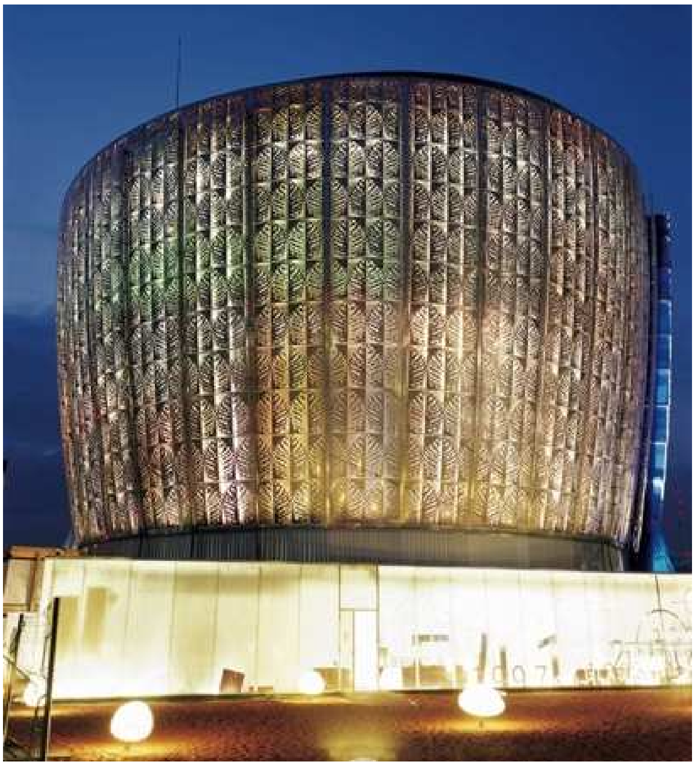


Figure 27. ETFE cushions, Dual System, EXPO Hannover.

Case study: Temporary as seasonal use

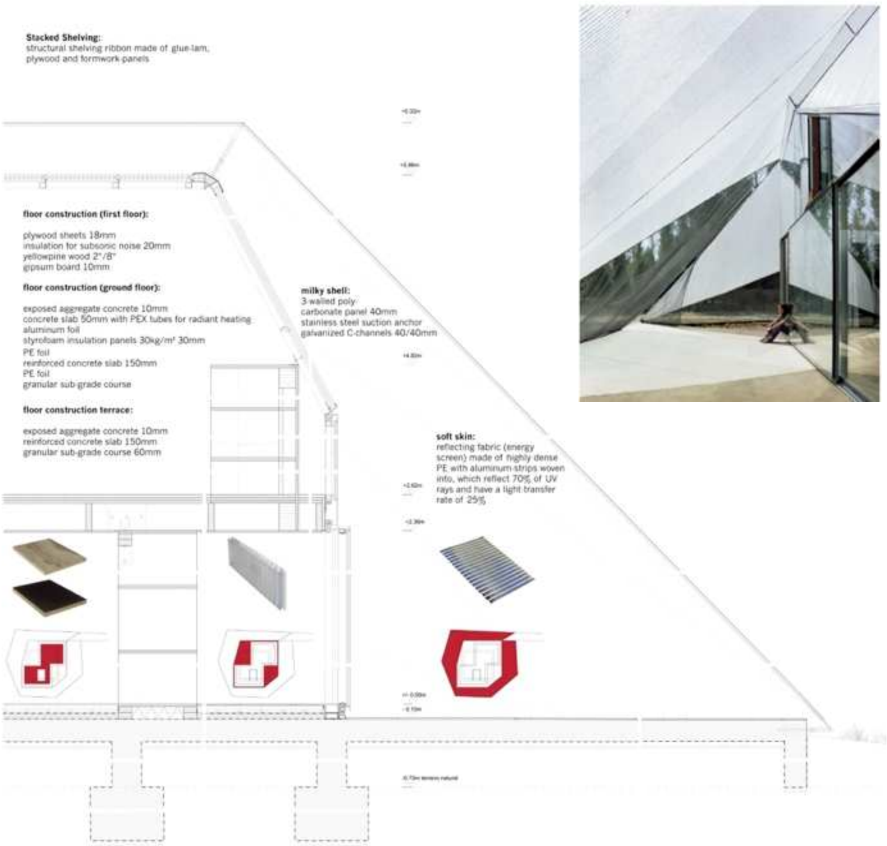


Figure 28. Adaptive skin made of textiles and nets. FAR Architects, Vertical section of the Wall House and a view of the open air perimeter protected by the soft textile skin (Source: Courtesy FAR Archives)

Conclusions

- Lightweight materials does not necessarily mean lightweight buildings; even visual lightness is a part of the same problem.
- Temporary buildings need a coherent system of removable foundation, as ballast or other pre-fabricated base elements
- Further development in BIPV on textile-based buildings.

References

Campioli A, Mangiarotti A, Zanelli A (2008) Textile Architecture in the Italian Context. In: The International Journal of Space Structures. 23(4): 201-206

Huntington CG (2004) The tensioned fabric roof. American Society of Civil Engineers, Reston

Kronenburg R (1995), Houses in Motion. The Genesis, History and Develpment of Portable Building. Academy Editions, London.

Kuma K (2004) The Transitoriness of Objects, in Temporary. Lotus International, 122:34-49

Otto F (1984) Sun Sails of Roman Theatres in Institute for Lightweight Structures, IL30. Vela Toldos Sonnenzelte Sun and Shade, n. 30. Druckerei Heinrich Fink KG, Stuttgart, pp 9-88

2. LCA methodology for temporary buildings

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Introduction

The purpose of this chapter is to provide rules for the assessment of the environmental performance of temporary buildings in mega events. The target group could be the mega event organization and/or the LCA practitioner involved in the LCA assessment of the temporary buildings.

Given the buildings short service life during the event (Expo events typically last for 6 months, Olympic games for three-four weeks), the strategies for their end of life after the event are of great importance for the environmental impacts reduction. So, starting from the international standards on LCA of buildings, LCA methodological proposals on the definition of the systems boundaries and on the allocation of impacts related to end of life scenarios was developed specifically for temporary buildings.

Temporary buildings: a definition

Temporary buildings for mega events are buildings with a short service life strictly related to the event duration.

A critical first step for the development of the methodology for assessing the environmental performance of temporary buildings in mega events is to define the types of temporality associated with the mega events and the possible end of life scenarios, correlating them with constructive and technological design solutions.

With the aim of the mitigation of environmental impacts, it is clearly unsustainable designing disposable temporary buildings; instead the temporary nature must be designed as the possibility of extending to more uses and more lives the constructed object.

In the first two cases, the temporary nature of the building shall be a requirement in the design phase, an upstream objective of the project, since it requires the project to deal with the functionality of the second life and with technical characteristics that allow the reuse.

In this perspective, the temporariness of the buildings related to mega events, can be defined as: (1) temporary placement/location (with the disassembly and reassembly of the entire structure or of its parts separately elsewhere at the end of the event); (2) temporary function (with the refunctionalization of the structure for a new use at the end of the event); (3) temporary life (with the demolition at the end of the event and waste treatment without reuse of the building parts).

In the first two cases, the temporary nature of the building shall be a requirement in the design phase, an upstream objective of the project, since it requires the project to deal with the functionality of the second life and with technical characteristics that allow the reuse.

The temporary placement consists in the construction of temporary buildings, for example for exposition purposes as in the case of the Expo, which are then disassembled and relocated to meet the new requirements of use. A recent example of temporary placement is the Christ Pavilion designed by von Gerkan, Marg und Partner for the Expo 2000 in Hannover, and relocated to Volkenroda.

The temporary nature of function is characterized by the construction of permanent buildings, in which are allocated temporary functions during the event and that are functionally reconverted after the event, with a target useful to society. An example of a temporary function is the Turin Olympic Village, built for the 2006 Winter Olympics in order to accommodate delegations, and converted at the end of the event in social housing.

In both cases, the temporary nature must be thought in the design phase, so to be an upstream objective of the project, since it requires the project to deal with the functionality of the second life. Moreover, the objective is the realization of a structure used temporarily for the event, but physically durable and reused after the event.

Thinking about a “durable” temporariness, which is guaranteed by the extension of the useful life of the building, is a sustainable objective, not just from an environmental perspective, but also social (because it allows you to create useful equipment for the society), and economic (by enhancing the use value and the economic potential value of the structure).

The possible scenarios at the end of the first use (after the event) of the temporary building are: (1) reuse of the whole building for a similar/compatible use (refunctionalization without modification) in the same place; (2) reuse of the whole building for the same use in another place (relocation); (3) reuse of the whole building for a different use (refunctionalization with modification) in the same place; (4) reuse of the whole building for a different use (refunctionalization with modification) in another place (relocation); (5) disassembly of the building and reuse of the divided building components for the same use; (6) disassembly of the building and reuse of the divided building components for other use; (7) demolition of the building and disposal/energy recovery/recycling of building materials. Partial reuse is also possible, with a mix of the previous scenarios.

Clearly, these different scenarios have different environmental and economic value associated with them and in the case of the temporary nature it is important to spread the scenarios of reuse.

But the actual feasibility of the different scenarios basically depends on the technical and material choices of the project (construction with mechanical connections dry assembled, constructive reversibility and separability of materials, use of recyclable materials, etc.).

In relation to the solutions used in the project is thus possible to delineate the possible end of life scenarios and to associate the corresponding environmental impacts.

The purpose of the assessment

The purpose of the assessment is defined by the goal, the scope and the intended use of the assessment.

The goal of the assessment is to quantify the environmental performance of the temporary building (object of assessment) by means of the compilation of environmental information. In order to calculate the environmental performance of the building in terms of environmental impacts and aspects, the scope and intended use of the assessment shall be defined and documented.

The scope of the assessment is represented by what is included in the assessment with respect to the specifications of the object, i.e. the temporary building, to the quantification of the building and its life cycle, to the type of data. In particular, the scope and the intended use determine the level of detail required of the environmental information, and of other data used in the calculations. However, the calculation method remains the same.

Depending on the context, the intended use of the assessment may include the following alternatives: (1) assistance in a decision-making process, for example: (a) comparisons of the environmental performance of different design options for temporary buildings (e.g. alternative materials, products, technical solutions); (b) comparisons of the environmental performance of the different scenarios post-event of the temporary building (e.g. demolition and reconstruction, relocation and reuse of the building in another place, on site refunctionalization of the building); (c) identification of the potential for environmental performance improvements; (2) declaring performance with respect to legal requirements or for acquiring access to incentives (e.g. Green Public Procurement, minimum requirement in a tender); (3) documenting the environmental performance of a building for use in, for example: (a) certification/labeling of the building (e.g. LEED, EPD of the building); (b) declaring environmental performance (e.g. award for sustainability of the organizer of the mega event); (c) marketing; (4) support for policy development.

A simplified LCA assessment (screening) should complement the design already during the preliminary phase, the concept design, in order to make a rough estimate of the environmental performance to guide the design choices. With the evolution of the project, the assessment may be revised and updated to support decision making. Once the building is built, the LCA (detailed) should be performed based on the documentation for building (as-built) and EPD certification of product; the evaluation results detailed LCA can be used to realize a certification of building and for communication.

The degree of detail in the data collection and the level of detail between hypothetical assumptions and monitoring of the construction may affect the LCA results: for this reason the phase in which the LCA is developed shall be stated (ex ante or ex post). In case the LCA is prepared in advanced, it is strongly recommended to monitor the data (consumption of energy etc.) during the use phase or at least before the dismantling phase.

If the mega event organizer requires the development of an LCA during the design phase of the temporary buildings, to support the design and material choices, it could be recommended to update the LCA at the end of construction, by monitoring the changes from the initial project to the as-built and analyse and justify all the differences between initial assumptions and actual consumptions and emissions. This approach could be considered a strategic vision and a KPI (key performance indicator) of the quality of the project.

LCA of buildings: standards and references

To set an LCA of buildings there are different regulatory references, developed at the international (ISO) and European (CEN) level. European ones are newer and more "evolved", so that the ISO standards are gradually adapting to these. In all standards recurs two levels of evaluation: the scale of the building and the scale of the building product. In fact, in order to make a proper LCA of a building is necessary to know the environmental profile of the products used and, if possible, to know the actual profile of the specific product used (LCA with primary data instead of LCA from the databases). In fact, in the building sector, who are responsible of the environmental impacts and of the application of strategies for the containment of the impacts, are on one hand the designers, who are responsible for the characteristics of the building and therefore for the impacts generated in the use phase, and the manufacturers of equipment and components, which are responsible for the characteristics of the products and for the processes of procurement of raw materials and of production. Obviously the designers (and constructors) also have the responsibility to choose the materials of which the building is done, so to be the market demand that can be the driving force for a competition among producers. But without a proper environmental information which accompanies the marketing of products, this conscious choice by the designers can hardly be implemented. Hence the need to create standards for the LCA of buildings based on environmental certification of products (EPD, Environmental Product Declaration). The EPD is a product certification that communicates in a transparent way the LCA results of product evaluation. The EPD is a certification recognized not only in Europe, but also internationally, because the reference standards are international (ISO and CEN). Currently, in Europe, is being discussed on making this certification directly related to CPR (Construction Product Directive), which requires for the marketing of products on European soil the presence of a certification of core benefits guaranteed by the product (eg. mechanical resistance, thermal resistance, acoustic resistance, etc.). Among the others essential requirements, also that of sustainability has been identified; but currently there is a lack of rules for the verification of such a requirement, so it is not yet applied. Discussions are ongoing to get the EPD certification as reference for the requirement of sustainability by CPR.

Building level
EN 15643-1:2010 Sustainability of construction works – Sustainability assessment of buildings – Part 1: General framework
EN 15643-2:2011 Sustainability of construction works – Assessment of buildings – Part 2: Framework for the assessment of environmental performance
EN 15643-3:2012 Sustainability of construction works – Assessment of buildings – Part 3: Framework for the assessment of social performance
EN 15643-4:2012 Sustainability of construction works – Assessment of buildings – Part 4: Framework for the assessment of economic performance

EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method
EN 16309:2014+A1:2014 Sustainability of construction works – Assessment of social performance of buildings – Calculation methodology
Product level
CEN/TR 15941:2010 Sustainability of construction works - Environmental product declarations - Methodology for selection and use of generic data
EN 15804:2012+A1:2013 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
EN 15942:2011 Sustainability of construction works - Environmental product declarations - Communication format business-to-business

Table 1. CEN standard for the LCA of buildings

Building level
ISO 15392:2008 Sustainability in building construction - General principles
ISO/TS 12720:2014 Sustainability in buildings and civil engineering works - Guidelines on the application of the general principles in ISO 15392
ISO/TR 21932:2013 Sustainability in buildings and civil engineering works - A review of terminology
ISO 21929-1:2011 Sustainability in building construction - Sustainability indicators - Part 1: Framework for the development of indicators and a core set of indicators for buildings
Product level
ISO 21930:2007 Sustainability in building construction - Environmental declaration of building products

ISO 21931-1:2010 Sustainability in building construction - Framework for methods of assessment of the environmental performance of construction works - Part 1: Buildings

Table 2. ISO standard for the LCA of buildings

In the international technical documents and standards (ISO 2006; CEN 2012; EC-JRC 2011) the procedures to allocate environmental impacts between first and second life, whether materials/components are reused or recycled, are clearly afforded, even though on a general basis; moreover, many different views of the topic can be found in the recent literature, where goods value is taken into account as well (Nicholson et al., 2009; Pertl, Obersteiner, Salhofer, 2011; Wolf, Chomkhamsri, Ardente, 2013). However, accepted rules with respect to the specific case of buildings are lacking, especially when dealing with temporary ones.

The extension of the system boundaries: first use and second use

LCA of temporary buildings requires quite a number of assumptions and clarifications: unlike "permanent" buildings (CEN 2011), in temporary structures the focus is not on the operational phase, but on the materials and components production and the end-of-life. In the majority of the present studies on buildings end-of-life (Thomark, 2001; Thomark, 2002; Blengini, 2009) the attention is mainly devoted to recycling and to reuse of "long-life" buildings; so all the impacts are allocated on the first life and all the environmental benefits are attributed to the second life.

In devising the methodology for temporary structures our major concern was increase the awareness of architects and designers as well as of policy makers about environmental impacts associated with specific project choices, and so point out possible strategies to reduce the environmental load in the entire life cycle. As a consequence, the best strategies for reducing the potential impacts stem from the selection of low-impact materials (e.g. recycled products) and to improve the reuse and recycling at the end of life.

In the methodology special care has been paid to allocations procedures for the end-of-life scenarios (after the event) in order to improve project choices aimed at recycling materials from temporary structures dismantling and at favouring construction reversibility and structure reuse, giving this way a second life to the entire pavilion structure or at least to some of its components.

With the aim of the reduction of environmental impacts, it is clearly unsustainable designing disposable temporary buildings with a short service life; so the strategies for the extension after the first use in the mega event were considered of great importance. Instead of designing a temporary service life, the temporary nature should be designed as the possibility of extending the constructed object to more uses, expanding its service life.

For this reason the proposed methodology provides for an extension of the system boundaries that considers as the useful life of the building both the first use (during the event) and the second use (after the event). If the temporary building is demolished at the end of the mega event, the reconstruction of a second building with the same characteristics of the temporary building constructed for the event shall be assumed.

Following are the rules to take in count for the LCA of temporary buildings.

Functional or declared unit. The functional unit (or functional equivalent) shall be declared and shall include the relevant technical and functional characteristics of the building (e.g. the regulatory and client's specific requirements), the reference study period and the required service life of the building, the type of use (e.g. office, exhibition), the pattern of use (e.g. occupancy). The technological and functional requirements include, for example, the requirements of structural safety, fire safety, security, burglary, indoor air quality, adaptability, energy efficiency, accessibility, disassembly, recyclability, maintainability, durability, useful life of a building or the assembled system (EN 15643-2: 2011).

A common reference unit shall be used to present the result of the indicators of the environmental assessment relative to the functional equivalent. To allow different possible uses, the results shall be expressed: (1) per the entire building, (2) per m^2 per year (related to net floor area), (3) per m^3 per year (related to gross heated volume).

The LCA shall follow a "cradle to grave" approach, i.e. including all life cycle stages of the building, with a modular approach in the presentation of results (see Figure 1).

The object of the assessment is a temporary building with a first use related to the mega event and a second use after the mega event: the service life of the building is extended to the end of the second use.

Comparisons should only be made between buildings with the same function (in the first use and in the second use). A description of the type of use and pattern of use shall be declared also for the second use, specifying in the scenarios if it is necessary a refunctionalization of the building.

Reference study period. Assessment shall be carried out on the basis of a chosen reference study period, the same for all the assessments, so as to ensure comparability of the results. The reference study period shall be of 10 years. The reference study period corresponds to the required service life of the building (see 4.2). According to EN 15978, if the reference study period is longer than the service life of the temporary building, scenarios for demolition and construction of an equivalent new building shall be developed. These scenarios shall provide for an extension of the service life which, when combined with the required service life of the object of assessment, is equal to or more than the reference study period. The full value of impacts and aspects for both the first use (during the event) and the second use (after the event) shall be taken into account.

Required service life. Temporary buildings shall cover a Required Service Life (ReqSL) of 10 years (according to Eurocode, the structural lifetime for temporary buildings shall be of 10 years), considering the first use during the mega event and defining a second use after the mega event.

If the temporary building (as a whole or divided in its components) is reused after the mega event, its service life is extended to the period of reuse.

If the temporary building is not reused after the first use, the production of another temporary buildings (with the same characteristics) shall be considered to cover the Required Service Life.

For example, if the temporary building is not reused after the six month of the first use during the mega event, the production of another temporary building (with the same characteristics) shall be considered to cover the others 9 years of the Required Service Life.

LCA results shall be reported according to the EN 15804 modules but also dividing the impacts between first use and second use. For the impacts not specifically related with one of the two use (for example the impacts related to the production of the building components reused), the impacts shall be divided considering the time of use and the time for construction-deconstruction. For example, in case of reuse of the material structure, if the first use of the temporary building related to the mega event is of six month during the mega event and three months for the construction and three months for the disassembly, the impacts related to the mega event are 1/10 of the total impacts of the building components reused and the impacts related to the second use post-event are 9/10 of the total impacts of the building components reused.

System boundaries. The system boundary includes the building in all its parts, the building-integrated technical system and the building related furniture, fixtures and fittings. It includes also the surrounding area of the building (and related paving, facility, green, etc.) during the first use.

The surrounding area of the building is excluded in the second use due to the fact that probably the area on which the building will be located during the second use is not already known.

Life Cycle Stages. The core process of assessment is the building. The assessment includes all the upstream and downstream processes needed to establish and maintain the function(s) of the building, in the first use and in the second use.

Figure 1 describes the system boundary and the different stages of the life cycle of the temporary building. The processes are divided into information modules (e.g. A1-A3, A4-A5) according to the "modularity principle" of EN 15978:2011. The organisation of the different modules used for the assessment of the building corresponds to the modular structure of information from EPD for construction products, processes and services according to EN 15804.

The environmental information shall be given for each module, and not only as an aggregated value (with the exception of Module A1-A3). The LCA of the building shall cover all modules in the stages A to C. Module D is voluntary and beyond the system boundaries.

The Module numbers are in compliance with the standard EN 15978:2011, but doubled to be referred to the first use and the second use. So, the reference "$_1$" means first use (related to the mega event) and the reference "$_2$" means second use (beyond the mega event). For example, "A_2 1-3 " refers to the product stage of building products necessary to the second use of the building beyond the mega event.

Not all processes are relevant for every type of temporary building: not all the type of temporary buildings cover all stages of the life cycle, so not all modules must always be considered.

Due to the short time of the first use of temporary building (mega events last less than 1 year), the maintenance activities that shall be considered are only the ones related to cleaning. The modules $B_1$3 Repair, $B_1$4 Replacement, $B_1$5 Refurbishment, considered in the EN 15978:2011, are not included because the period of time of the first use of temporary buildings in mega events typically is shorter than 1 year, so it is supposed that there is no need of repair, replacement and refurbishment.

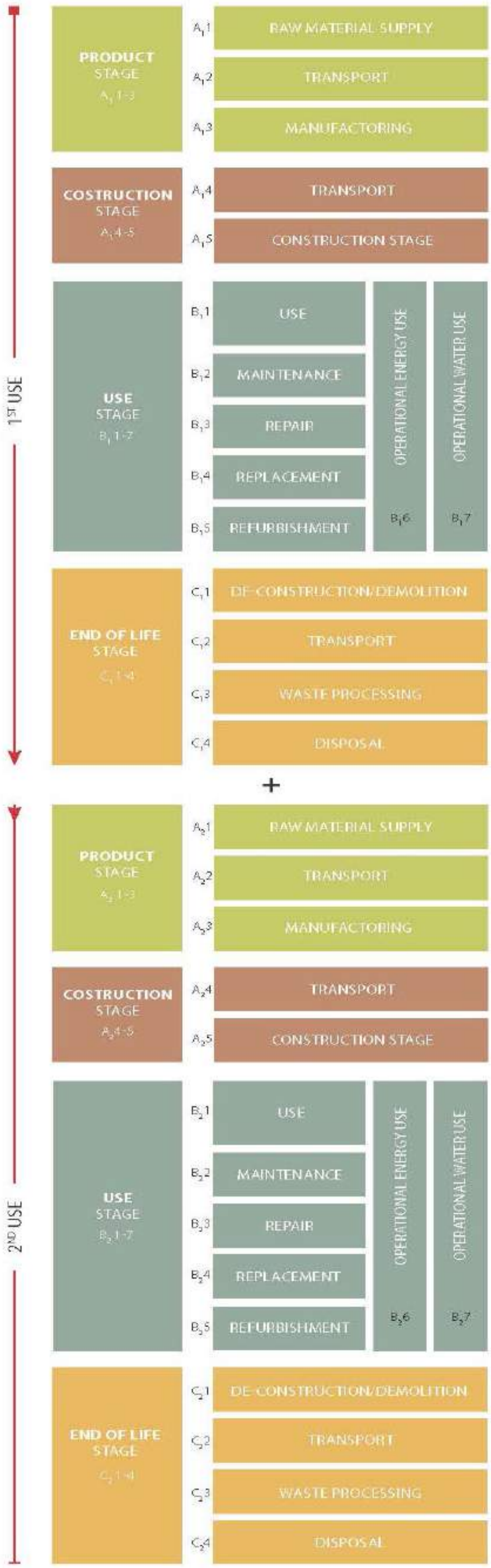

Figure 1. Building life cycle system boundaries, illustrated with EN 15978:2011 as reference

Deconstruction or demolition after the first use. At the end of the mega event, the deconstruction, dismantling and/or demolition of the temporary building shall be considered, including initial on-site sorting of the materials. The boundary of the deconstruction process includes on-site operations and operations undertaken in temporary works located off-site as necessary for the deconstruction processes after decommissioning up to and including on-site deconstruction, dismantling and/or demolition. At this point, the building's demolition or deconstruction may be considered as a multi-output process that provides a source of materials, products and building elements that are to be discarded, recovered, recycled.

Only if the building at the end of event is reused on the same site, deconstruction and demolition activities shall not be counted (unless it is necessary to repair or replace damaged or deteriorated parts).

The subsequent modules $C_1$2-$C_1$3-$C_1$4 and D_1 shall be considered only if the scenario at the end of the event (at the end of the first use) provides for the total or partial demolition of the building and the demolition waste are conferred to the sorting plant or landfill. They shall also be considered in the other cases, for those parts of the work that are not reused and are conferred to the sorting plant or landfill (e.g. foundations).

If the building is completely reused on site without replacement of materials and without integration of new materials, the modules $C_1$2-$C_1$3-$C_1$4-D_1 and $A_2$1-$A_2$2-$A_2$3-$A_2$4-$A_2$5 shall not be considered, unless for those components that should be modified or treated (e.g. cleaning), and the assessment continues from the modules $A_2$4-$A_2$5.

If the building is completely reused elsewhere (disassembled and reassembled) without replacement of materials and without integration of new materials, the modules $C_1$2-$C_1$3-$C_1$4-D_1 and $A_2$1-$A_2$2-$A_2$3 shall not be considered, unless for the components that should be modified or treated (e.g. cleaning) or replaced (e.g. foundations), and the assessment continues from the modules $A_2$4-$A_2$5.

In all the cases with partial replacement of materials, the modules $C_1$2-$C_1$3-$C_1$4-D_1 shall be considered for those materials that are demolished and transferred to the sorting plant or landfill and in $A_2$1-$A_2$2-$A_2$3 shall be considered the replacement of these parts.

For all the materials and components of the temporary building that, at the end of the event (first use), are demolished and conferred to the sorting plant or landfill, all transports to final disposal of the discarded materials and products and/or until the end-of-waste state is reached (e.g. to a recycling site), including transport to and from possible intermediate storage/processing locations (e.g. to a sorting plant), and all waste processing, including collection of waste fractions from the deconstruction and waste processing of material flows intended for recycling and energy recovery, i.e. waste processing until the end-of-waste stage is reached, shall be considered. Materials and components intended for reuse are excluded.

Second use (beyond the mega event). All flows of materials and energy that are necessary to "integrate" or "reconstruct" the building for the second use beyond the mega event shall be considered in the modules A_2 1-3).

Depending on scenarios such flows can be: (1) if the building, at the end of the event, is completely demolished and the materials are landfilled, all flows (energy and materials) needed to "rebuild" a building that meet the new use shall be considered (adding again the modules A_1 1-3 and any supplementary materials needed for the new function, to make the building suitable for a second use); (2) if the building at the end of the event is reused, the flows relating to any supplementary materials required for example in relation to a possible new location (e.g. foundations), the adequacy with respect to the change of function (e.g. insulating materials to improve the thermal performance of the building), the integration of the missing parts in the case of partial reuse of components or replacement of broken/deteriorated components after the first use, etc. shall be considered.

In the case where the reuse beyond the mega event concerns only components or parts of the building (and not the entire building), aimed also at different locations, the "reconstruction" of the building to the second use shall be considered, considering again all flows (energy and materials) of the modules $A_1$1-3 as if a new building covers the second use, and subtracting the components and parts of work that are reused, even if in different buildings from the reference one (as if they were “avoided flows”). If the components are reused for different uses, less qualified (downcycling), it is necessary to count the actual product avoided (e.g. re-use of a beam of laminated wood as a bench, subtract impacts avoided as if it were a solid wood).

In the case of reuse of components unaltered compared to the first use, these modules shall not be considered, unless the components should be modified or treated (e.g. cleaning).

Transport (second use). Depending on scenarios the transport to the building site can be: (1) if the building at the end of the event is completely demolished and the materials were landfilled, all transports shall be considered again using data from the module $A_1$4 (as the place of relocation is not a hypothesis of the project, it can be considered the same site of the mega event); (2) if the building at the end of the event is reused on the same site, new transport are not calculated; (3) if the building at the end of the event is dismantled and relocated elsewhere, the transports of all components of the building from the site of the first use to the site of the second use shall be considered.

In case of reusing of the components separately, in different buildings with different locations, for the evaluation the transports from the site of the first use to the site of the second use shall be counted, adopting different actual distances (if known) or one relative distance considering the building into which most of the materials are reused, "as if" it merges together all the components in a single building. If no distance of the new use is known, a distance of 100 km can alternatively be assumed. Any different assumption shall be justified.

In all cases, even the transport of any supplementary materials shall be counted (e.g. new foundation in the case of relocation elsewhere, or supplementary materials for the refunctionalisation or for the replacement of damaged parts).

Conclusions

It must be highlighted that the most critical aspect in the impacts assessment concerns the correspondence between potential reusability (and recyclability) and effective post-event reuse. Of course, the evaluation is always based on the assumption of an end-of-life scenario, but often there is no effective reuse, even if the project has considered the dismantling in doing specific choices, because a proper network of operators has not been created5. The proper consideration of the relationships between technological and managerial elements is particularly critical because the lack of "jointly" planning the end of life of a structure can prevent its effective recycling / reuse (for the same use or for other use), even in front of technological solutions that allow it5. For all these reasons end-of-life management aspects deserve a special analysis.

References

Blengini, G.A., 2009, "Life cycle of buildings, demolition and recycling potential", Building and Environment, No. 44, pp. 319-330.

Boons, F., Lüdeke-Freund, F., 2013, "Business models for sustainable innovation: state-of-the-art and steps towards a research agenda", Journal of Cleaner Production, No. 45, pp. 9-19.

Campioli, A., Lavagna, M., 2007, "Life cycle design in building and construction sector", in Life Cycle Management, 27-29 Aug., Zurich.

CEN, 2011, EN 15978, “Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method”.

CEN, 2012, EN 15804, “Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products”.

EC-JRC, 2011, European Commission - Joint Research Centre, “International Reference Life Cycle Data System (ILCD) Handbook. Recommendations for Life Cycle Assessment in the European context based on existing environmental impact assessment models and factors”, Publications Office of the European Union, Luxembourg.

Kohler, N., König, H., Kreissig, J. E Lützkendorf, T., 2010, “A life cycle approach to buildings”, Institut für internationale Architektur-Dokumentation, Detail Green Book, München.

ISO, 2006, ISO 14044, “Environmental management. Life cycle assessment. Requirements and guidelines”.

Lavagna, M., 2006, “Acciaio e disassemblabilità. Von Gerkan, Marg und Partner, The Christ Pavilion, Expo 2000 in Hannover e monastero di Volkenroda”, Costruzioni metalliche, No. 1, Jan-Feb., pp. 29-39.

Lavagna, M., 2007, “Lightness and Temporariness in Life Cycle Assessment”, Ephemeral Architecture. Time and Textile, Tensinet Symposium 2007, Libreria Clup, Milano.

Lavagna, M., 2008, “Life Cycle Assessment in edilizia. Progettare e costruire in una prospettiva di sostenibilità ambientale”, Hoepli, Milano.

Nicholson, A.L., et al., 2009, “End-of-life LCA allocation methods”, Sustainable Systems and Technology, 2009. http://dspace.mit.edu/handle/1721.1/60047

PAS 2050, 2008, “Guide to PAS 2050. How to assess the carbon footprint of goods and services”, British Standards (BSI).

PAS 2050, 2011, “Specification for the assessment of the life cycle greenhouse gas emissions of goods and services”, British Standards (BSI).

Pertl, A., Obersteiner, G., Salhofer, S., 2011, “Life cycle assessment aspects of reuse products”, Life Cycle Management, 28-31 Aug., Berlin.

Thormark, C., 2001, “Recycling Potential and Design for Disassembly in Buildings”, KFS AB, Lund, Sweden, 2001.

Thormark, C., 2002, “A low energy building in a life cycle - its embodied energy, energy need for operation and recycling potential”, Building and Environment, n. 37, pp. 429-435.

Wolf, M.A., Chomkhamsri, K., Ardente, F., 2013, “Modelling recycling, energy recovery and reuse in LCA”, Life Cycle Management, Gothenburg.

2.1 Matrix for the environmental sustainability evaluation of temporary buildings

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In order to evaluate the environmental sustainability of mega events temporary buildings, the research group has developed a matrix template which represents a support tool for both designers and organizers. By assuming the selection of criteria defined in this matrix as a design support tool, designers can orient their choices in a sustainable way from the very early design stages. By adopting this matrix template as an evaluation tool, organizers can assess the environmental sustainability of temporary structures proposed by designers according to a pre-defined and shared evaluation framework and make comparisons between different design projects by simply summing up the points achieved by each of them.

All the qualitative and quantitative criteria, which have been selected as assessment parameters of the matrix template (20 criteria in toto), are organized by four categories:
- sustainable site management (4 criteria: habitat protection, open areas, rainwater management, heat island reduction);
- green building design strategies (4 criteria: energy consumption, renewable energy production, indoor natural lighting, indoor water consumption, construction and demolition waste management);
- products and materials environmental performance (4 criteria: responsible extraction of raw materials, environmental information disclosure, recycled content, local manufacturing);
- temporary building life cycle assessment (7 criteria: global warming potential, ozone depletion potential, acidification potential of soil and water, eutrophication potential, photochemical ozone creation potential, abiotic depletion potential of elements, abiotic depletion potential of fossil fuels).

As can be seen from the matrix template below, each criterion is accompanied by:
- a brief description (e.g. criterion: renewable energy production | description: to reduce environmental harms associated to fossil fuel energy by adopting renewable energy systems);
- the point to assign when the criterion is accomplished (e.g. 1 point);
- the benchmark for the assessment (e.g. minimum 5% of renewable energy production in relation to the total energy demand). In the proposed matrix template, the benchmarks have been defined according to those ones developed by existing sustainability assessment protocols.
Since the matrix template has been developed as a modifiable model, other criteria can be added, points can be differently attributed, benchmarks for the assessment may be defined with other percentages and a criteria weighting method can be introduced.
In the following pages can be seen the developed evaluation matrix.

SUSTAINABLE SITE MANAGEMENT			
Criterion	Description	Point	Benchmark
HABITAT PROTECTION	To preserve existing natural elements (vegetation and water) by maintaning o restoring them.	1 point	Minimum 30% of the total site area.
OPEN AREAS	To create exterior open spaces which encourages interaction with the environment and the temporary structures.	1 point	Minimum 30% of the buil-dable area.
RAINWATER MANAGEMENT	To reduce meteoric water waste and run-off by installing water recovery systems and choosing permeable pavements.	1 point	Minimum 50% of permeable pavement in relation to the total open area.
HEAT ISLAND REDUCTION	To minimize effects on micro-climates and human/wildlife ha-bitats by choosing materials for outdoor paving and roofing with an high albedo and/or adopting vegetated roofs.	1 point	SRI>30 (pavement). SRI>80 (roof). Minimum 50% of vegetated roof in relation to the total roof area.

GREEN BUILDING DESIGN STRATEGIES			
Criterion	Description	Point	Benchmark
ENERGY CONSUMPTION	To reduce environmental harms associated with excessive ener-gy use by reducing levels of energy consumption.	1 point	Improvement of the energy consumption by at least 5% in relation to the calculated baseline.
RENEWABLE ENERGY PRODUCTION	To reduce environmental harms associated to fossil fuel energy by adopting renewable energy systems.	1 point	Minimum 5% of the total energy demand.
INDOOR NATURAL LIGHTING	To reduce the use of electrical lighting by introducing dayli-ght into the space. To connect building users with the outdoor environment.	1 point	sDA (spatial Daylight Au-tonomy) of at least 75% for perimeter floor area.
INDOOR WATER CONSUMPTION	To reduce indoor water consu-mption by installing water-sa-ving devices.	1 point	Reduction by at least 20% in relation to the calculated baseline.
CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT	To reduce construction and demolition waste by adopting dry assembled construction technologies.	1 point	Minimum 40% of dry assem-bled systems in relation to the total weight.

PRODUCTS AND MATERIALS ENVIRONMENTAL PERFORMANCE			
Criterion	Description	Point	Benchmark
RESPONSIBLE EXTRACTION OF RAW MATERIALS	To reward project teams for selecting products verified to have been extracted or sourced in a responsible manner (FSC, PEFC, etc.).	1 point	Minimum 25% of certified products in relation to the total weight.
ENVIRONMENTAL INFORMATION DISCLOSURE	To encourage the use of products for which life cycle information is available and that have environmentally, economically, and socially preferable life cycle impacts (EPD).	1 point	Minimum 50% of certified products (at least a cradle to gate EPD) in relation to the total weight.
RECYCLED CONTENT	To reward project teams for selecting products verified to have been manufactured with a recycled content percentage.	1 point	Minimum 10% of recycled content in relation to the total weight.
LOCAL MANUFACTURING	To encourage the use of products verified to have been locally manufactured (radius from the project site < 800 km).	1 point	Minimum 30% of locally manufactured products in relation to the total weight.

TEMPORARY BUILDING LIFE-CYCLE ASSESSMENT			
Criterion	Description	Point	Benchmark
GLOBAL WARMING POTENTIAL (GWP)	To encourage the use of products and design solutions with a low impact on GWP.	1 point	Reduction by at least 10% in relation to the building baseline.
OZONE DEPLETION POTENTIAL (ODP)	To encourage the use of products and design solutions with a low impact on ODP.	1 point	Reduction by at least 10% in relation to the building baseline.
ACIDIFICATION POTENTIAL OF SOIL AND WATER (AP)	To encourage the use of products and design solutions with a low impact on AP.	1 point	Reduction by at least 10% in relation to the building baseline.
EUTROPHICATION POTENTIAL (EP)	To encourage the use of products and design solutions with a low impact on AP.	1 point	Reduction by at least 10% in relation to the building baseline.
PHOTOCHEMICAL OZONE CREATION POTENTIAL (POCP)	To encourage the use of products and design solutions with a low impact on AP.	1 point	Reduction by at least 10% in relation to the building baseline.
ABIOTIC DEPLETION POTENTIAL OF ELEMENTS (ADPe)	To encourage the use of products and design solutions with a low impact on AP.	1 point	Reduction by at least 10% in relation to the building baseline.
ABIOTIC DEPLETION POTENTIAL OF FOSSIL FUELS (ADPf)	To encourage the use of products and design solutions with a low impact on AP.	1 point	Reduction by at least 10% in relation to the building baseline.

2.2 LCA of representative models of temporary structures for mega events

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The temporary use of building during mega events such as Expo 2015 [1], raises mainly technical issues which reflect in technological choices during design phase, consistent with the end of the event and the end of life of the temporary structures.

The research work starts from the identification of some constructive solutions used for the construction of temporary structures, and from the evaluation of environmental impacts associated with different materials and techniques.

The objective of the evaluation is twofold: for defining the solution with lower impacts trough both a comparison of structural and technological models and a comparison between end-of-life scenarios that include demolition, dismantling/relocation and use extension for a new function.

Structural models

Three structural models have been defined starting from recurring constructive solutions, on condition that they have the same spatial configuration, but different constructive solutions and materials, in order to better describe the technology for temporariness.

In reference to the constructive practices and site-specific characteristics (soil bearing capacity, load conditions, etc.), not-reversible foundations are often used (reinforced concrete beams; concrete slab), and these are adopted in model 1 and 2. On the contrary, Model 3 adopts reversible foundation (pile foundation), only usable for single-storey buildings on resistant soil, in order to note the difference between impacts.

The other building subsystems use total-reversible constructive solutions..

The first structural model (**figure 1**) has reinforced concrete beams foundation, X-lam structure which also solves the function of envelope with wood fibre insulation board, wood slat external cladding, gypsum fibre board internal cladding.

The second structural model (**figure 2**) has concrete slab foundation, glue laminated timber load-bearing structure, envelope with freestanding wood stud (not load-bearing), cork panel insulation interposed, wood-based fibres and thermosetting resins panel external cladding, gypsum fibre board internal cladding; the covering is completed with cross wood stud, cork panel insulation interposed, OSB panel, bituminous sheet waterproof membrane.

The third structural model (**figure 3**) has reversible piles anchor foundation, steel columns and beams frame, corrugated metal sheet on steel profiles roof frame, steel sandwich panel (EPS insulation panel interposed) external cladding fixed on steel profiles; the covering is complete with EPS insulation panel, bituminous sheet waterproof membrane and wavy metal sheet.

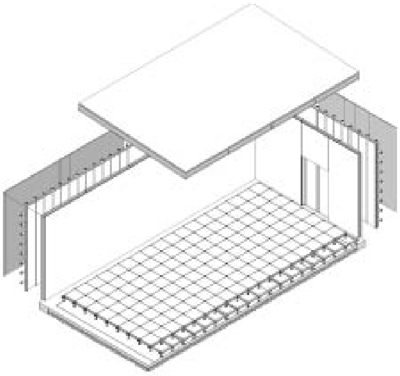


Figure 1. *model 1 (X-lam)*

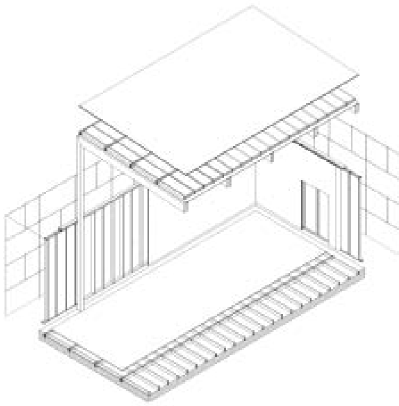


Figure 2. *model 2 (glue laminated timber)*

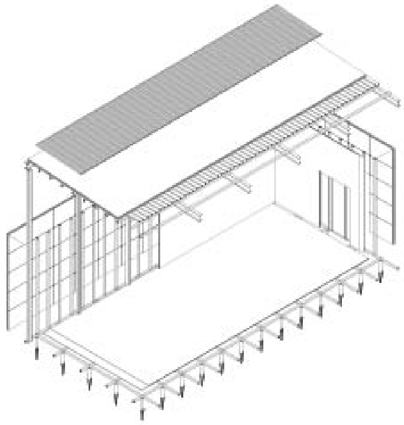


Figure 3. *model 3 (steel)*

Comparison between structural models

A comparative LCA of the three structural models is carried out in order to perform a critical analysis of the impacts of each technological subsystem within each structural model and a comparison between technological subsystems, obtained from different constructive technologies, .

This study includes:

- "Production" phase, i.e. extraction of raw materials, their transportation to the production plant where the single components and/or the building materials are manufactured and their manufacturing process;
- "Transport" phase of building materials from the plant to the construction site, whose impacts depend on the means of transport (in this case by lorry), the distance (in this case steady 150 km), and the weight of transported material;
- "End of life" phase, which involves landfilling of not-recyclable materials or recycling of recyclable materials. According to the allocation procedure proposed by Frischknecht [2] impacts of recycling are considered outside the system boundaries, and only impacts of transportation to sorting plant are accounted for.

This comparison excludes impacts related to "temporary use" phase, because the thermal performance and energy consumptions are assumed to be the same in each models, and "assembly and disassembly" phases, whose values are not only difficult to source, but can also be considered relatively "low" for the high level of prefabrication of temporary construction, at least compared to a traditional construction site.

The results of this analysis, by comparing the totality of Primary Energy Intensity (PEI) and Global Warming Potential (GWP) normalized to m^{2}year at all stages of life, reveal (**figure 4**): model 2 (glue laminated timber) is the most impactful, especially during the production phase, followed by model 3 (which uses steel technologies) and model 1 (X-lam), respectively; however, the data are significantly influenced by reinforced concrete beams foundation in model 1 and concrete slab foundation in model 2. Indeed, assessing the impact without foundations in each model (**figure 5**) and considering only the temporary technologies, it is possible to note how model 2 (glue laminated timber) becomes less impactful than both model 1 (X-lam) and model 3 (steel).

It is also important to emphasize how X-lam solution fulfils simultaneously the function of load-bearing and envelope: if we compare the sum of the impacts of load-bearing structure, vertical envelope and cover in each model (**figure 6**), it is possible to note that model 1 and 2 have similar values, while model 3, built using steel technology, turns out to be the most impactful.

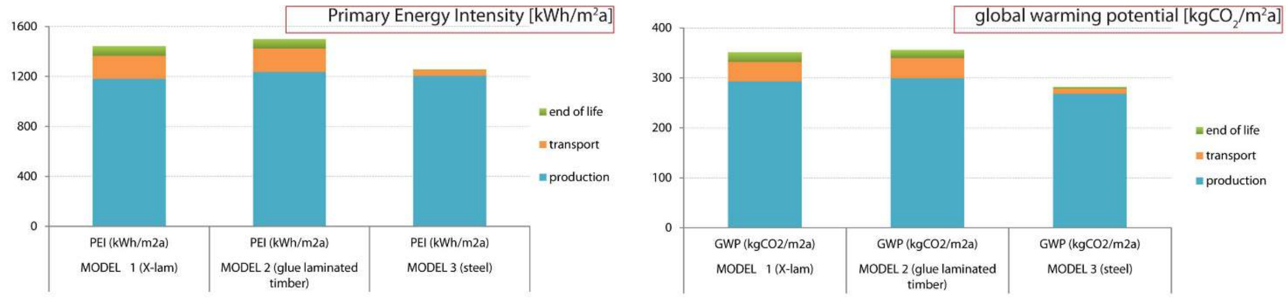


Figure 4. *Comparison between structural models: PEI,GWP impacts*

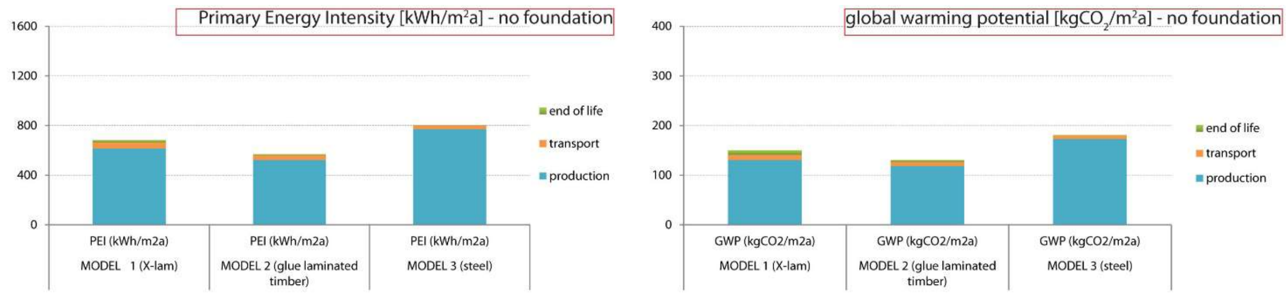


Figure 5. *Comparison between structural models without foundation: PEI and GWP impacts*

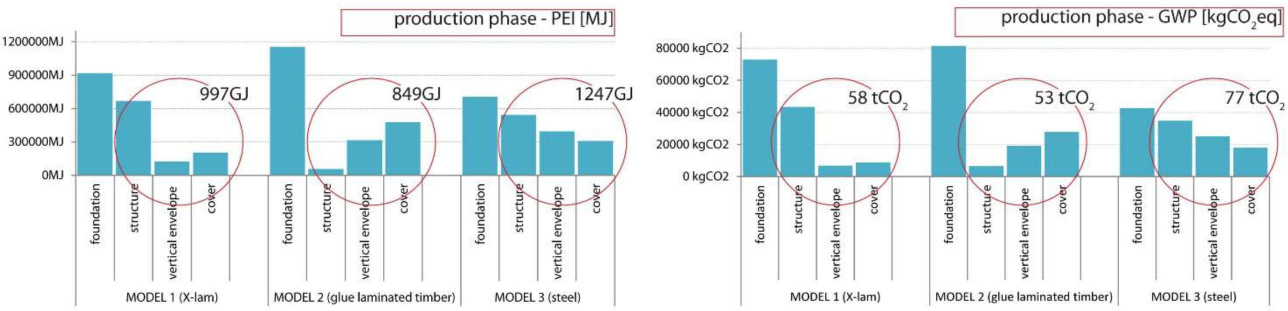


Figure 6. *Comparison between technology subsystems in production phase: PEI and GWP impacts*

Comparison between end of event scenarios

After the comparison between structural models and the evaluation of some of the most common technologies for the construction of temporary structures, a further comparison to evaluate which scenarios can be more efficient at the end of the event has been realized.

The European Directive 2008/98/CE [3] defines the waste hierarchy, to identify which is the less impactful end of life. This hierarchy, as applied to the case of temporary structures, would lead to the definition of three scenarios (from the best to the worst): requalification – replacement – recycling of temporary structures.

Although the European directive suggests which the best end of life is, it is always safer to carry out the LCA in order to check the real impacts in relation to the specific case; in principle, a detailed analysis could identify a reverse hierarchy.

To make a comparison between these scenarios there is an allocation of impacts issues in case of multifunctionality of unit process; the theme of the allocation of impacts at the end of life is still largely debated in the literature. The standard UNI EN ISO 14044:2006 [4] states that, whenever is possible, the allocation of the impacts should be avoided by dividing the unit process into two or more sub-processes and by collecting the input and output data related to these sub-processes. Alternatively, it should be avoided by expanding the system boundaries; in this case the boundaries of the system have been extended to the second use of the building.

To have an equivalent functional unit (equal performance), “the need for space (30x15x4,5m) for temporary event (1 year) and permanent use (9 years)” has been defined as functional unit. The system boundaries are extended to "two uses" of the building, the first related to temporary use in connection to the event and the second related to permanent use post event.

Three scenarios are assumed (**Figure 7**): the first involves the "demolition" at the end of the event, with a useful life of the structure closely dependent on the duration of the event, at the end of which the demolition of buildings occurs.

In this scenario it is necessary to consider the *production* phase, the *transport* from the plant to the building site phase and the *end of life*. Since the functional unit is “the need of a space for 1 year and then for 9 years”, it is also necessary to consider the impacts related to the reconstruction of the same structure for permanent use.

The second scenario involves the "relocation" of the structure in a different location from the original one, in service of permanent use. Then, it is necessary to consider the *production* phase, the *transport* from the plant to building site, the *transport* from first to second building site, the *production* and the *transport* of additional material to realize new foundation, the *end of life* after the second useful life.

The third scenario involves the transition from temporary pavilion to permanent building: “extension of use” maintaining the original site of the event. In this scene the *production* phase, the *transport* to the site and the *end of life* are the only phases that need be accounted for.

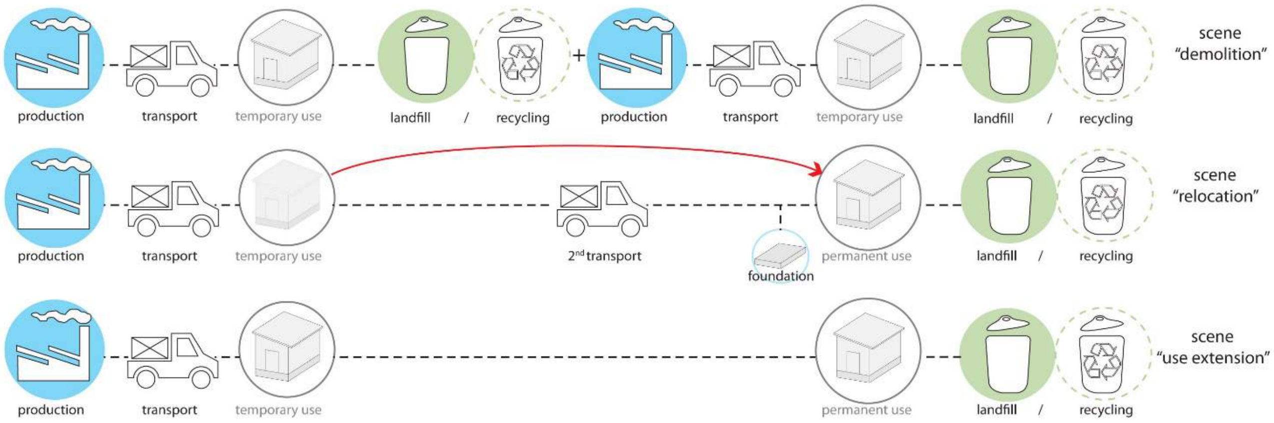


Figure 7. *Flowchart end of event scenarios*

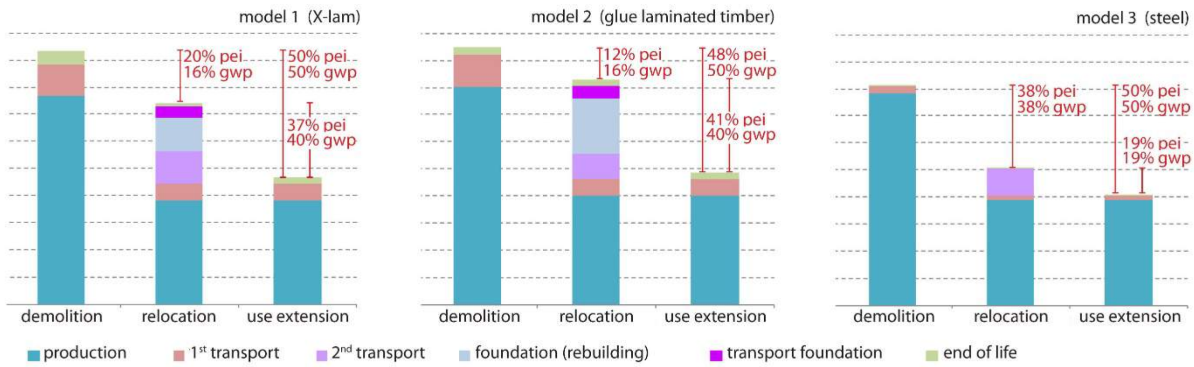


Figure 8. *Comparison between end of event scenarios in each model*

It may be seen from **figure 8** that in all the three models the results are coherent with the hierarchy prescribed by European Directive 2008/98 /CE: the “demolition” scenario is the most impactful, while “use extension” scenario is less impactful than the “relocation” scenario.

There is a difference between the technologies and materials used: in model 3 “relocation” scenario is particularly low impactful because the foundations are reversible (dismantled and reused); in this case there are not impacts related to the production and the transport of the new foundations.

The most significant aspect is the interpretation of the results obtained by comparing the impacts of demolition/reconstruction and the impacts of relocation of temporary structure: relocation, in contrast to what is commonly understood, is not always the most eco-efficient scenario, as the most impactful technological subsystem (foundation) is not normally reversible and must be rebuilt. So the impacts of the reconstruction of the foundations, added to the impacts generated by the transport from the first to the second site on the medium-long distance (150 km), can effectively reduce the environmental benefit from the "avoided" impacts of demolition and reconstruction of the structure (as shown in model 2). To make an eco-efficient relocation scenario we must pay attention to the distance between the first and the second site and also to the type of foundation used.

Conclusions

Different original contributions emerge from this research; indeed, the LCA results here presented point out that (1), as for the technology adopted, the role of foundations is central; (2), as for the end of life scenarios, relocation/reuse in different places is critical. Furthermore, considering the methodological aspects, the present analysis is innovative regarding both the procedure of end of life impacts allocation and the choice of the functional unit and system boundaries (extension to two uses), and can be replicated in other studies about temporary buildings owing to its general approach not bound to any specific situation.

It should be emphasized that the models here studied are small size and single-storey buildings, therefore some conclusions might be affected by such characteristics. For this reason, a further element of study is the assessment of larger pavilions (in the next paragraph, related to Expo2015 Clusters) in order to understand whether the considerations here drawn are still valid and relatively independent from the size.

Another key point, both in the case of relocation and in the case of the use extension, is the role of the integration of new materials to fulfil new functions: thinking, for example, about thermal insulation, usually in temporary buildings it is not paid much attention to the aspects of energy saving (in the case of Expo 2015, which takes place in the summer, there is no need to care for thermal insulation); of course, the design of possible re-use of temporary pavilions must include the integration of thermal insulation to provide adequate performance of comfort and containment of environmental impacts related to the use phase of the second life of the building.

References

[1] Lavagna M., Arena M., Dotelli G., Zanchi M., “Le strutture temporanee per Expo Milano 2015: valutazione ambientale e soluzioni per la gestione del fine vita”, Techne. Journal of Technology for Architecture and Environment, n. 7, 2014, pp. 171-177;

[2] Kloepffer W., “Allocation Rule for Open-Loop Recycling in Life Cycle Assessment”, International Journal of Life Cycle Assessment, 1(1), 1996, pp. 27–31;

[3] Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives, Official Journal of the European Union, L 312/3, 22.11.2008;

[4] UNI EN ISO 14044:2006, Environmental management, life cycle assessment, requirements and guidelines

2.3 LCA evaluation of the Expo 2015 Clusters

Andrea Campioli, Monica Lavagna, Sara Ganassali, Michele Paleari (Dep. ABC)

The Expo 2015 Clusters were selected as a case study of mega events temporary structures. The pavilions provided by Expo S.p.A. at the 9 thematic areas of Clusters can be divided into two categories, depending on their construction method and chosen materials. The contruction of "Islands, sea and food", "Dry Areas", "BioMediterraneo" and "Cereals and Tubers" Clusters, with a total of 43 pavilions, was assigned to ta leading manufacturer of laminated wood turnkey buildings. From the architectural point of view, the Clusters have a modular structure composed by laminated wood portals; each of them has a size of 12 m wide and 10 m height (Figure 1) and they allow to create pavilions with rectangular or square plan, freely arranged in 12x12 m module.

In this context we carried out a detailed environmental analysis of the materials used for the "Islands, sea and food" Cluster. With regard to the other three Clusters we analyzed only the external envelope system, each of them designed in a different way and with different materials to emphasize the originality of each Cluster. This methodological choice arises from the fact that the laminated wood structures are the same in each pavilion; therefore, the envelope facade systems are responsible of the alterations in LCA analysis results between the different Clusters.

The foundations system of each pavilion (not only for Clusters) was designed and built before the buildings projects, by Expo S.p.A. The foundations are placed on a concrete mat foundation with thickness of 50 cm, in which the technical systems are inserted.

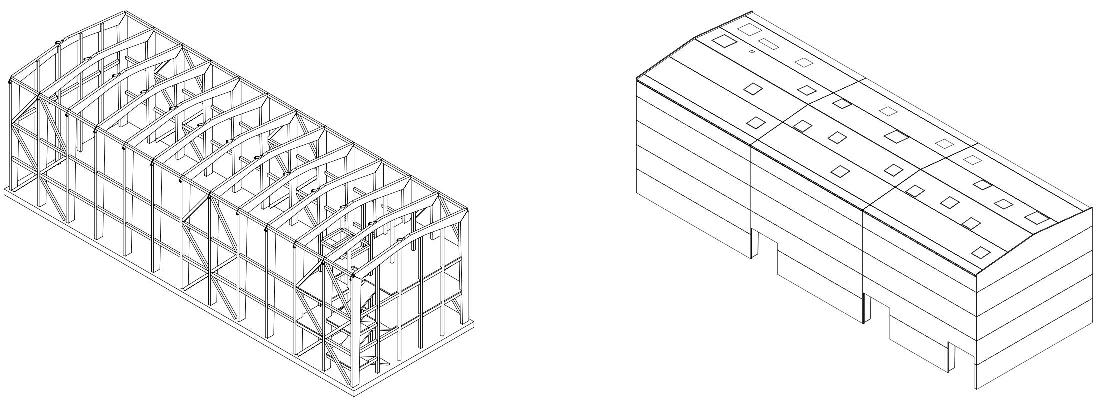


Figure 1. Axonometry of laminated wood structure and envelope of "Islands, sea and food" Cluster pavilionT

The laminated wood pillars are fixed on the plinths through steel bolted plates.
The load-bearing structure is composed by laminated wood portals which are placed at a distance of 2.75 meters from each other and their modularity contributes to a different arrangement of the Clusters buildings. The pillars, which are tapered towards the top, are fastened to the beam through a

system of steel plates and bolts. The technical area of every pavilion (which hosts stairs and service structures) is supported by a frame system of wooden beams and pillars (20x20 cm, 16x20 cm, 20x24 cm). The floors are present in the technical area only and are made by X-Lam panels, dry assembled and covered with linoleum tiles (ground floor and first floor) or with a floating flooring (second floor used as a service space). The inner exhibition space, which is reserved to the nations, has a smooth cement floor.

The external cladding of the pavilions is built with prefabricated panels with a thickness of 6.5 cm. It's made by the following layers (from inside to outside):

- three-layered spruce wooden panel, type NORDPAM 3S, thickness of 13 mm
- extruded polystyrene thermal insulation, thickness of 40 mm
- OSB/3 wooden panel, thickness of 12 mm.

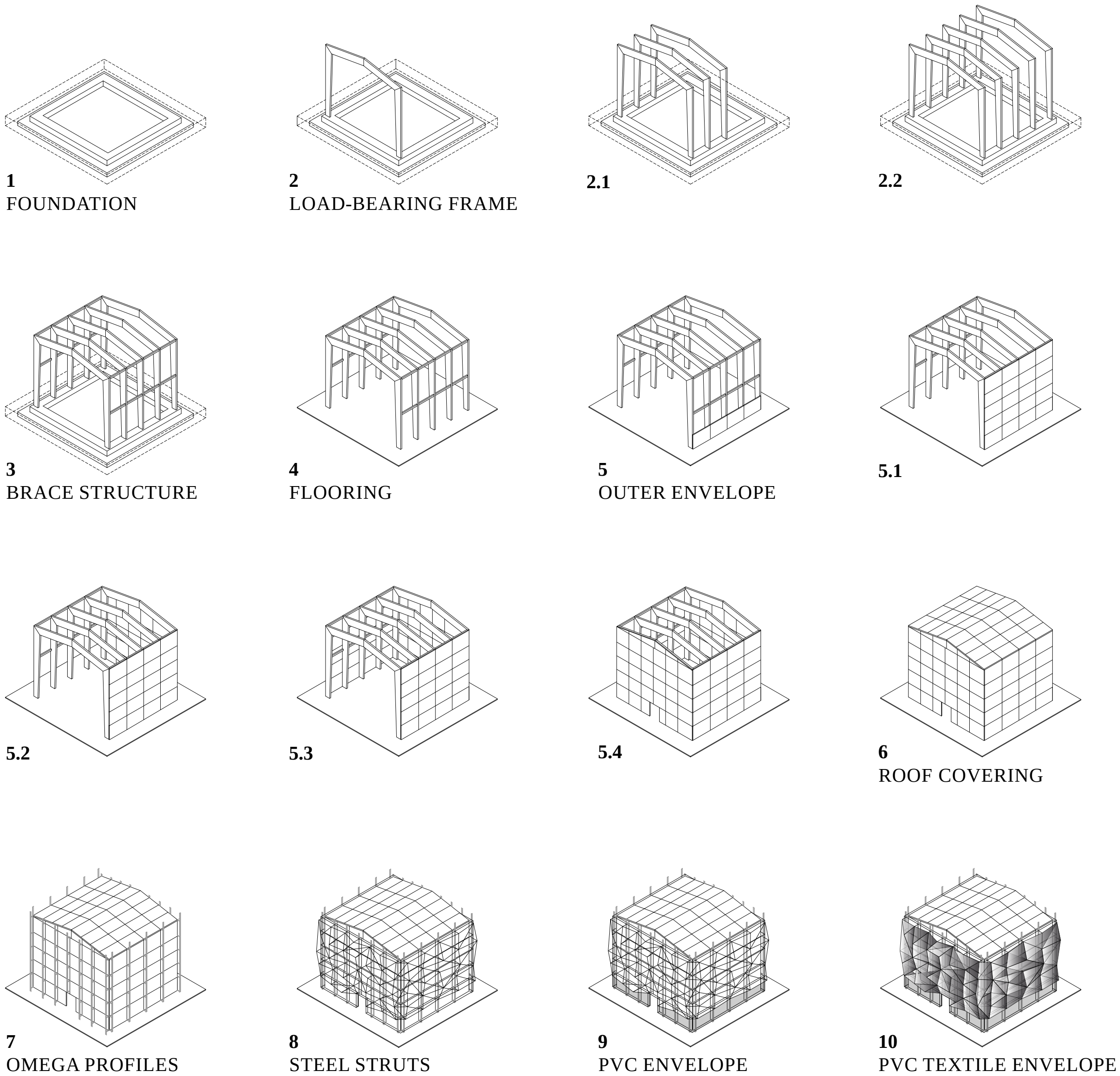


Figura 3. Axonometry of Cluster constructive system

The internal partitions of the pavilions, both in the technical area and in the exhibition space, are built with plasterboard slabs, in order to allow a good flexibility in spaces arrangement.

The following table shows the materials amount used for the construction of the "Island, sea and food" Cluster pavilions and the materials amount used for the construction of the fourth Clusters cladding. These values are expressed in kilograms and were used in the software Simapro 8 for the construction of processes with the database Ecoinvent 3. Life Cycle Assessment results are illustrated and explained in the following paragraphs. The evaluations comparison allow to understand which are the materials and the end of life scenarios with the lower impacts.
The LCA is from cradle to grave and the reference study period is of 10 years. Impacts related to the use phase are not considered because the impacts are the same in the three scenarios.The amount of materials were calculated from executive drawings (more detailed than the bill of quantities).

BIOMEDITERRANEO CLUSTER CLADDING

Materials	kg
Aluminum	26.739
Cellular polycarbonate	15.000
Galvanized steel	38.452

CEREALS AND TUBERS CLUSTER CLADDING

Aluminum	11.381
Cellular polycar-	14.736
Fibercement	62.628
Galvanized steel	38.651
Juta	1842
Paint	828,90

DRY LANDS CLUSTER CLADDING

Galvanized steel	18.728
PVC	2.051

ISLAND, SEA AND FOOD CLUSTER CLADDING

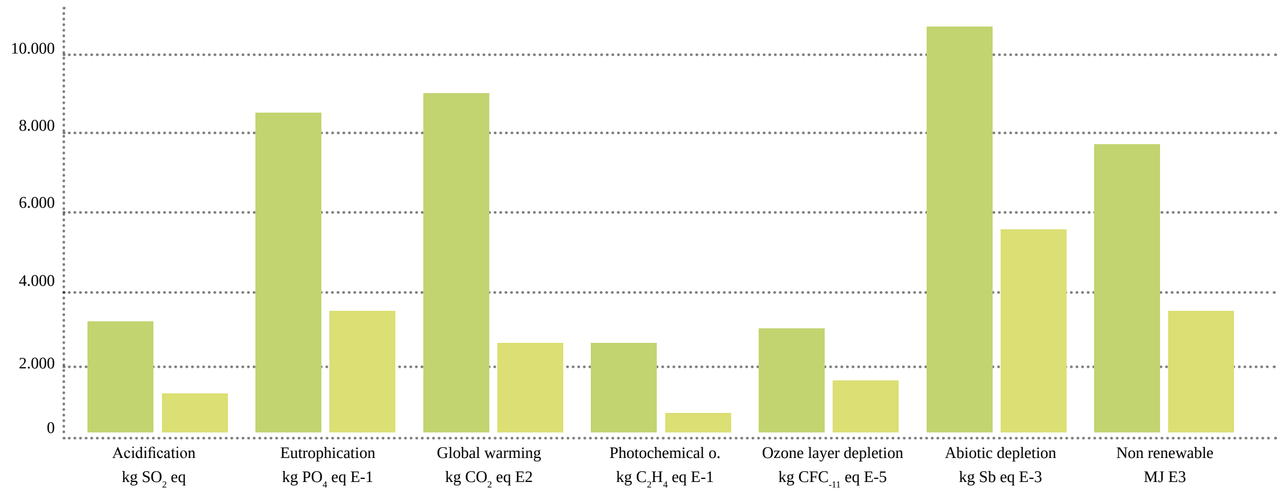
Fibercement	1.897
Galvanized steel	52.105
Glued laminated	53.125
PVC	555
PVC SHEET	65

EXHIBITION PAVILIONS

Materiale	kg
Aluminium	17
Bitume sheet	21
Calcium sil. panel	271
Cardboard	232
Ceramic tiles	269
Concrete	13.104.532
Concrete idrodrain	10.240
Galvanized steel	42.739
Gypsum plaster	25.312
Gypsum plasterboard	12.365
Linoleum	13
Nylon	1
OSB panel	11.857
Paint	900
Policarbonate	288
Polyethylene	2
Polystyrene	1600
PVC	3.251
Rockwool	1.344
Tanganika wood	83
Three layered wood	11.092
Timeber wood	107.428
Vapor barrier	98

2.3.1 EVALUATION 1: Comparison of production impacts of the "Islands, sea and food" Cluster, both considering and omitting the impacts of the foundations

The results of the first Life Cycle Assessment evaluation highlight the significant contribution in anthropogenic emissions caused by the foundation system; it is not reversible and it will be demolished at the end of Expo, provoking a remarkable impact on the environment. On the contrary, the wooden structure was designed to be reversible; therefore, the high impact of production may be "diluted" thanks to the extension of the lifespan, when the Clusters will be disassembled and reused with a new function, at the end of the event. The concrete was used only in the foundations and in the reinforced slab, provided by Expo S.p.A.; it is responsible for more than half of the total environmental impacts. Assuming a project with a reversible foundation system (without the impacts due to the disposal of concrete and reinforcement steel), the production processes of wood components and steel connections become responsible of the major amount of the emissions. Expo Milano is a mega event in which the dismantling of structures must be done completely at the end of the event. The end of life scenario of foundations considers the landfill disposal without any possibility of reuse in an hypothetical second useful life of pavilions.



IMPACT CATEGORY	u.o.m	PAVILIONS WITH FOUNDATION SYSTEM	PAVILIONS WITHOUT FOUNDATION SYSTEM
Acidification	kg SO_2 eq	3.546	1.541
Eutrophication	kg PO_4 eq E-1	8.154	3.780
Global warming (GWP100)	kg CO_2 eq E2	8.299	2.555
Photochemical oxidation	kg C_2H_4 eq E-1	2.531	1.323
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-5	3.472	1.833
Abiotic depletion	kg Sb eq E-3	11.178	5.514
Non renewable, fossil and nuclear	MJ E3	7.857	3.716

Figure 3. Impacts production comparison of "Islands, sea and food" Cluster with the foundation system and omitting foundation system impacts

2.3.2 EVALUATION 2: Comparison of the impacts of three alternative end of life scenarios of the "Islands, sea and food" Cluster

Expo pavilions will have a very short time of use, but they contain an high residual function after their first use. This allow the design of a possible "second" use. Through the Life Cycle Assessment evaluation of structures we want to illustrate which could be the environmental benefit and the impacts reduction if the pavilion structure will be reused, instead of disposed. To assume the same reference function, we defined a functional unit extended to two uses: a useful space for Expo, for a timespan of six months, and a useful space for the exhibition contest in Lodi, for 9 years.

The end of life scenarios assumed are three:

1. the extension of the useful life after Expo, with the permanence of the structures on site and the subsequent transition of the pavilions from temporary to permanent buildings. This lead to an integration of some new materials that are necessary to make the structure compliant to the Italian rules for permanent buildings (scenario 1_Figure 4);
2. the reuse of pavilions through the disassembly and the relocation of them in Lodi, with the addition of some new materials that are necessary to make the structure compliant to the Italian rules for permanent buildings (scenario 2_Figure 5);
3. the demolition of the structures at the end of the event, with landfilling or recycling of the materials and the consecutive new production and new construction in Lodi of another exhibition structures (scenario 3_Figure 6).

We omitted, in all scenarios, considering that the impacts are the same, the steps of:

- the construction site activities;
- use phase and energy consumptions;
- demolition-disassembly of the structures at end of life.

The final results show that the case of the reuse on site is the scenario with a lower environmental impact. This is because in this option is only necessary the addition of new materials to the wooden structure. We counted production and transport to the Expo site. As end of life scenario we counted only one disposal.

The reuse (Scenario 2) is convenient to obtain the reduction of the environmental impacts in the Life Cycle Assessment, thanks to the avoided production of new products and the consequent avoided consumption of resources and energy. The final results show that the greenhouse gasses emissions are higher than in the first scenario, because in this case we included also the transport of the Clusters components to the new site, the dismantling of the not reversible foundations system and the addition of a new foundations system. The last item is built in a traditional way with concrete plinths and the materials amount is smaller than what provided by Expo.

EVALUATION SCENARIO 1

MATERIALS PRODUCTION AND TRANSPORT TO EXPO 2015 SITE

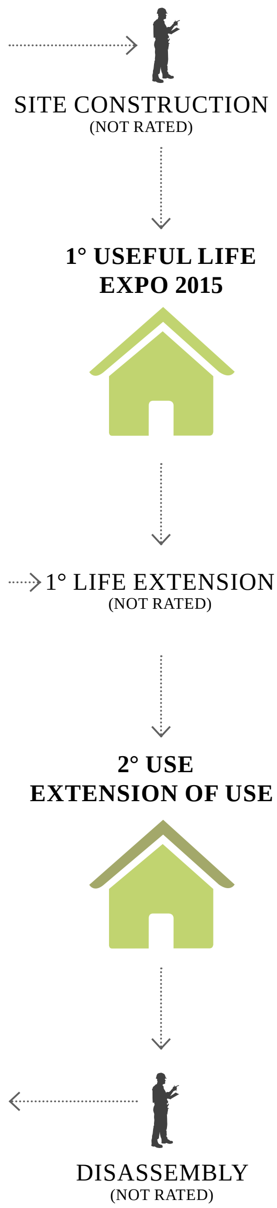
IMPACT CATEGORY	u.o.m		+	
Acidification	kg SO_2 eq	3.546		143
Eutrophication	kg PO_4 eq E-1	8.154		293
Global warming (GWP100)	kg CO_2 eq E3	830		40
Photochemical oxidation	kg C_2H_4 eq E-2	25.309		524
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	34.724		2.784
Abiotic depletion	kg Sb eq E-4	111.778		1.000
Non renewable, fossil and nuclear	MJ E3	7.857		639

NEW MATERIALS PRODUCTION AND TRANSPORT TO POST-EXPO

IMPACT CATEGORY	u.o.m		+	
Acidification	kg SO_2 eq	2.239		120
Eutrophication	kg PO_4 eq E-1	6.142		243
Global warming (GWP100)	kg CO_2 eq E3	332		33
Photochemical oxidation	kg C_2H_4 eq E-2	14.119		439
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	20.448		2.231
Abiotic depletion	kg Sb eq E-4	7.767		836
Non renewable, fossil and nuclear	MJ E3	4.499		535

MATERIALS TRANSPORT TO DISPOSAL AND DISPOSAL

IMPACT CATEGORY	u.o.m		+	
Acidification	kg SO_2 eq	161		4.891
Eutrophication	kg PO_4 eq E-1	330		3.002
Global warming (GWP100)	kg CO_2 eq E3	45		73
Photochemical oxidation	kg C_2H_4 eq E-2	590		12.818
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	3.131		6.212
Abiotic depletion	kg Sb eq E-4	11.232		683
Non renewable, fossil and nuclear	MJ E3	718		905



TOTAL EMISSIONS

IMPACT CATEGORY	u.o.m	
Acidification	kg SO_2 eq	11.192
Eutrophication	kg PO_4 eq E-1	18.166
Global warming (GWP100)	kg CO_2 eq E3	1.340
Photochemical oxidation	kg C_2H_4 eq E-2	53.806
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	69.634
Abiotic depletion	kg Sb eq E-4	22.587
Non renewable, fossil and nuclear	MJ E3	14.439

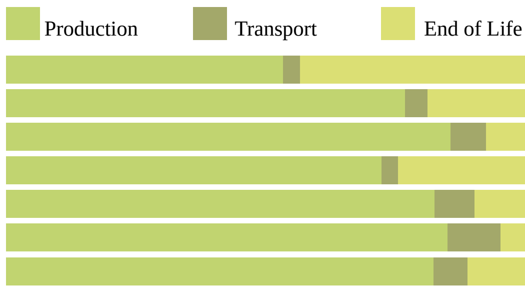


Figure 4. Anthropogenic emissions produced by scenario 1

EVALUATION SCENARIO 2

MATERIALS PRODUCTION AND TRANSPORT TO EXPO 2015 SITE

TRANSPORT TO DISPOSAL AND DISPOSAL OF SOME MATERIALS

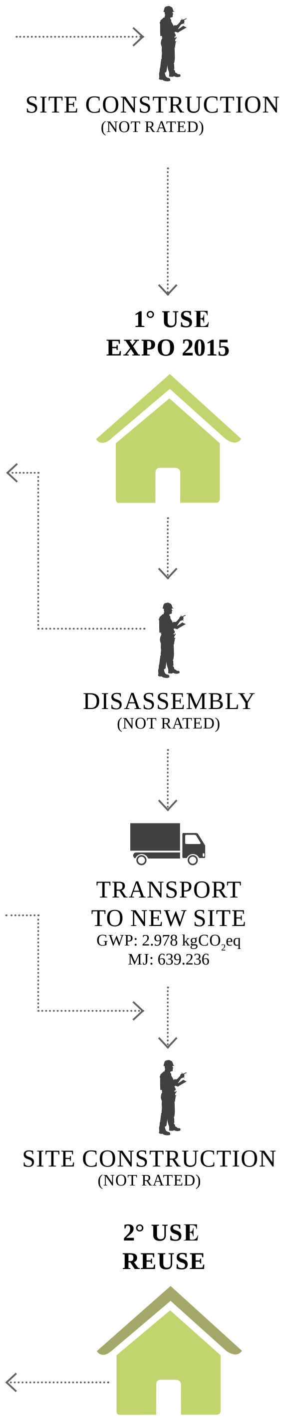
IMPACT CATEGORY	u.o.m	Transport	+ Disposal
Acidification	kg SO_2 eq	48	179
Eutrophication	kg PO_4 eq E-1	99	1.801
Global warming (GWP100)	kg CO_2 eq E3	134	38
Photochemical oxidation	kg C_2H_4 eq E-2	176	724
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	936	2.411
Abiotic depletion	kg Sb eq E-4	336	247
Non renewable, fossil and nuclear	MJ E3	215	576

NEW MATERIALS PRODUCTION AND TRANSPORT TO NEW SITE

IMPACT CATEGORY	u.o.m	Production	+ Transport
Acidification	kg SO_2 eq	3.493	120
Eutrophication	kg PO_4 eq E-1	8.421	245
Global warming (GWP100)	kg CO_2 eq E3	661	33
Photochemical oxidation	kg C_2H_4 eq E-2	19.718	439
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	29.825	2.331
Abiotic depletion	kg Sb eq E-4	11.100	836
Non renewable, fossil and nuclear	MJ E3	6.955	535

MATERIALS TRANSPORT TO DISPOSAL AND DISPOSAL

IMPACT CATEGORY	u.o.m	Transport	+ Disposal
Acidification	kg SO_2 eq	161	3.034
Eutrophication	kg PO_4 eq E-1	330	2.436
Global warming (GWP100)	kg CO_2 eq E3	45	80
Photochemical oxidation	kg C_2H_4 eq E-2	590	9.026
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	3.131	3.934
Abiotic depletion	kg Sb eq E-4	1.123	349
Non renewable, fossil and nuclear	MJ E3	718	379



TOTAL EMISSIONS

IMPACT CATEGORY	u.o.m	
Acidification	kg SO_2 eq	12.736
Eutrophication	kg PO_4 eq E-1	21.800
Global warming (GWP100)	kg CO_2 eq E3	1.708
Photochemical oxidation	kg C_2H_4 eq E-2	58.546
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	80.283
Abiotic depletion	kg Sb eq E-4	26.224
Non renewable, fossil and nuclear	MJ E3	17.926

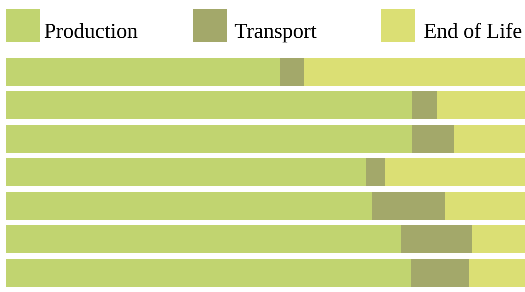


Figure 5. Anthropogenic emissions produced by scenario 2

EVALUATION SCENARIO 3

MATERIALS PRODUCTION AND TRANSPORT TO EXPO 2015 SITE

MATERIALS TRANSPORT TO DISPOSAL AND DISPOSAL

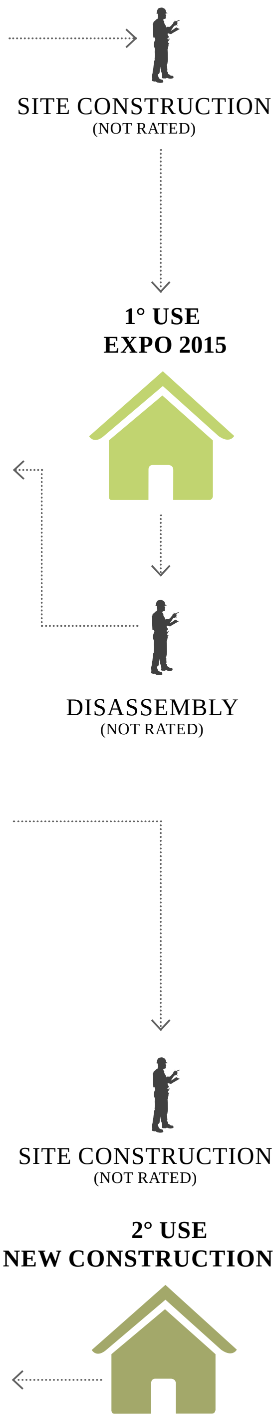
IMPACT CATEGORY	u.o.m		+
Acidification	kg SO_2 eq	41	3.134
Eutrophication	kg PO_4 eq E-1	84	2.763
Global warming (GWP100)	kg CO_2 eq E3	11	70
Photochemical oxidation	kg C_2H_4 eq E-2	151	7.551
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	800	6.082
Abiotic depletion	kg Sb eq E-4	2.870	6.585
Non renewable, fossil and nuclear	MJ E3	184	883

2° MATERIALS PRODUCTION AND TRANSPORT TO NEW SITE

IMPACT CATEGORY	u.o.m		+
Acidification	kg SO_2 eq	4.620	2.628
Eutrophication	kg PO_4 eq E-1	11.580	6.472
Global warming (GWP100)	kg CO_2 eq E3	807	483
Photochemical oxidation	kg C_2H_4 eq E-2	31.637	17.392
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	42.168	24.434
Abiotic depletion	kg Sb eq E-4	150.131	86.477
Non renewable, fossil and nuclear	MJ E3	10.095	5.784

MATERIALS TRANSPORT TO DISPOSAL AND DISPOSAL

IMPACT CATEGORY	u.o.m		+
Acidification	kg SO_2 eq	161	3.034
Eutrophication	kg PO_4 eq E-1	330	2.436
Global warming (GWP100)	kg CO_2 eq E3	447	453
Photochemical oxidation	kg C_2H_4 eq E-2	590	9.026
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	3.131	3.934
Abiotic depletion	kg Sb eq E-4	11.232	349
Non renewable, fossil and nuclear	MJ E3	718	379



TOTAL EMISSIONS

IMPACT CATEGORY	u.o.m	
Acidification	kg SO_2 eq	17.306
Eutrophication	kg PO_4 eq E-1	32.093
Global warming (GWP100)	kg CO_2 eq E3	2.331
Photochemical oxidation	kg C_2H_4 eq E-2	92.172
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	118.051
Abiotic depletion	kg Sb eq E-4	382.554
Non renewable, fossil and nuclear	MJ E3	26.540

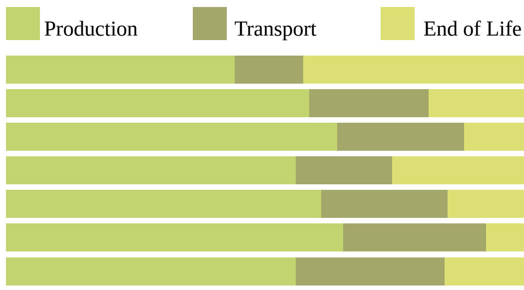


Figure 6. Anthropogenic emissions produced by scenario 3

The third scenario shows higher environmental impacts compared to the previous scenes because it involves the complete dismantling of the Clusters buildings at the end of the Universal Exhibition and a complete rebuild of the pavilions to the new site in Lodi. After the second lifespan, estimated in 9 years, it will be landfilles and recycled again.

The emissions due to materials transport for the relocation and reconstruction of the temporary buildings in the new site are similar to the other cases because Lodi can be considered “adjacent” to Milano and its distance from the Expo site is about 40 km. The impacts produced by the pavilions dislocation increase when we consider the transport towards cities at further distances. In an hypothetical Life Cycle Assessment, the choice to disassembly the buildings at the end of the event and to rebuild them in another country lead the transport to influence the emissions in a negative way: it could become responsible for the highest percentage of impacts. The materials separability, the reversibility of the assembly operations, the buildings modularity and the selective demolition are scenarios that promote recycling. However, these options require specific projects and market conditions for make them favorable. The recycling process allows a reduction of the environment pollution originated from waste, a reduction of raw materials consumption through the re-entering of materials in the circulation and a reduction of the energy costs arising from materials extraction, refining and transportation to manufacturing (Figure 7).

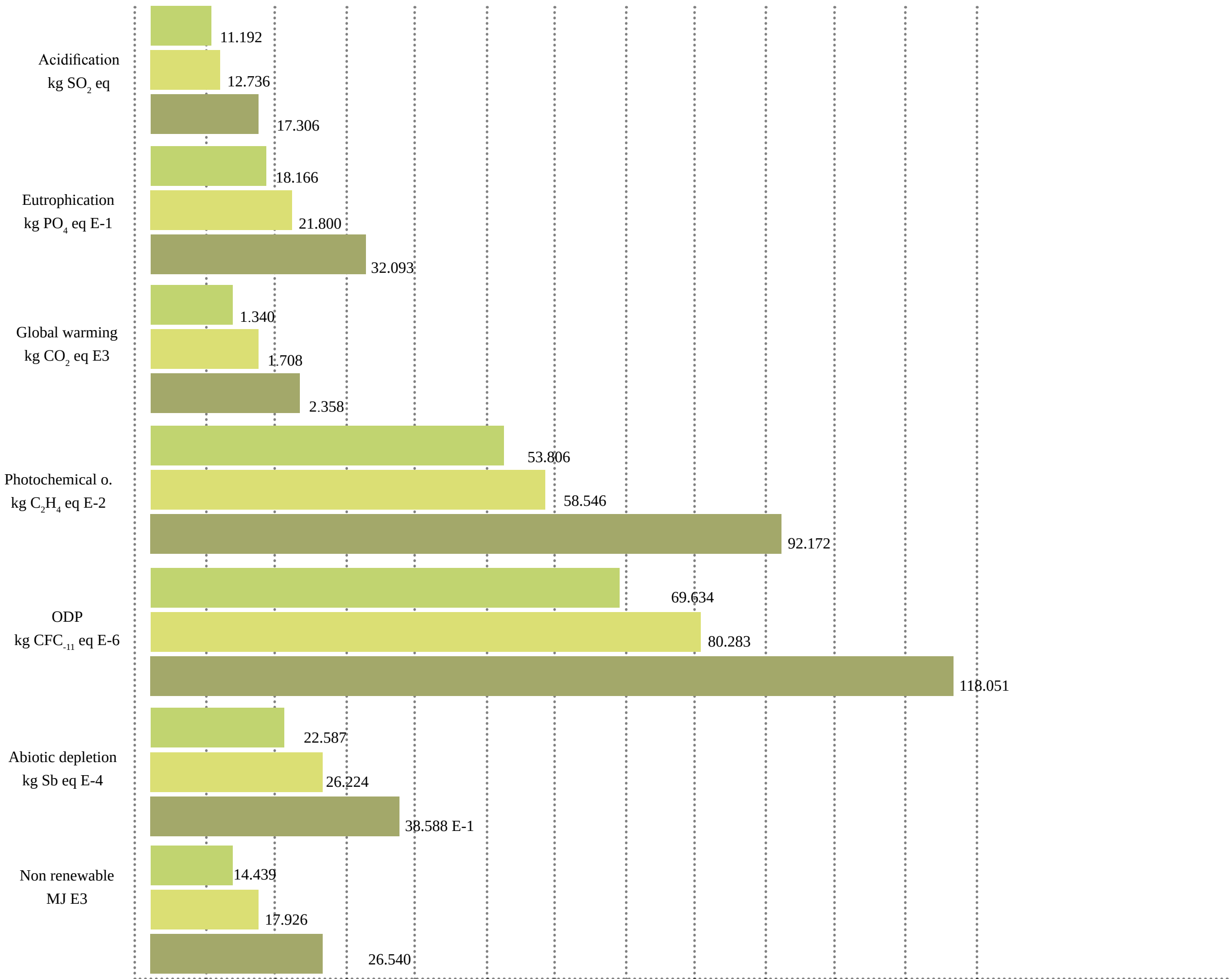


Figure 7. Impacts comparison with Life Cycle Assessment methodology of three different end of life scenarios

2.3.3 EVALUATION 3: Comparison of the production impacts among the cladding systems of Clusters buildings

An additional evaluation examines the cladding systems of the four Clusters pavilions built by Rubner: "Biomediterraneo", "Cereals and Tubers", "Dry lands" and "Islands, sea and food" Clusters. They have the same wooden structure, but the use of different materials in the cladding systems on the facades causes different environmental impacts. Due to the dimensional difference among systems and the use of different materials, the anthropogenic emissions were calculated considering the impacts caused by the production of every square meter of the cladding. In each case, the cladding is installed on a support structure made by steel elements, that have different sizes according to the materials loads that they have to support. The structure is composed by omega profiles (with thickness of 2 mm) and steel struts welded on a sheet metal bent, with "C" shape. The tubular supports for the PVC textiles and the supports for the rigid aluminum or polycarbonate panels are fixed on the steel structure.

The cladding of the "Biomediterraneo" Cluster is made of two materials: corrugated steel panels and colored polycarbonate panels.

The cladding of the "Cereals and Tubers" Cluster is made of galvanized steel profiles, with fewer connections in aluminum and wood, that supports the colored polycarbonate panels and fiber-cement. The cladding of the "Dry Areas" Cluster is made of steel struts with different length, which support a grid of colored PVC.

The cladding of the "Islands, sea and food" Cluster consists of a steel substructure on which is placed an opaque colored PVC sheet, in the lower part, and a colored PVC textile, in the upper part. It is pulled on metal struts with different length to create a "cloud" effect on the facades.

The final results (Figure 8) show that the highest impacts are related to the cladding system of the "Cereals and Tubers" Cluster. In this system the use of polycarbonate and fiber-cement panels and the use of aluminum-wood substructure, cause an increase of the emissions in the atmosphere. The polycarbonate panels are used even in the "Biomediterraneo" Cluster, but in smaller amount. The lowest value belongs to the "Dry Areas" Cluster, because of the amount of steel for the substructure and of the PVC grid textile are lower than in the other cases.

For each Cluster the steel structure has a greater impacts than the other materials. The same cladding system is used in the "Islands, sea and food" Cluster, but the impacts are twice as much as the previous one. This happens because in this Cluster there is a greater articulation of the supporting substructure and an increased use of PVC textile. It is necessary to remind that the amount of materials of the first three Clusters were acquired by preliminary bill of materials and preliminary projects, while the amount of materials in the "Islands" Cluster was analyzed in details.

ENVIRONMENTAL IMPACT OF ENVELOPE TO m^2

IMPACT CATEGORY	u.o.m	BIOMED.	CEREALS & TUBERS	DRY LANDS	ISLANDS
Acidification	kg SO_2 eq E-2	41,26	67,68	4,21	9,08
Eutrophication	kg PO_4 eq E-2	11,03	17,46	1,50	2,80
Global warming (GWP100)	kg CO_2 eq	63,04	124,30	10,58	19,48
Photochemical oxidation	kg C_2H_4 eq E-2	26,36	45,36	5,79	10,14
Ozone layer depletion (ODP)	kg CFC_{-11} eq E-6	16,53	29,90	3,31	7,96
Abiotic depletion	kg Sb eq E-4	28,21	95,14	9,64	25,55
Non renewable, fossil and nuclear	MJ E1	68,66	132,36	11,58	21,83

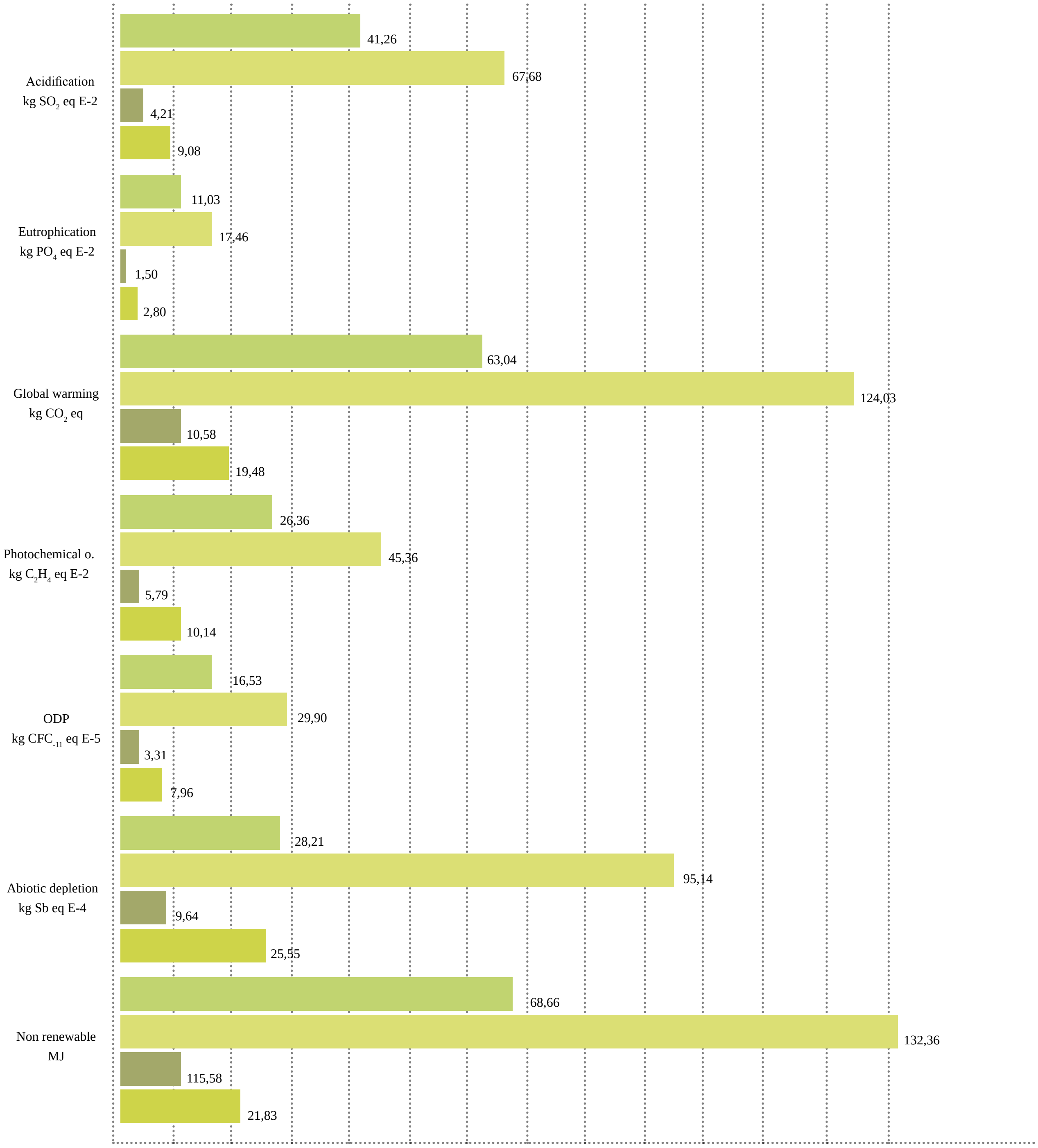


Figure 8. Anthropogenic emissions produced by Clusters envelope m^2

3. Products and systems for temporary buildings: qualitative and quantitative criteria to support decisions

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Dept. of Architecture, Built Environment and Construction Engineering (ABC)

Reducing environmental impacts of mega events temporary buildings requires both the development of an awareness on the issue of temporality in relation to sustainability and the definition of innovative methods and tools for the management of environmental information to foster its diffusion and traceability.
Starting from the specific case study of Expo Milano 2015, the research group has developed two different datasheet templates to assess the environmental profile at both the level of construction products and building systems.
As can be seen from the datasheet templates proposed in the following pages, these documents have been defined by selecting a group of qualitative and quantitative criteria which are useful to assess the environmental profile of products and and construction solutions.
The adoption of this tool represents a valid aid for:
- organizers of mega events who can adopt these environmental datasheets both as a support tool for evaluating the sustainability of the structures proposed by designers and as an informative parameter useful to develop guidelines to be delivered to designers;
- designers who can adopt these datasheets both as a design support tool to evaluate the sustainability of products and systems chosen for their projects and as a decision support tool to make comparisons among different materials and solutions.
The choice of the assessment criteria has been carried out by focusing the attention not only on those quantitative indicators which are typical of an LCA[1] analysis (Global Warming Potential GWP, Ozone Depletion Potential ODP, etc.), but also on a series of qualitative parameters, such as the installation and assembling technology or the end of life scenarios, which are significative in the case of temporary buildings.
All the selected parameters, both at the product and system level, have been organized in four categories.

General features

At the system level, it is declared each component which has been considered as part of the building solution (e.g. the system datasheet of a plasterboard wall takes into account: plasterboard panels, metal substructure, fasteners) and its weight percentage in relation to the total weight system.
In this first information category, it is also declared the production site of each component and the assembling place and construction technology of the system.
At the level of product indeed, they are described all the substances of whom is made the product

1 Life Cycle Assessment

and their weight percentage in relation to the reference unit which has been considered (e.g. 1 m^2 of plasterboard is made of 99% gypsum and 1% paper sheets). Then, it is declared the production site, the raw material supply and the reference service life of the product.

Environmental impact

Both in the system and product datasheet, all the environmental indicators, which have been considered significative to assess the environmental profile of a product/system (GWP, ODP, AP, EP, POCP, ADPe, ADPf)[2], are declared in their units of measure.

At the system level, values associated to environmental impacts are expressed in relation to each component and they are referred just to the product stage (A1= raw material supply; A2= transport to production site; A3= production). At the level of the product indeed, environmental impacts are expressed in relation to the reference unit which has been considered and they refer also to other lifecycle phases, not only to the product stage (C1= deconstruction/demolition; C2= transport; C3= waste processing; C4= landfilling; D= reuse, recycling or energy recovery potential).

Resource use

Both in the system and product datasheets, there is a quantitative evaluation of the total use of primary energy (renewable and non-renewable) and of fresh water resources. It is also declared the potential recycled content of the product or system and if manufacturers have obtained some certifications about responsible extraction of raw materials (FSC, PEFC, etc.).

End of life

Both at the system and product level, there is a focus about potential reuse, recycling and energy recovery scenarios. At the system level, they are also specified conditions (e.g. dry construction technology) which facilitate these end-of-life scenarios.

Both the datasheets are accompanied by an image which describes the analysed product/system.

At the top of the documents it is also declared the reference unit according which all the values, which appear in the datasheet, are expressed.

In order to get information useful to complete these datasheets, Environmental Product Declarations (EPDs) represent the best data-sources. [EPDs are documents which assess the environmental impacts of products and systems. They are usually commissioned by manufacturers and collected in open-source platforms such as environdec.com or bau-umwelt.de].

It is also possible to assume databases as information sources. For example the Ecoinvent database, which has been developed at ETH Zurich, represents a well-developed and complete database where to get information about environmental impacts of different materials.

Data-sources should be chosen in order to get information as much as possible consistent and coherent with the product or system whose environmental profile wants to be assessed. Thus, if it is possible, it is better to get information from EPDs than from inventories or databases.

2 For the meaning of the abbreviations, see the datasheet templates proposed in the following pages.

It has to be underlined that in the EPDs data are not always related to all the lifecycle phases (A1-A3= product stage; A4-A5= construction process stage; B1-B7= use stage; C1-C4= end of life stage; D= reuse, recycling or energy recovery potential) by adopting a "from cradle to cradle" approach. It is more frequent that EPDs data refer only to the product stage (A1= raw material supply; A2= transport to production site; A3= production) by adopting a "from cradle to gate" approach. Indeed, information about the environmental impacts of the production phase are fundamental in order to assess the environmental profile of a product/system.

SYSTEM DATASHEET

Reference unit [m²]
Component 1 [quantity (qty) | dimensions (dim) | thickness (thk) | density (dens) | weight (wt)]
Component 2 [quantity | dimensions | thickness | weight]
Component 3 [quantity | dimensions | thichness | weight]
Total system weight [kg]

image

GENERAL FEATURES [SOURCE OF DATA]

%	Description and percent composition (by weight) of the system components
	Production site - Assembling place
	Installation - Assembling technology

ENVIRONMENTAL IMPACT [SOURCE OF DATA]

		Component 1 Source of data	Component 2 Source of data	Component 3 Source of data	Tot. amount	UM*
GWP	Global Warming Potential					[kg CO_2 eq]
ODP	Ozone Depletion Potential					[kg CFC-11 eq]
AP	Acidification Potential of soil and water					[kg SO_2 eq]
EP	Eutrophication Potential					[kg $(PO_4)^{3-}$eq]
POCP	Photochemical Ozone Creation Potential					[kg C_2H_4eq]
ADPe	Abiotic Depletion Potential for Elements					[kg Sb eq]
ADPf	Abiotic Depletion Potential of Fossil Fuels					[MJ]

RESOURCE USE [SOURCE OF DATA]

Total use of renewable primary energy	[MJ]
Total use of non-renewable primary energy	[MJ]
Use of fresh water resources	[m³]
Recycled content (specifying if pre-consumer recycled content or post-consumer recycled content)	
Responsible extraction of raw materials (FSC, PEFC, etc.)	

END OF LIFE [SOURCE OF DATA]

Conditions of the system components to facilitate reuse

Conditions of the system components to facilitate recycling process

Conditions of the system components to facilitate energy recovery

* UM = Unit of Measure

PRODUCT DATASHEET [manufacturer]

Reference unit [m^2/m^3/kg/ton]
Dimensions [mm] | Thickness [mm]
Density [kg/m^3]
Weight [kg/m^2]

image

GENERAL FEATURES [SOURCE OF DATA]

- Description and percent composition (by weight) of the product
- Production site - Raw material supply
- Reference Service Life

ENVIRONMENTAL IMPACT [SOURCE OF DATA]

	Production			Use	End of life				RRR	UM
	A1	A2	A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP Global Warming Potential										[kg CO_2 eq]
ODP Ozone Depletion Potential										[kg CFC-11 eq]
AP Acidification Potential of soil and water										[kg SO_2 eq]
EP Eutrophication Potential										[kg $(PO_4)^{3-}$ eq]
POCP Photochemical Ozone Creation Potential										[kg C_2H_4 eq]
ADPe Abiotic Depletion Potential for Elements										[kg Sb eq]
ADPf Abiotic Depletion Potential of Fossil Fuels										[MJ]

RESOURCE USE [SOURCE OF DATA]

Total use of renewable primary energy (PERT)	[MJ]
Total use of non-renewable primary energy (PENRT)	[MJ]
Use of fresh water resources (FW)	[m^3]
Recycled content (specifying if pre-consumer recycled content or post-consumer recycled content)	
Responsible extraction of raw materials (FSC, PEFC, etc.)	

END OF LIFE [SOURCE OF DATA]

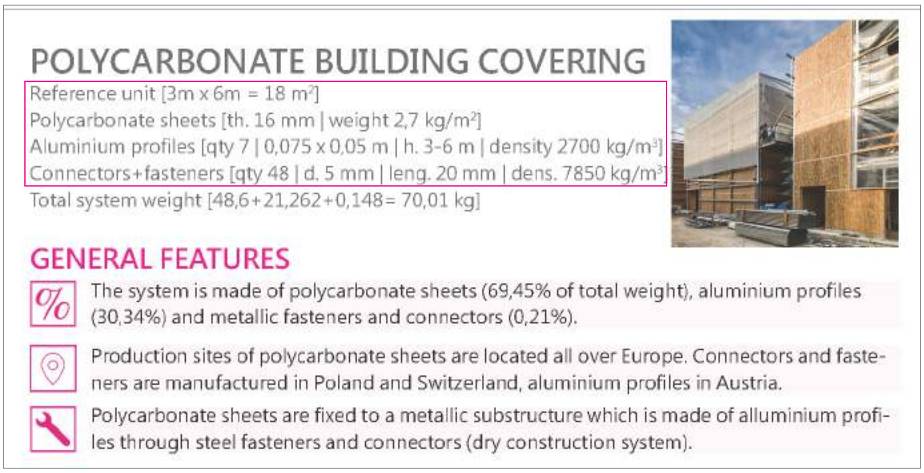
Material for re-use	[kg]
Material for recycling	[kg]
Material for energy recovery	[kg]

* nd = not declared

Here below it is proposed the guided example of the system "Polycarbonate building covering" which explains how to complete the datasheet.

As first step, it is necessary to establish which components of the system have to be considered. In this case: polycarbonate sheets, aluminium profiles, steel fasteners and connectors. Then it must be established the reference unit of the system according which all the values are expressed. In this case it is equal to 18 m^2 (6 m x 3 m).

For each component of the system, it has to be declared: quantity, in relation to the established reference unit (e.g. how many fasteners are necessary for this 18 m^2 building envelope), dimensions (e.g. thickness of polycarbonate sheets), density (e.g. density of aluminium profiles equal to 2700 kg/m^3) and, if this data is not available, weight.


POLYCARBONATE BUILDING COVERING

Reference unit [3m x 6m = 18 m^2]

Polycarbonate sheets [th. 16 mm | weight 2,7 kg/m^2]

Aluminium profiles [qty 7 | 0,075 x 0,05 m | h. 3-6 m | density 2700 kg/m^3]

Connectors+fasteners [qty 48 | d. 5 mm | leng. 20 mm | dens. 7850 kg/m^3]

Total system weight [48,6+21,262+0,148= 70,01 kg]

GENERAL FEATURES

The system is made of polycarbonate sheets (69,45% of total weight), aluminium profiles (30,34%) and metallic fasteners and connectors (0,21%).

Production sites of polycarbonate sheets are located all over Europe. Connectors and fasteners are manufactured in Poland and Switzerland, aluminium profiles in Austria.

Polycarbonate sheets are fixed to a metallic substructure which is made of alluminium profiles through steel fasteners and connectors (dry construction system).

Once defined density values of each component, it is possible to calculate the total system weight. For example, in the case of the polycarbonate building envelope, it is calculated the weight of each system component by multiplying volume and density.

Weight [kg]= density [kg/m^3] x volume [kg]

Volume [m^3]= quantity x (surface [m^2] x thickness [m])

Volume [m^3]= quantity x (pi x r^2 [m^2] x height [m])

POLYCARBONATE SHEETS (quantity= 6; weight= 2,7 kg/m^2; dimensions= 2 m x 1,5 m; thickness= 0,016 m)

Weight= 2,7 kg/m^2 x (6 x 2 m x 1,5 m) x 0,016 m = **48,6 kg**

ALUMINIUM PROFILES (density= 2700 kg/m^3; dim= 0,075 m x 0,05 m; thickness= 0,0015 m)

TYPE A (quantity= 4; height= 3 m)

TYPE B (quantity= 3; height= 6 m)

Weight= 2700 kg/m^3 x [4(0,175 m x 3 m) + 3(0,175 m x 6 m)] x 0,0015 m= **21,2625 kg**

STEEL FASTENERS (quantity= 48; density= 7850 kg/m^3; diameter= 0,005 m; height= 0,03 m)

Weight= 7850 kg/m^3 x [48(pi x $0,0025^2$ m^2 x 0,03 m)]= **0,221841 kg**

Once having calculated the weight of each component (or assumed information by technical files), it

is also possible to define the percent composition (by weight) of the system.
Then, by assuming data which are available in the technical files or in the EPDs, the following two criteria “Production site/Assembling place and “Installation/Assembling technology” can be completed.

POLYCARBONATE BUILDING COVERING

Reference unit [3m x 6m = 18 m²]
Polycarbonate sheets [th. 16 mm | weight 2,7 kg/m²]
Aluminium profiles [qty 7 | 0,075 x 0,05 m | h. 3-6 m | density 2700 kg/m³]
Connectors+fasteners [qty 48 | d. 5 mm | leng. 20 mm | dens. 7850 kg/m³]
Total system weight [48,6+21,262+0,148= 70,01 kg]

GENERAL FEATURES

The system is made of polycarbonate sheets (69,45% of total weight), aluminium profiles (30,34%) and metallic fasteners and connectors (0,21%).

Production sites of polycarbonate sheets are located all over Europe. Connectors and fasteners are manufactured in Poland and Switzerland, aluminium profiles in Austria.

Polycarbonate sheets are fixed to a metallic substructure which is made of alluminium profiles through steel fasteners and connectors (dry construction system).

The second information category, which is named “Environmental impact”, can be drawn up by getting data related to environmental impacts, as expressed by the EPDs of the products or by a LCA database, and multiplying them for the effective quantities of the system.
For example, the EPD of the polycarbonate sheets declares 1 kg as reference unit. Thus, in order to obtain the effective environmental impacts of the policarbonate sheets which make of the system, it is necessary to multiply all the values for 48,6 kg (weight of the polycarbonate sheets in the system).

ENVIRONMENTAL IMPACT [LCA data related to the product stage A1 + A2 + A3]

	Polycarbonate sheets EPD data reworking	Aluminium profiles EPD data reworking	Connec.+fasteners EPD data reworking	Tot. amount	UM
GWP	200,718	132,465	0,645	333,829	[kg CO_2 eq]
ODP	48,6	3,7 E-7	2,529 E-10	48,6	[kg CFC-11 eq]
AP	363,042	1,356	0,16 E-2	36,44 E-1	[kg SO_2 eq]
EP	44,712	35,296 E-3	14,641 E-5	0,447 E-2	[kg $(PO_4)^3$ eq]
POCP	78,246	6,676 E-2	12,489 E-5	0,783 E-2	[kg C_2H_4eq]
ADPe	352,836 E-6	0,017 E-2	13,843 E-6	0,0005	[kg Sb eq]
ADPf	4325,4	1320,401	7,787	5653,588	[MJ]

POLYCARBONATE SHEETS (EPD reference unit= 1 kg)
Weight (system)= 48,6 kg

GWP (reference unit)= 4,13 kg CO_2 eq
GWP (system)= 4,13 x 48,6= **200,718 kg CO_2 eq**
ODP (reference unit)= 1,99 E-4 kg CFC-11 eq
OPD (system)= 1,99 E-4 x 48,6= **48,6 kg CFC-11 eq**

AP (reference unit)= 7,47 kg SO_2 eq

AP (system)= 7,47 x 48,6= **363,042 kg SO_2 eq**

EP (reference unit)= 0,92 kg $(PO_4)^{3-}$eq

EP (system)= 0,92 x 48,6= **44,712 kg $(PO_4)^{3-}$eq**

POCP (reference unit)= 1,61 kg C_2H_4eq

POCP (system)= 1,61 x 48,6= **78,246 kg C_2H_4eq**

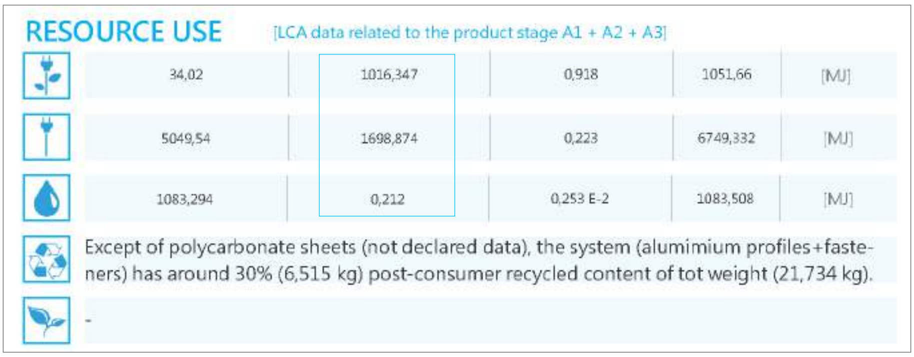
ADPe (reference unit)= 7,26 E-6 kg Sb eq

ADPe (system)= 7,26 E-6 x 48,6= **352,836 E-6 kg Sb eq**

ADPf (reference unit)= 89 MJ

ADPf (system)= 89 x 48,6= **4325,4 MJ**

The third information category, which reports the total use of primary energy (renewable and non-renewable) and of fresh water resources, can be completed by following the same procedure. Assuming EPDs data, which, for example, in the case of aluminium profiles are expressed according to the functional unit of 1 kg, it is necessary to multiply all the values for the effective quantity in the system (21,2625 kg).



Total use of renewable primary energy | PERT (reference unit)= 47,8 MJ

PERT (system)= 47,8 x 21,2625= **1016,347 MJ**

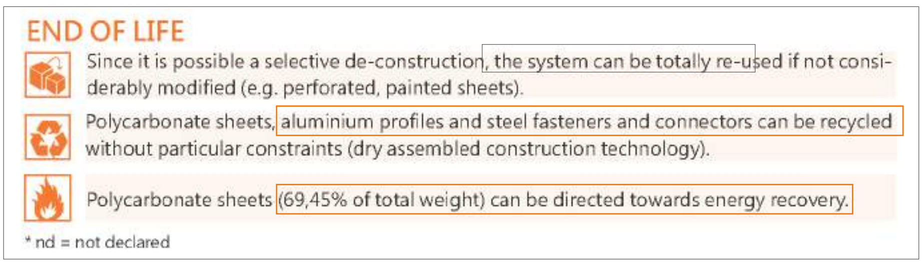
Total use of non-renewable primary energy | PENRT (reference unit)= 79,9 MJ

PENRT (system)= 79,9 x 21,2625= **1698,874 MJ**

Use of fresh water resources | FW (reference unit)= 0,00996 m^3

FW (system)= 0,00996 x 21,2625 m^3= **0,212 m^3**

The last information category, which is named "End of life" aims to describe end of life scenarios by declaring if the system is reusable, recyclable or if it can be directed towards thermal recycling.
As for the other parameters, also these data can be get from EPDs or from the technical information of the products which are directly supplied by manufacturers.



The datasheet template can be assumed also to make comparisons between different system solutions. The guided example proposed above describes the environmental profile of a single building envelope with a metal substructure and a cladding policarbonate sheets, but what if I would assess the environmental impacts of two different system solutions in order to choose the more sustainable one?

For example I can make a comparison between a building envelope with GRC cladding panels and another one with a PVC membrane.
In this case the methodology is the same as the guided example above.
It has to be chosen a reference unit which, also in this case, may be still 18 m^2 (6 m x 3 m). [This area is a good assumption as functional unit because, in the case of a building envelope, it is sufficiently vaste to rightly assess fasteners and connectors (1 m^2, for example, may be too little).]
After having assumed the functional unit, it is necessary to get information (density, dimensions, etc.) about all the components which make of the system. These information can be get from websites and technical files directly provided by manufacturers or, even better, from EPDs.

GRC PANEL
[Rieder Smart Elements]
Reference unit [1 ton]
Thickness [13 mm]
Weight [26-31,5 kg/m^2]
Density [2000-2420 kg/m^3]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

GRC panels are manufactured from sand and cement (90% of total weight), glass fibers, pigments and other additives (10%).

Production site of GRC panels is located in Kolbermoor (Germany).

Reference service life of the product is more than 50 years.

If the EPD of the product is available, also the environmental impacts can be directly get from there, instead of calculating them with inventory data, but it is important to pay attention to the functional unit according which each EPD has been developed. For example the EPD of GRC panels assumes 1 ton as functional unit; indeed, that one of the PVC membrane 1 m^2.

PVC MEMBRANE
[Mehler Texnologies]
Reference unit [1 m^2]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

PVC membrane is made of polyvinylchloride (PVC, 35% of total weight), polyethersulfone (PES, 30%), di-isononyl phthalat (DINP, 20%), others (titanium dioxide-flame retardants, 15%).

Production site of PVC membrane is located in Fulda (Germany).

Reference service life of the product is equal to 20/25 years.

Considering the area which has been considered as reference unit of the system (18 m^2), the environmental impacts, which are expressed in the two EPDs and thus related to a different reference unit (GRC panels - 1 ton | PVC membrane 1 m^2), have to be converted as it follows.

GRC PANELS (EPD reference unit= 1 ton; weight= 26-31,5 kg/m^2)
Weight (system)= 28,75 kg/m^2 x 18 m^2= 517,5 kg

GWP (reference unit)= 726 kg CO_2 eq
GWP (system)= (726 / 1000) x 517,5 kg= **375,705 kg CO_2 eq**
ODP (reference unit)= 4,384 E-6 kg CFC-11 eq
OPD (system)= (4,384 E-6 / 1000) x 517,5 kg= **2,269 E-6 kg CFC-11 eq**
AP (reference unit)= 2,098 kg SO_2 eq
AP (system)= (2,098 / 1000) x 517,5 kg= **1,086 kg SO_2 eq**
EP (reference unit)= 0,219 kg $(PO_4)^{3-}$eq
EP (system)= (0,219 kg / 1000) x 517,5 kg= **0,113 kg $(PO_4)^{3-}$eq**
POCP (reference unit)= 0,229 kg C_2H_4eq
POCP (system)= (0,229 / 1000) x 517,5 kg= **0,118 kg C_2H_4eq**
ADPe (reference unit)= 0,005 kg Sb eq
ADPe (system)= (0,005 / 1000) x 517,5 kg= **0,003 kg Sb eq**
ADPf (reference unit)= 8819 MJ
ADPf (system)= (8819 / 1000) x 517,5 kg= **4563,832 MJ**

PVC MEMBRANE (EPD reference unit= 1m^2)

GWP (reference unit)= 4,716 kg CO_2 eq
GWP (system)= 4,716 x 18= **84,888 kg CO_2 eq**
ODP (reference unit)= 7,603 E-8 kg CFC-11 eq
OPD (system)= 7,603 E-8 x 18= **1,368 E-6 kg CFC-11 eq**
AP (reference unit)= 1,631 E-2 kg SO_2 eq
AP (system)= 1,631 E-2 x 18= **0,293 kg SO_2 eq**
EP (reference unit)= 1,912 E-3 kg $(PO_4)^{3-}$eq
EP (system)= 1,912 E-3 x 18= **0,034 kg $(PO_4)^{3-}$eq**
POCP (reference unit)= 2,784 E-3 kg C_2H_4eq
POCP (system)= 2,784 E-3 x 18= **0,05 kg C_2H_4eq**
ADPe (reference unit)= 1,46 E-2 kg Sb eq
ADPe (system)= 1,46 E-2 x 18= **0,263 kg Sb eq**
ADPf (reference unit)= 8,987 E+1 MJ
ADPf (system)= 8,987 E+1 x 18= **1617,66 MJ**

By making a comparison between the environmental impacts of these two 18 m^2 building claddings,

it is clear that the GRC panels have higher environmental impacts than the PVC membrane.
Nevertheless, it has to be underlined that the PVC mebrane guarantees a reference service life of 20/25 years, GRC 50 years. Thus, if it would be made a coherent comparison between these two products, in the case of a permanent building, also the differents values of the reference service life have to be considered by, for example, doubling the environmental impacts of the PVC membrane. Indeed, in the case of temporary structures, the choice of a PVC membrane in comparison with the GRC cladding panels is a right choice, because it has lower environmental impacts and a shorter reference service life.
Moreover, it has to be underlined that, in order to assess the more sustainable solution, it has to be considered the system level, not only products by themselves. Thus, in this case, also other components, which can modify a lot the values of environmental impacts, have to be considered (e.g. supporting substructure and fasteners/connectors). Just by summing up the environmental impacts of all the components of a system (e.g GRC panels + supporting substructure + fasteners/connectors), it is possible to assess the environmental profile of a system or to make comparison between different solutions. For example, the GRC panels may have a different supporting system (substructure and fasteners), and thus different environmental impacts, in comparison with a PVC membrane. Indeed, it is possible to make a comparison between a GRC panels and a polycarbonate cladding systems, because it can be assumed that they have a similar supporting system (metal substructure + steel fasteners).

POLYCARBONATE SHEETS (reference unit= 18 m^2)

GWP (system)= **200,718 kg CO_2 eq**
OPD (system)= **48,6 kg CFC-11 eq**
AP (system)= **363,042 kg SO_2 eq**
EP (system)= **44,712 kg $(PO_4)^{3-}$eq**
POCP (system)= **78,246 kg C_2H_4eq**
ADPe (system)= **352,836 E-6 kg Sb eq**
ADPf (system)= **4325,4 MJ**

GRC PANELS (reference unit= 18 m^2)

GWP (system)= **375,705 kg CO_2 eq**
OPD (system)= **2,269 E-6 kg CFC-11 eq**
AP (system)= **1,086 kg SO_2 eq**
EP (system)= **0,113 kg $(PO_4)^{3-}$eq**
POCP (system)= **0,118 kg C_2H_4eq**
ADPe (system)= **0,003 kg Sb eq**
ADPf (system)= **4563,832 MJ**

By making a comparison between the environmental impacts of these two 18 m^2 building claddings, it is clear that the solution with polycarbonate sheets have higher environmental impacts than the GRC panels cladding system.

As already underlined, the role of the reference unit is really important to assess the environmental impacts of a construction product/system and, in the case of comparisons between different solutions, it has to be univocally defined for both the systems.

The reference unit represents the quantity of product necessary to ensure the performance, so it is strictly related to the product/system which is considered. For example, the quantity of product which is necessary to ensure a thermal resistance of 1 m^2K/W to an area of 1 m^2 may be a good choice to compare alternative insulating materials.

For example, by assuming three insulating materials with different density values, as:

- rock wool | 0,035 W/mK | thickness 35 mm | density 60 kg/m^3
- glass wool | 0,036 W/mK | thickness 36 mm | density 20 kg/m^3
- cellulose | 0,040 W/mK | thickness 40 mm | density 32 kg/m^3

the quantity of products to ensure the performance may be very different:

- rock wool= 2,100 kg
- glass wool= 0,720 kg
- cellulose= 1,280 kg

Thus, these reasonings clearly point out that the role of the reference unit is really important because it can change a lot the value of environmental impacts. For example, if it is necessary more quantity of rock wool (2,1 kg) to ensure the performance than the solution with glass wool (0,72 kg), it is likely to assume that the first solution may have more environmental impacts than the second one.

The importance of the reference unit and the assessment of environmental impacts not only at the product level but rather at the system level have been assumed by the research group as key-points by testing the developed datasheet templates. In fact, in order to explain the "contruction" of the environmental information, the two datasheet templates (product datasheet - system datasheet) have been applied to a sample of products and systems chosen for the Expo Milano 2015 pavillions.

The products and systems have been chosen according to the EPDs availability. Thus, they represent just an example and they have not been necessarily used in the Expo Milano 2015 pavillions.

In the following pages can be seen the completed datasheets.

GLUED LAMINATED TIMBER PORTAL

Columns [qty 2 | dim 0,8 m x 0,2 m x 9,4 m | density 508,37 kg/m³]
Beams [qty 1 | dim 0,8 m x 0,2 m x 11 m| density 508,37 kg/m³]
Connectors and fasteners [wgt 57,738 kg]
Total system weight [1529,177+894,731+57,738= 2481,646 kg]

GENERAL FEATURES

- The system is made of glue laminated timber (glulam) columns (62% of total weight), glulam beams (36%) and stainless steel connectors and fasteners (2%).
- Production sites of glulam columns and beams, as well as those ones of connectors and fasteners, are located in Germany.
- Columns and beam are fixed together trough metallic connectors and fasteners (dry construction system).

ENVIRONMENTAL IMPACT [LCA data related to the product stage A1 + A2 + A3]

	Glulam columns EPD data reworking	Glulam beam EPD data reworking	Connect.+fasteners EPD data reworking	Tot. amount	UM
GWP	-1942,356	-1136,485	168,017	-2910,823	[kg CO_2 eq]
ODP	6,362 E-5	3,722 E-5	6,582 E-8	1009,09 E-7	[kg CFC-11 eq]
AP	2,364	1,383	0,415	41,635 E-1	[kg SO_2 eq]
EP	0,463	0,271	0,038	77,271 E-2	[kg $(PO_4)^{3-}$eq]
POCP	0,445	0,260	0,032	73,807 E-2	[kg C_2H_4eq]
ADPe	0,202 E-2	0,119 E-2	0,004	0,682 E-2	[kg Sb eq]
ADPf	6564,358	3840,848	2026,604	12431,81	[MJ]

RESOURCE USE [LCA data related to the product stage A1 + A2 + A3]

	33372,948	19526,725	336,612	53236,285	[MJ]
	8760,198	5125,648	239,035	14124,882	[MJ]
	4846,309	2835,606	0,658	7682,574	[MJ]

- Except of glulam colums and beam which do not have any recycled content, the system has around 2% (57,738 kg) post consumer recycled content of the total weight (2481,646 kg).
- FSC and PEFC certification of the structural glued laminated timber.

END OF LIFE

- Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. damaged, painted columns/beams etc.).
- The dry-assembled system is totally recyclable. Stainless steel connectors and fasteners can be recycled without particular constraints, as well as glued laminated timber.
- Glulam columns and beams (98% of total weight) can be directed towards energy recovery.

* nd = not declared

STRUCTURAL GLUED LAMINATED TIMBER [BS Holz]

Reference unit [1 m³]
Density [508,37 kg/m³]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

Glued laminated timber is manufactured from coniferous species, mainly spruce fir (87,45% of the total weight), water (10,45%), MUF** adhesives (1,94%), PRF** (0,09%), PUR** (0,03%).

Production sites of the members of the BS Holz association are located all over Germany.

Reference service life of the product is more than 100 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production			Use	End of life				RRR	UM
	A1	A2	A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP	-7,548 E+2	3,674 E+1	7,233 E+1	-	-	4,589 E-1	8,188 E+2	0,0 E+0	-3,724 E+2	[kg CO_2 eq]
ODP	5,126 E-6	1,944 E-6	1,408 E-5	-	-	9,0 E-10	1,186 E-6	0,0 E+0	-8,511 E-5	[kg CFC-11 eq]
AP	2,423 E-1	1,825 E-1	3,613 E-1	-	-	1,97 E-3	6,981 E-3	0,0 E+0	-3,829 E-1	[kg SO_2 eq]
EP	6,135 E-2	3,098 E-2	6,714 E-2	-	-	4,565 E-4	5,893 E-4	0,0 E+0	-3,715 E-3	[kg $(PO_4)^{3-}$eq]
POCP	4,453 E-2	1,642 E-2	8,703 E-2	-	-	2,132 E-4	4,642 E-4	0,0 E+0	-2,565 E-2	[kg C_2H_4eq]
ADPe	5,371 E-4	1,17 E-6	1,357 E-4	-	-	9,7 E-9	1,225 E-7	0,0 E+0	-6,454 E-6	[kg Sb eq]
ADPf	8,804 E+2	4,89 E+2	8,129 E+2	-	-	6,475 E+0	4,616 E+1	0,0 E+0	-4,194 E+3	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de + website brettschichtholzde]

	9,195 E+3	1,173 E+1	1,888 E+3	-	-	8,578 E-3	4,701 E+0	0,0 E+0	-3,388 E+2	[MJ]
	1,055 E+3	5,573 E+2	1,3 E+3	-	-	6,507 E+0	8,777 E+1	0,0 E+0	-7,617 E+3	[MJ]
	8,233 E+2	8,594 E+1	7,019 E+2	-	-	1,22 E-1	4,987 E+1	0,0 E+0	3,475 E+3	[m³]

The product does not have any recycled content.

FSC and PEFC certification.

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

Glued laminated timber is totally re-usable.

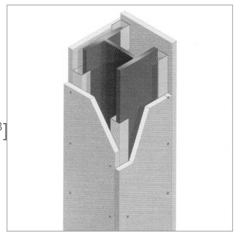
Glued laminated timber is 100% recyclable. The secundary material is applied in the production of wood based panels (e.g. chipboards).

Glued laminated timber can be totally directed towards energy recovery.

* nd = not declared
** MUF= melamine-urea-formaldehyde ** PRF= phenol-resorcin-formaldehyde ** PUR= polyurethane adhesives

COATED STEEL PROFILE

HEA 240 profile [qty 1 | h. 4 m | wgt 60,3 kg/ml]
Gypsum board [qty 8 | dim 0,30 x 2 m | wgt 10 kg/m²]
Aluminium profile [qty 4 | dim 0,075 x 0,05 m | h. 4 m | density 2700 kg/m³]
Fasteners [qty 160 | d. 5 mm | leng. 20 mm | density 7850 kg/m³]
Total system weight [241,2 + 48 + 11,34 + 0,493 = 301,033 kg]



GENERAL FEATURES

The system is made of a steel profile (80% of total weight), gypsum boards (16%), aluminium profiles (3,8%) and stainless steel fasteners (0,2%).

Production sites of steel profiles and gypsum boards are located all over Germany. Fasteners are manufactured in Poland and Switzerland, aluminium profiles in Austria.

The steel profile is covered with gypsum boards which are fixed to a metallic substructure made of alluminium profiles through steel fasteners (dry construction system).

ENVIRONMENTAL IMPACT [LCA data related to the product stage A1 + A2 + A3]

	HEA 240 profile EPD data reworking	Gypsum boards EPD data reworking	Alum. profiles EPD data reworking	Fasteners EPD data reworking	Total	UM
GWP	418,482	14,784	70,6482	1,434	505,349	[kg CO_2 eq]
ODP	3,353 E-8	1,872 E-9	1,973 E-7	5,62 E-10	2,333 E-7	[kg CFC-11 eq]
AP	0,849	0,019	0,723	3,547 E-3	15,956 E-1	[kg SO_2 eq]
EP	0,089	0,335 E-2	0,019	3,254 E-4	11,174 E-2	[kg $(PO_4)^{3-}$eq]
POCP	0,168	18,624 E-4	0,036	2,775 E-4	20,61 E-2	[kg C_2H_4eq]
ADPe	0,687 E-4	6,96 E-4	9,31 E-5	3,076 E-5	0,089 E-2	[kg Sb eq]
ADPf	4100,4	227,184	704,214	17,303	5049,101	[MJ]

RESOURCE USE [LCA data related to the product stage A1 + A2 + A3]

	2026,08	8,832	542,052	2,874	2579,838	[MJ]
	4293,36	227,184	906,066	2,041	5428,651	[MJ]
	0,639	36,144	0,113	0,006	36,902	[MJ]

The system (steel profile+gypsum boards+aluminium profiles+steel fasteners) has around 60% (180,175 kg) post consumer recycled content of the total weight (301,033 kg).

-

END OF LIFE

Since it is possible a selective de-construction, all the components of the system can be re-used, if not considerably modified (e.g. perforated, painted boards etc.).

Gypsum boards can be recycled by specific plants (e.g. KnaufRecycling project). Steel/aluminium profiles and metallic fasteners are recycled without particular constraints by steelworks.

Cellulose fibers, once separated from gypsum core in specific recycling plants, can be directed towards energy recovery.

* nd = not declared

STRUCTURAL STEEL PROFILE [bauforumstahl]

Reference unit [1 ton]

Density [7850 kg/m^3]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de + website bauforumstahl.de]

Structural steel profiles are mainly made of iron with a small carbon content between 0 and 0,6%. The content of other elements is significantly less.

Production sites of the members of the Bauforumstahl association are located all over Germany.

Reference service life of the product is not declared.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production A1 + A2 + A3	Use B1-5 nd*	End of life C1	C2	C3	C4	RRR D	UM [-]
GWP	1735	-	-	-	-	-	-959	[kg CO_2 eq]
ODP	1,39 E-7	-	-	-	-	-	6,29 E-9	[kg CFC-11 eq]
AP	3,52	-	-	-	-	-	-1,32	[kg SO_2 eq]
EP	3,7 E-1	-	-	-	-	-	-1,26 E-1	[kg $(PO_4)^{3-}$eq]
POCP	6,98 E-1	-	-	-	-	-	-4,14 E-1	[kg C_2H_4eq]
ADPe	2,85 E-4	-	-	-	-	-	-1,11 E-4	[kg Sb eq]
ADPf	17000	-	-	-	-	-	-7450	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	840	-	-	-	-	-	92,4	[MJ]
	17800	-	-	-	-	-	-7210	[MJ]
	2,65	-	-	-	-	-	-0,275	[m^3]

The product has around 62% (618 kg) post consumer recycled-content of the total weight (1000 kg).

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

Steel profiles can be reused. Currently, around 11% of the products manufactured by the members of the bauforumstahl association are re-used after dismantling.

Steel profiles are 100% recyclable without any problems after dismantling. Currently, around 88% of the products are used for closed-loop recycling.

-

* nd = not declared

FLOOR WITH PROFILED STEEL SHEET

Reference unit [3m x 1m = 3m²]
Profiled steel sheets [wgt 6,9 kg/m²]
OSB [th. 15 mm | wgt 9,3 kg/m²]
Fasteners [qty 20 | d. 8 mm | leng. 50 mm | density 7850 kg/m³]
Polyvinyl chloride floor covering [wgt 2,9 kg/m²]
Total system weight [20,7 + 55,8 + 0,591 + 8,7 = 85,791 kg]

GENERAL FEATURES

The system is made of profiled steel sheets (24% of the total weight), OSB (65%), metallic fasteners (1%) and polyvinyl chloride floor covering (10%).

Production sites of profiled steel sheets and fasteners are in Germany. Polyvinyl floor covering is manufactured in different places in Europe, OSB in Austria.

OSB panels are fixed to underlying profiled steel sheets through metallic fasteners (dry construction system). Polyvinyl chloride floor covering is glued together with OSB.

ENVIRONMENTAL IMPACT

[LCA data related to the product stage A1 + A2 + A3]

	Steel sheets EPD data reworking	OSB EPD data reworking	Fasteners EPD data reworking	Polyvinyl covering EPD data reworking	Total	UM
GWP	49,5	-83,79	1,721	23,4	-9.168	[kg CO_2 eq]
ODP	1,053 E-7	0,144 E-5	6,744	5,1 E-8	15,970 E-7	[kg CFC-11 eq]
AP	0,174	0,077	0,426 E-2	4,8 E-2	3,034 E-1	[kg SO_2 eq]
EP	1,476 E-2	0,015	0,039 E-2	6 E-3	3,582 E-2	[kg $(PO_4)^{3-}$eq]
POCP	22,74 E-3	0,013	0,033 E-2	16,8 E-3	5,292 E-2	[kg C_2H_4eq]
ADPe	0,399 E-2	0,848 E-4	3,691 E-5	8,1 E-5	0,419 E-2	[kg Sb eq]
ADPf	666	0,391	20,764	540	1227,156	[MJ]

RESOURCE USE

[LCA data related to the product stage A1 + A2 + A3]

	Steel sheets	OSB	Fasteners	Polyvinyl covering	Total	UM
	27	1,229	3,449	25,5	57,178	[MJ]
	690	0,428	2,449	540	1232,877	[MJ]
	267	0,209	0,007	132	399,215	[m³]

The system has around 2% (1,641 kg) post consumer recycled content of the total weight (85,791 kg).

-

END OF LIFE

The system is reusable for 25% of the total weight. OSB and polyvinyl chloride floor covering are not reusable, because they cannot be separated, since they are glued together.

Profiled metal sheets and metallic fasteners can be easily recycled by steelworks. OSB and polyvinyl chloride floor covering cannot be separated, thus also not recycled.

OSB as well as polyvinyl chloride floor covering (75% of total weight) can be directed towards energy recovery.

* nd = not declared

PROFILED STEEL SHEET [IFBS]

Reference unit [1m²]
Weight [6,9 kg/m²]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

Profiled steel sheets are made of a core of steel, which is protected against corrosion with a zinc coating (th. 0,75 µm - content of at least 99 weight percent zinc).

Production site of profiled steel sheets is located in Germany.

Reference service life of the product is around 40 - 45 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production A1 + A2 + A3	Use B1-5 nd*	End of life C1	C2	C3	C4	RRR D	UM
GWP	16,50	-	-	-	-	0,01	-9,62	[kg CO_2 eq]
ODP	3,51 E-8	-	-	-	-	9,35 E-12	2,80 E-9	[kg CFC-11 eq]
AP	0,058	-	-	-	-	0,000	-0,036	[kg SO_2 eq]
EP	4,92 E-3	-	-	-	-	7,93 E-6	-2,91 E-3	[kg $(PO_4)^{3-}$eq]
POCP	7,58 E-3	-	-	-	-	6,15 E-6	-5,49 E-3	[kg C_2H_4eq]
ADPe	1,33 E-3	-	-	-	-	3,41 E-9	-3,49 E-7	[kg Sb eq]
ADPf	222	-	-	-	-	0,13	-115	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	9	-	-	-	-	0	1	[MJ]
	230	-	-	-	-	0	-110	[MJ]
	89	-	-	-	-	-0,4	-14	[m³]

The product does not have any recycled content.

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

Thin walled profiled sheets made of steel can be collected and recycled after the phase of use.

Thin walled profiled sheets are 91% recyclable. It means that 6,5 kg of the reference unit are recycled for closed-loop recycling.

0

* nd = not declared

X-LAM FLOOR

Reference unit [3m x 1m = 3m²]
X-Lam panel [th. 0,3 m | density 491,65 kg/m³]
Connectors+Fasteners [wgt 0,488 kg]
Fiber reinforced concrete (FRC) panels [th. 0,01 m | density 1725 kg/m³]
Floating floor [wgt 48 kg/m²]
Total system weight [442,485+0,488+51,75+144 = 638,723 kg]

GENERAL FEATURES

The system is made of X-Lam panels (69,3% of total weight), steel fasteners and connectors (0,08%), FRC panels (8,1%) and floating floor (22,52%).

Production sites of X-Lam panels, steel fasteners and floating floor are located in Germany. FRC panels are manufactured in different places in Europe.

X-Lam panels are fixed to the structure through stainless steel fasteners and connectors. Floating floor is installed on FRC panels (dry construction system).

ENVIRONMENTAL IMPACT

[LCA data related to the product stage A1 + A2 + A3]

	X-Lam panels EPD data reworking	Conn.+fasteners EPD data reworking	FRC panels EPD data reworking	Floating floor EPD data reworking	Total	UM
GWP	-541,593		22,459	39,03	-478,683	[kg CO_2 eq]
ODP	2,949 E-5		1,966 E-6	21,27 E-9	3,148 E-5	[kg CFC-11 eq]
AP	0,605		7,4 E-2	12,57 E-2	0,812	[kg SO_2 eq]
EP	0,12		8,28 E-3	21,54 E-3	0,15	[kg $(PO_4)^{3-}$eq]
POCP	0,122		16,042 E-3	11,28 E-3	0,149	[kg C_2H_4eq]
ADPe	55,46 E-5		-	28,47 E-4	-	[kg Sb eq]
ADPf	2047,5		-	930,3	-	[MJ]

RESOURCE USE

[LCA data related to the product stage A1 + A2 + A3]

	9729,33		216,832	160,11	10109,118	[MJ]
	3053,7		355,47	1024,05	4437361	[MJ]
	2007,459		409,342	0,39	2417,197	[m³]

Except of FRC panels (not declared data), the system has around 9% (21,058 kg) post-consumer recycled content of total weight (638,723 kg).

-

END OF LIFE

Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. damaged, painted X-Lam panels).

The system is 100% recyclable. Dry assembled construction technology allows to separate and recycle each component of the system.

X-Lam panels (69,3% of total weight) can be directed towards energy recovery.

* nd = not declared

X-LAM PANEL
[BSP Holz]

Reference unit [1 m³]
Density [491,65 kg/ m³]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

X-Lam panels are manufactured from coniferous species, mainly spruce fir (87,5% of total weight), water (10,5%), MUF adhesives (1,4%), PUR (0,5%), PRF (0,1%).

Production sites of the members of the BSP Holz association are located all over Germany.

Reference service life of X-Lam panels is more than 100 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production			Use	End of life				RRR	UM
	A1	A2	A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP	-7,31 E+2	7,23	1,22 E+2	-	-	4,45 E-1	7,93E+2	0,00	-3,60 E+2	[kg CO_2 eq]
ODP	4,29 E-6	7,71 E-8	2,84 E-5	-	-	8,89 E-10	1,19E-6	0,00	-8,23 E-5	[kg CFC-11 eq]
AP	2,41 E-1	3,12 E-2	4,00 E-1	-	-	1,91 E-3	6,98 E-3	0,00	-3,70 E-1	[kg SO_2 eq]
EP	5,83 E-2	7,10 E-3	6,75 E-2	-	-	4,42 E-4	5,89 E-4	0,00	-3,55 E-3	[kg $(PO_4)^{3-}$eq]
POCP	5,19 E-2	3,18 E-3	8,01 E-2	-	-	2,07 E-4	4,64 E-4	0,00	-2,48 E-2	[kg C_2H_4eq]
ADPe	4,97 E-4	2,23 E-7	1,19 E-4	-	-	9,39 E-9	1,23E-7	0,00	-6,23 E-6	[kg Sb eq]
ADPf	8,55 E+2	1,00 E+2	1,32 E+3	-	-	6,28	4,62 E+1	0,00	-4,05 E+3	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	9,12 E+3	3,67 E-1	1,69 E+3	-	-	8,31 E-3	4,70	0,00	-3,28 E+2	[MJ]
	1,00 E+3	1,03 E+2	2,29E+3	-	-	6,31	8,78 E+1	0,00	-7,39 E+3	[MJ]
	8,06 E+2	4,51	1,42 E+3	-	-	1,18 E-1	4,99 E+1	0,00	3,36 E+3	[m³]

The product does not have any recycled content.

FSC and PEFC certification.

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

X-Lam panels are totally re-usable.

X-Lam panels are 100% recyclable. Secundary material is applied in the production of wood based panels (e.g. chipboards).

X-Lam panels can be totally directed towards energy recovery.

* nd = not declared

POLYCARBONATE BUILDING COVERING

Reference unit [3m x 6m = 18 m^2]
Polycarbonate sheets [th. 16 mm | weight 2,7 kg/m^2]
Aluminium profiles [qty 7 | 0,075 x 0,05 m | h. 3-6 m | density 2700 kg/m^3]
Connectors+fasteners [qty 48 | d. 5 mm | leng. 30 mm | dens. 7850 kg/m^3]
Total system weight [48,6+21,262+0,148= 70,01 kg]

GENERAL FEATURES

The system is made of polycarbonate sheets (69,45% of total weight), aluminium profiles (30,34%) and metallic fasteners and connectors (0,21%).

Production sites of polycarbonate sheets are located all over Europe. Connectors and fasteners are manufactured in Poland and Switzerland, aluminium profiles in Austria.

Polycarbonate sheets are fixed to a metallic substructure which is made of allluminium profiles through steel fasteners and connectors (dry construction system).

ENVIRONMENTAL IMPACT

[LCA data related to the product stage A1 + A2 + A3]

	Polycarbonate sheets EPD data reworking	Aluminium profiles EPD data reworking	Connec.+fasteners EPD data reworking	Tot. amount	UM
GWP	200,718	132,465	0,645	333,829	[kg CO_2 eq]
ODP	48,6	3,7 E-7	2,529 E-10	48,6	[kg CFC-11 eq]
AP	363,042	1,356	0,16 E-2	36,44 E-1	[kg SO_2 eq]
EP	44,712	35,296 E-3	14,641 E-5	0,447 E-2	[kg $(PO_4)^{3-}$eq]
POCP	78,246	6,676 E-2	12,489 E-5	0,783 E-2	[kg C_2H_4eq]
ADPe	352,836 E-6	0,017 E-2	13,843 E-6	0,0005	[kg Sb eq]
ADPf	4325,4	1320,401	7,787	5653,588	[MJ]

RESOURCE USE

[LCA data related to the product stage A1 + A2 + A3]

	34,02	1016,347	0,918	1051,66	[MJ]
	5049,54	1698,874	0,223	6749,332	[MJ]
	1083,294	0,212	0,253 E-2	1083,508	[MJ]

Except of polycarbonate sheets (not declared data), the system (alumimium profiles+fasteners) has around 30% (6,515 kg) post-consumer recycled content of tot weight (21,734 kg).

-

END OF LIFE

Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. perforated, painted sheets).

Polycarbonate sheets, aluminium profiles and steel fasteners and connectors can be recycled without particular constraints (dry assembled construction technology).

Polycarbonate sheets (69,45% of total weight) can be directed towards energy recovery.

* nd = not declared

POLYCARBONATE SHEETS [PlasticsEurope]

Reference unit [1 kg]
Thickness [16 mm]
Weight [2,7 kg/m²]

GENERAL FEATURES

[SOURCE OF DATA: EPD from plasticseurope.org + website plasticseurope.org]

Polycarbonate (PC) is a a thermoplastic moulding compound. It is a polymer which is made of identical units of bisphenol A connected by carbonate-linkages in its backbone chain.

Production sites of the members of the Plastics Europe association are located all over Europe.

Reference service life of the product is more than 25 years.

ENVIRONMENTAL IMPACT

[SOURCE OF DATA: EPD from plasticseurope.org]

	Production	Use	End of life				RRR	UM
	A1 + A2 + A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP	4,13	-	-	-	-	-	-	[kg CO_2 eq]
ODP	1,99 E–4	-	-	-	-	-	-	[kg CFC-11 eq]
AP	7,47	-	-	-	-	-	-	[kg SO_2 eq]
EP	0,92	-	-	-	-	-	-	[kg $(PO_4)^{3-}$eq]
POCP	1,61	-	-	-	-	-	-	[kg C_2H_4eq]
ADPe	7,26 E–6	-	-	-	-	-	-	[kg Sb eq]
ADPf	89	-	-	-	-	-	-	[MJ]

RESOURCE USE

[SOURCE OF DATA: EPD from plasticseurope.org]

	0,7	-	-	-	-	-	-	[MJ]
	103,9	-	-	-	-	-	-	[MJ]
	22,29	-	-	-	-	-	-	[MJ]
	-							
	-							

END OF LIFE

[SOURCE OF DATA: EPD from plasticseurope.org + website plasticseurope.org]

-

Polycarbonate sheets are 100% recyclable. Secundary material is applied in the production of e.g. new PC sheets and/or other plastic products.

Polycarbonate sheets can be totally directed towards energy recovery.

* nd = not declared

PVC MEMBRANE [Mehler Texnologies]

Reference unit [1 m²]

GENERAL FEATURES

[SOURCE OF DATA: EPD from bau-umwelt.de]

PVC membrane is made of polyvinylchloride (PVC, 35% of total weight), polyethersulfone (PES, 30%), di-isononyl phthalat (DINP, 20%), others (titanium dioxide-flame retardants, 15%).

Production site of PVC membrane is located in Fulda (Germany).

Reference service life of the product is equal to 20/25 years.

ENVIRONMENTAL IMPACT

[SOURCE OF DATA: EPD from bau-umwelt.de]

	Production	Use	End of life				RRR	UM
	A1 + A2 + A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP	4,716	-	-	4,22 E-5	-	2,27	-1,44	[kg CO_2 eq]
ODP	7,603 E-8	-	-	8,81 E-16	-	3,28 E-11	-4,35 E-10	[kg CFC-11 eq]
AP	1,631 E-2	-	-	1,91 E-7	-	5,5 E-4	-1,99 E-3	[kg SO_2 eq]
EP	1,912 E-3	-	-	4,62 E-8	-	4,28 E-5	-2,24 E-4	[kg $(PO_4)^{3-}$eq]
POCP	2,784 E-3	-	-	-6,57 E-8	-	3,11 E-5	-1,83 E-4	[kg C_2H_4eq]
ADPe	1,46 E-2	-	-	1,95 E-12	-	3,26 E-7	-1,49 E-7	[kg Sb eq]
ADPf	8,987 E+1	-	-	5,77 E-4	-	1,07	-1,89 E+1	[MJ]

RESOURCE USE

[SOURCE OF DATA: EPD from bau-umwelt.de]

	4,98	-	-	3,43 E-5	-	1,02 E-1	-2,09	[MJ]
	9,577 E+1	-	-	5,79 E-4	-	1,21	-2,19 E+1	[MJ]
	5,604E-2	-	-	3,3 E-8	-	5,59 E-3	-3,26 E-3	[m³]

The product does not have any recycled content.

-

END OF LIFE

[SOURCE OF DATA: EPD from bau-umwelt.de]

-

PVC membrane is 100% recyclable. Secundary material is applied in the production of e.g. windows, pipes and foils.

PVC membrane can be totally directed towards energy recovery.

* nd = not declared

GRC PANEL
[Rieder Smart Elements]

Reference unit [1 ton]
Thickness [13 mm]
Weight [26-31,5 kg/m²]
Density [2000-2420 kg/m³]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

GRC panels are manufactured from sand and cement (90% of total weight), glass fibers, pigments and other additives (10%).

Production site of GRC panels is located in Kolbermoor (Germany).

Reference service life of the product is more than 50 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production			Use	End of life				RRR	UM
	A1	A2	A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP	583	33	110	-	-	-	-	-	-	[kg CO_2 eq]
ODP	4,18 E-6	1,02 E-8	1,94 E-7	-	-	-	-	-	-	[kg CFC-11 eq]
AP	1,656	0,260	0,182	-	-	-	-	-	-	[kg SO_2 eq]
EP	0,151	0,051	0,017	-	-	-	-	-	-	[kg $(PO_4)^{3-}$eq]
POCP	0,250	-0,054	0,033	-	-	-	-	-	-	[kg C_2H_4eq]
ADPe	5,83 E-3	1,30 E-6	2,40 E-5	-	-	-	-	-	-	[kg Sb eq]
ADPf	5259	457	3103	-	-	-	-	-	-	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	964	17	72	-	-	-	-	-	-	[MJ]
	5920	459	3217	-	-	-	-	-	-	[MJ]
	598	1,631	70	-	-	-	-	-	-	[m^3]

The product does not have any recycled content.

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

-

GRC panels are 100% recyclable. Secundary material is applied in the production of aggregates with different grain sizes and dimensions.

-

* nd = not declared

U-GLASS CURTAIN WALL

Reference unit [6m x 3m = 18m²]
U-profile glass panels [wgt 24,58 kg/m²]
Aluminum profiles [qty 4 | dim 0,075 x 0,05 | h. 3-6 m | dens. 2700 kg/m³]
Connectors+fasteners [qty 60 | d. 5 mm | leng. 20 mm | dens. 7850 kg/m³]
Total system weight [442,44+12,757+0,185= 455,382 kg]

GENERAL FEATURES

The system is made of U-profile glass panels (97,15% of the total weight), aluminium profiles (2,8%) and steel connectors and fasteners (0,05%).

Production site of U-profile glass panels is located in Schmelz (Germany). Connectors and fasteners are manufactured in Poland and Switzerland, aluminium profiles in Austria.

U-profile glass panels are fixed to a metallic substructure which is made of alluminium profiles through steel fasteners and connectors (dry construction system).

ENVIRONMENTAL IMPACT

[LCA data related to the product stage A1 + A2 + A3]

	U-glass panels EPD data reworking	Aluminium profiles EPD data reworking	Connect.+fasteners EPD data reworking	Tot. amount	UM
GWP	694,26	79,479	0,538	774,277	[kg CO_2 eq]
ODP	4,212 E-7	22,198 E-8	2,107 E-10	6,434 E-7	[kg CFC-11 eq]
AP	2,16	8,139 E-1	1,33 E-3	29,752 E-1	[kg SO_2 eq]
EP	0,216	0,166 E-2	1,22 E-4	23,73 E-2	[kg $(PO_4)^{3-}$eq]
POCP	15,696 E-2	0,314 E-2	1,041 E-4	19,712 E-2	[kg C_2H_4eq]
ADPe	2,574 E-3	0,821 E-5	1,153 E-5	0,269 E-2	[kg Sb eq]
ADPf	8175,06	792,241	6,49	8973,789	[MJ]

RESOURCE USE

[LCA data related to the product stage A1 + A2 + A3]

	204,426	609,808	1,078	815,312	[MJ]
	9222,516	1019,324	0,765	10242,606	[MJ]
	199,926	0,127	0,002	200,055	[MJ]

The system has around 12% (55,5 kg) post-consumer recycled content of total weight (455,382 kg).

-

END OF LIFE

Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. printed, damaged panels).

U-profile glass panels, as well as aluminum profiles, can be recycled without particular constraints (dry assembled construction technology).

-

* nd = not declared

U-PROFILE GLASS PANEL [Pilkington]

Reference unit [1 m²]
Weight [24,58 kg/m²]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

U-profile glass panels are made of quartz sand (35-45% of total weight), cullet (30-45%), sodium carbonate (10-20%), dolomite (10-20%), others (3,5%, barium, sodium hydroxide, etc).

Production site of U-profile glass panels is located in Schmelz (Germany).

Reference service life of the product is equal to 50 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production	Use	End of life				RRR	UM
	A1 + A2 + A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP	38,57	-	-	-	-	-	-	[kg CO_2 eq]
ODP	2,34 E-8	-	-	-	-	-	-	[kg CFC-11 eq]
AP	0,12	-	-	-	-	-	-	[kg SO_2 eq]
EP	0,012	-	-	-	-	-	-	[kg $(PO_4)^{3-}$eq]
POCP	8,72 E-3	-	-	-	-	-	-	[kg C_2H_4eq]
ADPe	1,43 E-4	-	-	-	-	-	-	[kg Sb eq]
ADPf	454,17	-	-	-	-	-	-	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	11,357	-	-	-	-	-	-	[MJ]
	512,362	-	-	-	-	-	-	[MJ]
	11,107	-	-	-	-	-	-	[m³]

The product has around 12% (2,86 kg) post consumer recycled-content of total weight (24,58 kg).

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

0 [kg]

U-profile glass panels are 100% recyclable. Secundary material is applied in the production of glass products.

0 [kg]

* nd = not declared

GLAZED ALUMINIUM CURTAIN WALL

Reference unit [6m x 3m = 18m^2]
Double glazed unit [wgt 20,12 kg/m^2]
Aluminium profiles [qty 7 | dim. 0,075 x 0,05 | h. 3-6 m | dens. 2700 kg/m^3]
Connectors+fasteners [qty 48 | d. 5 mm | leng. 20 mm | dens. 7850 kg/m^3]
Total system weight [362,16+12,757+0,148= 375,065 kg]

GENERAL FEATURES

The system is made of double glazed units (96,5% of total weight), aluminium profiles (3,4%) and steel connectors and fasteners (0,1%).

Production sites of double-glazed units are located all over the world. Connectors and fasteners are manufactured in Poland and Switzerland, aluminium profiles in Austria.

Double-glazed units are fixed to a metallic substructure which is made of allumunium profiles through steel fasteners and connectors (dry construction system).

ENVIRONMENTAL IMPACT

[LCA data related to the product stage A1 + A2 + A3]

	Double glazed units EPD data reworking	Aluminium profiles EPD data reworking	Connect.+fasteners EPD data reworking	Tot. amount	UM
GWP	565,2	74,479	0,430	645,109	[kg CO_2 eq]
ODP	60,84 E-10	2,220 E-7	1,686 E-10	2,282 E-7	[kg CFC-11 eq]
AP	3,654	0,814	0,010 E-1	44,69 E-1	[kg SO_2 eq]
EP	253,8	0,021	9,761 E-5	25382,127 E-2	[kg $(PO_4)^{3-}$eq]
POCP	-	0,040	8,326 E-5	-	[kg C_2H_4eq]
ADPe	3,42	10,474 E-5	9,228 E-6	3,42 E-2	[kg Sb eq]
ADPf	-	792,240	5,191	-	[MJ]

RESOURCE USE

[LCA data related to the product stage A1 + A2 + A3]

	372,6	609,808	0.862	983,270	[MJ]
	8334	1019,324	0.612	9353,936	[MJ]
	4392	0,127	0,02	4392,129	[MJ]

The system has around 30% (111,924 kg) post-consumer recycled content of total weight (377,943 kg).

-

END OF LIFE

Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. printed, damaged double-glazed units).

Double-glazed units, as well as aluminum profiles, can be recycled without particular constraints (dry assembled construction technology).

-

* nd = not declared

DOUBLE-GLAZED UNIT [Saint-Gobain]

Reference unit [1 m²]
Weight [20,12 kg/m²]
Thickness [4 - 16 - 4 mm]

GENERAL FEATURES
[SOURCE OF DATA: EPD from saint-gobain.com]

Double-glazed units are made of two glass panes (th. 4 mm) which are separated by a spacer from aluminium or plastic composite (th. 16 mm) which is filled with argon.

Production sites of double-glazed units are located all over the world.

Reference service life of the product is equal to 30 years.

ENVIRONMENTAL IMPACT
[SOURCE OF DATA: EPD from saint-gobain.com]

	Production A1 + A2 + A3	+ Use B1-5	+ End of life C1 + C2 + C3 + C4	+ RRR D	UM [-]
GWP	TOT= 31,4				[kg CO_2 eq]
ODP	TOT= 3,38 E-10				[kg CFC-11 eq]
AP	TOT= 0,203				[kg SO_2 eq]
EP	TOT= 14,1				[kg $(PO_4)^{3-}$eq]
POCP	-				[kg C_2H_4eq]
ADPe	TOT= 0,190				[kg Sb eq]
ADPf	-				[MJ]

RESOURCE USE
[SOURCE OF DATA: EPD from saint-gobain.com]

	TOT= 20,7	[MJ]
	TOT= 463	[MJ]
	TOT= 244	[m³]

The product has around 30% (6 kg) post consumer recycled-content of total weight (20,12 kg).

-

END OF LIFE
[SOURCE OF DATA: EPD from saint-gobain.com]

-

The collect rate of glass at the end of life which is declared by the manufacturer is 5%. Secundary material is applied in the production of glass products.

-

* nd = not declared

LIGHT METAL ROOF

Reference unit [3m x 1m = 3m^2]
Steel sheet sandwich panels [th. 115 mm | density 42 kg/m^3]
Fasteners [qty 20 | d. 8 mm | leng. 150 mm | density 7850 kg/m^3]
Total system weight [14,49+ 1,183= 15,673 kg]

GENERAL FEATURES

The system is made of steel sheet sandwich panels (92,5% of total weight) and metallic fasteners (7,5%).

Production sites of steel sheet sandwich panels are located all over the Europe. Fasteners are manufactured in Poland and Switzerland.

Steel sheet sandwich panels are fixed to the structure through steel fasteners (dry construction system).

ENVIRONMENTAL IMPACT

[LCA data related to the product stage A1 + A2 + A3]

	Steel sheet sandwich panels EPD data reworking	Fasteners EPD data reworking	Total amount	UM
GWP	112,5	3,443	115,943	[kg CO_2 eq]
ODP	7,29 E-5	1,349 E-9	729,013 E-7	[kg CFC-11 eq]
AP	3,45 E-1	8,513 E-3	3,535 E-1	[kg SO_2 eq]
EP	3,78 E-2	7,808 E-4	3,858 E-2	[kg $(PO_4)^{3-}$eq]
POCP	7,59 E-2	0,666 E-3	7,657 E-2	[kg C_2H_4eq]
ADPe	0,543 E-2	7,383 E-5	0,550 E-2	[kg Sb eq]
ADPf	1740	41,529	1781,529	[MJ]

RESOURCE USE

[LCA data related to the product stage A1 + A2 + A3]

	69,6	6,897	76,497	[MJ]
	1830	4,898	1834,898	[MJ]
	nd	0,013	-	[MJ]

Data not declared since it is not available the recycled content of steel sheet sandwich panels.

-

END OF LIFE

Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. perforated, damaged panels).

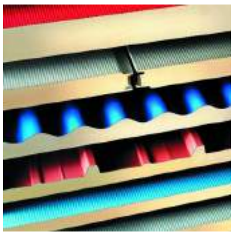
Steel sheet sandwich panels can be recycled, once separated in their two components (steel sheets and polyurethane core). Fasteners can be recycled without particular constraints.

Polyurethane core, once separated from steel sheets, can be directed towards energy recovery.

* nd = not declared

STEEL SHEET FACING SANDWICH PANEL [PU Europe]

Reference unit [1m²]
Density [42 kg/m³]
Thickness [115 mm]



GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

Steel sheet facing sandwich panels are made of steel sheets (65% of total weight) with a core made of polyurethane (PU, 35%).

Production sites of the members of the PU Europe association are located all over Europe.

Reference service life of the product is equal to 50 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production	Use	End of life				RRR	UM
	A1 + A2 + A3	B1-5 nd*	C1	C2	C3	C4	D	
GWP	37,5	-	-	0,201	0,37	10,9	-18,6	[kg CO_2 eq]
ODP	2,43 E-5	-	-	3,5 E-12	3,32 E-10	1,08E-10	-1,11 E-9	[kg CFC-11 eq]
AP	1,15 E-1	-	-	1,17 E-3	1,75 E-3	4,44 E-3	-6,34 E-2	[kg SO_2 eq]
EP	1,26 E-2	-	-	2,79 E-4	9,23 E-5	1,1 E-3	-5,09 E-3	[kg $(PO_4)^{3-}$eq]
POCP	2,53 E-2	-	-	-4,66 E-4	1,03 E-4	2,97 E-4	-8,58 E-3	[kg C_2H_4eq]
ADPe	1,81 E-3	-	-	7,47 E-9	5,09 E-8	7,61 E-8	-7,91 E-7	[kg Sb eq]
ADPf	580	-	-	2,76	4,2	2,67	-201	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	23,2	-	-	0,109	1,09	0,169	-4,81	[MJ]
	610	-	-	2,77	6,53	3,01	-208	[MJ]
	-	-	-	-	-	-	-	[m³]

-

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

0

Steel sheet facing sandwich panel is 58% recyclable. It means that 7,99 kg of secundary material is applied in the production of new steel by steelworks.

36% of the product can be directed towards energy recovery.

* nd = not declared

PLASTERBOARD WALL
[Bundesverband der Gipsindustrie e.V]

Reference unit [3m x 6m = 18 m^2]
Plasterboard [th. 12,5 mm] - Insulating panel [th. 60 mm]
Total sistem weight [438,56 kg]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

The system is made of plasterboard panels (82% del peso tot.), a mineral wall core (7,4%) and a galvanized steel sub-structure (8,9%).

Production sites of the members of the Bundesverband der Gipsindustrie e.V association are located all over Germany.

Plasterboard panels are fixed to a metallic substructure which is made of aluminium profiles through steel fasteners (dry construction system).

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production A1 + A2 + A3	Use B1-5 nd*	End of life C1	C2	C3	C4	RRR D	UM [-]
GWP	224,0	-	0,0	1,5	1,8	32,1	-62,2	[kg CO_2 eq]
ODP	3,36 E-7	-	0,00	8,08 E-11	3,78 E-11	5,31 E-9	2,06 E-9	[kg CFC-11 eq]
AP	5,40 E-1	-	0,00	6,68 E-3	9,64 E-5	3,53 E-2	-2,20 E-1	[kg SO_2 eq]
EP	7,39 E-2	-	0,00	1,61 E-3	2,04 E-5	7,19 E-3	-1,79 E-2	[kg $(PO_4)^{3-}$ eq]
POCP	6,83 E-2	-	0,00	-2,39 E-3	1,14 E-5	1,08 E-2	-3,30 E-2	[kg C_2H_4 eq]
ADPe	1,23 E-2	-	0,00	6,88 E-8	9,38 E-9	2,04 E-6	-2,41 E-6	[kg Sb eq]
ADPf	3326,7	-	0,0	20,7	0,2	76,6	-749	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	A1 + A2 + A3	B1-5	C1	C2	C3	C4	D	UM
	205,2	-	0,0	0,8	0,0	5,9	-1,2	[MJ]
	3522,7	-	0,0	20,8	0,2	80,1	-728,9	[MJ]
	126	-	0,0	0,1	0,0	3,8	5,4	[m^3]

The system has around 53% (232,2 kg) post-consumer recycled content of total weight (438,56 kg).

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. perforated, damaged, painted panels).

Plasterboard panels are recycled by specific plants (e.g. KnaufRecycling project). Aluminium profiles and steel fasteners can be totally recycled by steelworks.

Sheets of paper, once separated from gypsum core, can be directed towards energy recovery.

* nd = not declared

PLASTERBOARD PANEL
[Bundesverband der Gipsindustrie e.V]

Reference unit [1m²]
Weight [10 kg]
Thickness [12,5 mm]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

Plasterboard panel is made of a gypsum core (99% of total weight), pressed between two sheets of paper (1%).

Production sites of the members of the Bundesverband der Gipsindustrie e.V association are located all over Germany.

Reference service life of the product is more than 50 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production A1 + A2 + A3	Use B1-5 nd*	End of life C1	C2	C3	C4	RRR D	UM [-]
GWP	2,09	-	-	-	-	-	-	[kg CO_2 eq]
ODP	2,23 E-10	-	-	-	-	-	-	[kg CFC-11 eq]
AP	3,24 E-3	-	-	-	-	-	-	[kg SO_2 eq]
EP	7,96 E-4	-	-	-	-	-	-	[kg $(PO_4)^{3-}$ eq]
POCP	2,96 E-4	-	-	-	-	-	-	[kg C_2H_4 eq]
ADPe	1,65 E-4	-	-	-	-	-	-	[kg Sb eq]
ADPf	32,21	-	-	-	-	-	-	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	1,75	-	-	-	-	-	-	[MJ]
	32,21	-	-	-	-	-	-	[MJ]
	10,54	-	-	-	-	-	-	[m³]

The product has around 56% (5,61 kg) post-consumer recycled content of total weight (10 kg).

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

Plasterboard panels are 100% reusable.

Plasterboard panels are 100% recyclable. Secundary material is applied in the production of new paper and gypsum dust.

Sheets of paper, once separated from gypsum core, can be directed towards energy recovery.

* nd = not declared

GYPSUM BOARD CEILING
[Bundesverband der Gipsindustrie e.V]

Reference unit [3m x 6m = 18 m²]
Gypsum boards [th. 12,5 mm] - Insulating panel [th. 60 mm]
Total sistem weight [438,56 kg]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

Gypsum board ceiling is made of gypsum boards (82% del peso tot.), a mineral wool core (7,4%) and a galvanized steel sub-structure (8,9%).

Production sites of the members of the Bundesverband der Gipsindustrie e.V association are located all over Germany.

Gypsum boards are fixed to a metallic substructure which is made of aluminium profiles through steel fasteners (dry construction system).

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production A1 + A2 + A3	Use B1-5 nd*	End of life C1	C2	C3	C4	RRR D	UM [-]
GWP	263,1	-	0,0	1,5	1,8	31,9	-62,2	[kg CO_2 eq]
ODP	3,88 E-7	-	0,00	8,02 E-11	3,78 E-11	5,27 E-9	2,06 E-9	[kg CFC-11 eq]
AP	5,69 E-1	-	0,00	6,62 E-3	9,64 E-5	3,51 E-2	-2,20 E-1	[kg SO_2 eq]
EP	7,06 E-2	-	0,00	1,60 E-3	2,04 E-5	7,14 E-3	-1,79 E-2	[kg $(PO_4)^{3-}$eq]
POCP	7,21 E-2	-	0,00	-2,37 E-3	1,14 E-5	1,08 E-2	-3,30 E-2	[kg C_2H_4eq]
ADPe	1,15 E-2	-	0,00	6,83 E-8	9,38 E-9	2,02 E-6	-2,41 E-6	[kg Sb eq]
ADPf	3872,7	-	0,0	20,6	0,2	75,9	-749	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	204,7	-	0,0	0,8	0,0	5,8	-1,2	[MJ]
	4078,1	-	0,0	20,6	0,2	79,4	-728,9	[MJ]
	152,0	-	0,0	0,1	0,0	3,8	5,4	[m³]

The system has around 53% (232,2 kg) post-consumer recycled content of total weight (438,56 kg).

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

Since it is possible a selective de-construction, the system can be totally re-used if not considerably modified (e.g. perforated, damaged, painted boards).

Gypsum boards are recycled by specific plants (e.g. KnaufRecycling project). Aluminium profiles and steel fasteners can be totally recycled by steelworks.

Cellulose fibers, once separated from gypsum core, can be directed towards energy recovery.

* nd = not declared

GYPSUM BOARD
[Bundesverband der Gipsindustrie e.V]

Reference unit [1m²]
Weight [10 kg]
Thickness [12,5 mm]

GENERAL FEATURES [SOURCE OF DATA: EPD from bau-umwelt.de]

Gypsum boards are made of a mixture added with water equal to 80% of gypsum (CaSO4 x 2 H2O) and 20% cellulose fibers.

Production sites of the members of the Bundesverband der Gipsindustrie e.V association are located all over Germany.

Reference service life of the product is more than 50 years.

ENVIRONMENTAL IMPACT [SOURCE OF DATA: EPD from bau-umwelt.de]

	Production	Use	End of life				RRR	UM
	A1 + A2 + A3	B1-5 nd*	C1	C2	C3	C4	D	[-]
GWP	3,08	-	-	-	-	-	-	[kg CO_2 eq]
ODP	3,9 E-10	-	-	-	-	-	-	[kg CFC-11 eq]
AP	4,07 E-3	-	-	-	-	-	-	[kg SO_2 eq]
EP	6,98 E-4	-	-	-	-	-	-	[kg $(PO_4)^{3-}$eq]
POCP	3,88 E-4	-	-	-	-	-	-	[kg C_2H_4eq]
ADPe	1,45 E-4	-	-	-	-	-	-	[kg Sb eq]
ADPf	47,33	-	-	-	-	-	-	[MJ]

RESOURCE USE [SOURCE OF DATA: EPD from bau-umwelt.de]

	1,84	-	-	-	-	-	-	[MJ]
	47,33	-	-	-	-	-	-	[MJ]
	7,53	-	-	-	-	-	-	[m³]

The product has around 57% (5,68 kg) post-consumer recycled content of total weight (10 kg).

-

END OF LIFE [SOURCE OF DATA: EPD from bau-umwelt.de]

Gypsum boards are 100% reusable.

Gypsum boards are 100% recyclable. Secundary material is applied in the production of new paper and gypsum dust.

Cellulose fibers, once separated from gypsum core, can be directed towards energy recovery.

* nd = not declared

4. Business models & end of life of temporary buildings in mega events

di Marika Arena, Matteo Platti e Deborah Agostino

Introduction

The actual modes of disposal of buildings and building components at the end of a mega event are determined, not only by technical and construction choices (construction reversibility), but also by the need of identifying appropriate business models, commonly defined as a set of organizational and managerial arrangements that enable the "management" of technological solutions to pursue value creation.

The development of these business models requires to pay particular attention to two aspects. First, it requires to build (and then ensure over time the appropriate involvement of) a network of actors, who are autonomous in their decision-making processes. These actors constitute the value chain of recycling / reuse of a temporary building, which is configured as a multi-stakeholders system, characterized by the coexistence of different subjects, with potentially competing goals, who interact with each other and are influenced by the decisions of other stakeholders such as policy makers, local governments, local communities (Geyer and Jackson, 2004).

Therefore, from the earliest stages of the project, it is necessary not only to identify the possible operators that can be involved in the reuse and recycling value chains, but also to understand what are potential modes of integration, physical and informative flows between the operators and possible ways to value them. Obviously, in some cases, the networks of actors are more consolidated as, for example, in the case of wood and steel value chains; in other cases, the value chains can be less structured, and therefore they require an initial effort for the establishment of cooperation relationships between the operators.

Secondly, the design of the business model cannot ignore the multi-objective nature of the system of reuse and recycling. We must not forget that different end of life scenarios imply different levels of sustainability in economic and environmental terms, as well as different potential impacts on the social dimension. In general terms, from an environmental perspective reuse is typically better than recycle, and recycle for the same purpose is better than recycle for different purposes. However, depending on how these solutions are implemented in practice, they can generate significant trade-offs. It is therefore important to understand how different technological and organizational solutions impact on a wider performance system and define strategies that allow the maximization of the value creation (in a broad sense), through the synergy of interests of the various stakeholders involved.

In the end, it is useful to emphasize that the proper consideration of relationships between technological and managerial elements is particularly critical because the lack of "jointly" planning the end of life of a structure can prevent its effective recycling / reuse (for the same use or for other use), even in front of technological solutions that allow it.

In light of these considerations, this chapter aims to discuss how a business model for the management of the end of life of a temporary structure could be designed, pinpointing how different components of the business model could be configured and providing some examples based on past events. In so doing, we will make reference to two different scenarios: reuse and recycling.

The first scenario refers to the reuse of the whole building (Figure 29), which can happen in the same place where an event had taken place or in a different place, with the building being relocated. Furthermore, during its second life, a building can maintain its original function or it can be exploited for a different purpose.

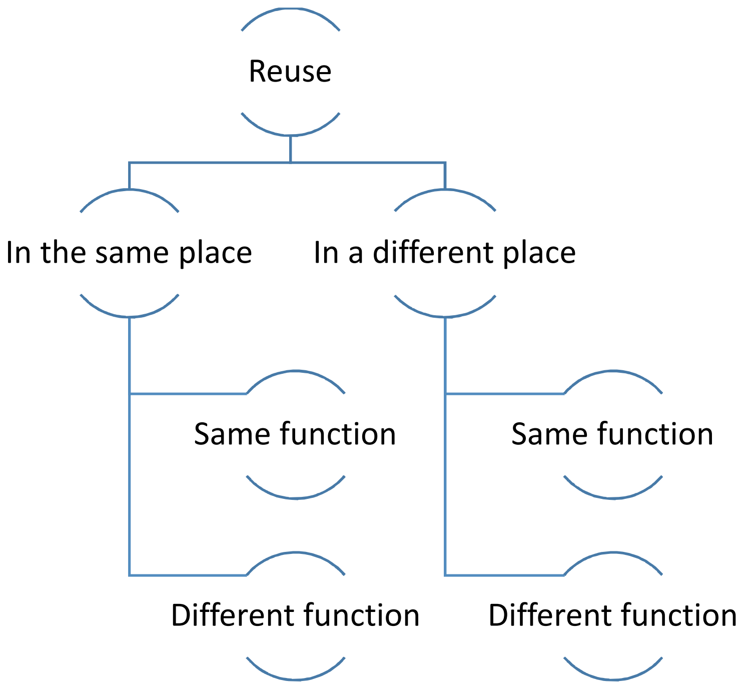


Figure 29. Reuse scenario for temporary buildings

The second scenario refers to the recycling of building elements and materials (Figure 30). This scenario could entail different recycling options that can be broadly distinguished into recycling of components in a new building and recycling of components and materials into new materials.

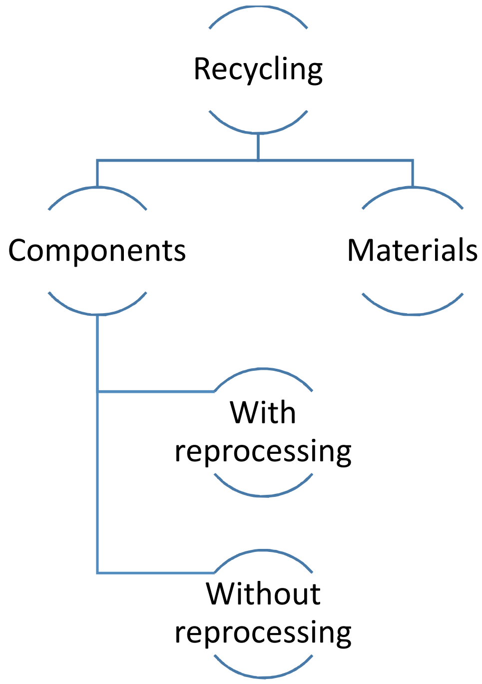


Figure 30. Recycling scenario for temporary buildings

The chapter is organized as follows: the next section introduces the framework that will be used to present the business model in the reuse and recycling scenarios, section three analyses the reuse scenario and section four analyses the recycling scenario, finally some concluding remarks are presented in section five.

Framework: what a business model is?

In literature, we can find a wide range of definitions of what a business model is and what kind of information it has to include (George & Bock, 2009; Osterwalder, 2004; Osterwalder, Pigneur, & Tucci, 2005). In general terms, a business model can be defined as “the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities” (Amit & Zott, 2001, Zott & Amit 2010).

In this work, we exploit business models for reuse and recycling with reference to the framework designed by Richardson (2008). This framework (Table 2) is articulated into three main sections: (1) the value proposition, (2) the value creation and delivery system (3) the value capture. Each of these sections, called building blocks, represents a different phase in the process of value creation. Furthermore, each building block is further divided into different subsections, called elements, on which an organization leverages to create value.

Building blocks	**Description**	**Elements**
(1) Value proposition	What a company delivers to the customers	(1.1) Offering
		(1.2) Target market
		(1.3) Basic strategy to attract customers
(2) Value Creation and delivery system	How the company creates and delivers value	(2.1) Resources and capabilities
		(2.2) Internal organization
		(2.3) Position in the value network
(3) Value Capture	How the company generates revenue and profit	(3.1) Revenue
		(3.2) Cost

Table 2. Business model framework

Relying on this framework, we describe the business arrangements that should be taken into consideration when managing a temporary building's end-of-life. In doing this, we need to embrace a specific point of view that is that of the owner of the temporary structure. However, since, the end-of-life of a temporary structure is a complex system that involves several stakeholders, we make an attempt to highlight also the perspectives of other different actors in the network (including, for instance local companies and the local communities).

Before addressing in details the deployment of the business model for different end of life scenario, we provide a synthetic outline of the reference framework with a general definition of different components. As follows, each building block is briefly analyzed, discussing its meaning and its constitutive elements.

Block 1. The value proposition. The value proposition explains how the company creates value to the customers. This includes several aspects relating to the external relationships of the company, such as what the company delivers to the customers (products or services), why customers agree to pay for the product or service delivery, which kind of customer's problem the company is trying to solve and the company's strategy to get competitive advantage. According to this, the value proposition comprises (1) the offering (2) the target market and (3) the basic strategy to attract customers and gain competitive advantage.

The **offering** element refers to the range of products and services a company provides to customers. It includes the description of the output of the company, the needs of the clients that want to be addressed and the problem the company would like to solve. Accordingly, the offering can be here represented by a temporary building or by its components or, in other cases, by the raw materials that constitute the building.

The **target market** represents the market segment for whom a company creates value. It refers to those groups of customers on whom the company wants to focus its marketing efforts. In the specific case, the target market comprises private and public organizations, and other entities (like NGOs, social enterprises, etc..) that might be interested in buying / receiving a building / some of its components / or some raw materials.

The **basic strategy to attract customers and gain competitive advantage** includes strategic considerations about why the market is not already served by other companies and how the company is going to obtain better performance than the competitors in terms of attracting customers and fulfill their problems and needs. All these considerations refer to the competitive leverages controlled by the company and how it exploits them. In this case, we can consider the main strategies that can be used to approach public, private and no profit organizations, in order to deliver them a building or part of it.

Block 2. The value creation and delivery system. The value creation and delivery system refers to how the company creates and delivers value to customers. This block investigates the source of competitive advantage by underlining how activities, resources and relationships with other actors of the value network can be combined in order to obtain high performance. The value creation and delivery system includes: (1) resources and capabilities, (2) internal organization, (3) position in the value network.

Resources and capabilities refers to the broad bundle of valuable tangible or intangible resources that the company can exploit in order to create, produce and sell the offering to clients. Resources can be physical, financial, intellectual, or human resources. Key resources can be considered as a particular set of resources that enable a company to obtain sustainable competitive advantage. According to the VRIN model (Barney 1991), key resources must be valuable, rare, inimitable (difficult to imitate) and non-substitutable. In this specific case, we can consider the resources that the owner of a temporary building must have in order to ensure a second life to the structure or to allow the recycling of its components.

Internal organization refers to all the key activities (and the linkages between them) that a company undertakes in order to fulfill its main goal of delivering its value proposition. Activities can be divided among suppliers, the owner of the building, partners and distributors. In the specific case, key activities mainly include all the activities that should be designed and performed for delivering the new structure to the customer, such as disassembling, transporting and reassembling the whole structure or part of it.

Position in the value network refers mainly to the link to suppliers, partners, customers, and, in general, to other actors involved in the network. These actors enable the company to share key resources and key activities, exploit economy of scale or reduce the market risk. In the specific case, we can consider all the actors involved in the disassembling and reassembling process (e.g. decommissioning and logistic companies) and in the economic transaction process – from the first-life owner to the second-life owner - of the temporary structure.

Block 3. The value capture. The value capture describes how the company generates revenue and profit. It includes: (1) revenue sources and (2) costs.

Revenues refer to the main revenue streams that allow the company to generate positive cash flows. The main issue is about understanding of how much each customer segment is ready to pay in order to obtain company's products and services. Accordingly, in the different scenarios, we will refer to the potential cash flow coming from the selling of a temporary building or of its components or, in other cases, of the raw materials.

Costs include those costs that the company sustains in order to implement its business model and operate in the market. These costs derive from the activities undertaken, the resources employed and the relationships in the network. Here, we are taking into account the main economics from the key activities (disassembling, transporting, reassembling). These costs could be heavily influenced by the peculiarity of each structure, however, it is possible to identify some general items that are likely to occur.

The reusing scenario

The first scenario entails the possibility of reusing a temporary building. Within this scenario, four alternative situations could happen (as highlighted in Figure 1). A temporary structure could be reused in its original place - becoming a permanent structure – or it can be moved in another place, being disassembled and rebuilt. Moreover, in its new life, the structure could conserve the same first life purpose of use or assume new functionalities. As follows, we discuss how different building blocks of the business model framework could be configured in order to support the implementation of the above alternatives (Table 3).

Building blocks	**Elements**	**Description**
(1) Value proposition	(1.1) Offering	Temporary building
	(1.2) Target market	Different market segments including, for instance, public and private organizations working in the social services sectors, such as education and welfare, schools and universities, large corporations.
	(1.3) Basic strategy to attract customers	(a) Assessment of customer needs and (b) reputational effects associated to the choice of a reusing solution
(2) Value Creation and delivery system	(2.1) Resources and capabilities	(a) Capability of adapting and remodeling the structure, (b) relationships within the network and (c) strength of the brand of a mega event.
	(2.2) Internal organization	(a) Designing; (b) disassembling and (c) transporting
	(2.3) Position in the value network	(a) Decommissioning companies and (b) market demand aggregator organizations
(3) Value Capture	(3.1) Revenue	Revenues related to the sale of the temporary structure
	(3.2) Cost	Costs related to the activities that must be conducted: (a) dismantling, (b) transporting, (c) remanufacturing and remodeling, (d) reconstructing and (e) site restoration.

Table 3. Business model in the reuse scenario.

<u>Block 1. The value proposition</u>. The value proposition depicts what a company delivers to the customers. According with the framework presented in section 2, it includes (1) the offering (2) the target market and (3) the basic strategy to attract customers and gain competitive advantages.

The offering. The offering consists of the temporary building itself at its end-of-life. In this scenario, the whole structure (or at least most of it) is expected to be reused. The buildings being taken into consideration represent the legacy of a mega event and their first life functionalities have been designed to respond to its needs and purposes. The Olympic Games, hold in London in 2014, and the Universal Exposition of Shanghai 2010 provide some interesting examples of mega events whose structures were partly reused. Many buildings used to host the athletes, the games and the events of the Olympic Games in one case, and the Exposition Pavilions and Halls in the other case, were designed with the idea of being reused after the end of the event.

During the London Olympic Games, the Olympic Stadium hosted a great number of sport events, mainly including athletics competitions and the opening and closing ceremonies. The Stadium was designed to be partially temporary and partially permanent. At the end of the Olympic Games, was partially disassembled and the remaining elements have been transformed into a permanent structure. The stadium now hosts the soccer games of a London football team, athletics competitions and live music events. It represents a valuable case study where a temporary structure has been transformed into a permanent structure, maintaining the original target and functionalities.

The main source of complexity to properly configure the offering concerns the need to design flexible and modular buildings, in order to allow them to fulfill customer needs and to be adapted and reused in the end. In particular, in the case of the Olympic Stadium presented above, the challenge was to assure the possibility of using the structure for minor audience competitions. This turned into the need to downgrade a 80.000 seats stadium to a 25.000 seats stadium.

The target market. Evaluating the target market of a temporary building requires to consider the possible entities that may be interested in buying or receiving it. Hence, the target market could include public, private or no-profit organizations that may need new spaces and indoor areas and that could answer their needs through reusing a temporary building (eventually transforming it into a permanent building). In the current economic context, an outlet that appears to be particularly interesting is that of public and private organizations that operate in the social services sector, such as education and welfare. If properly addressed, these organizations might prefer to answer to their needs through the reuse of a temporary building instead of through the construction of a new building with a positive impact on the economic, environmental and social sphere.

In the field of education, for instance, there are nurseries, kindergartens, primary, secondary and high schools or universities looking for new rooms where their classes can be hold and their activities conducted. In this sense, these needs may be addressed by reusing a temporary building, in order to obtain leisure and recreation areas, meeting rooms, auditoriums, gyms, study halls and other facilities. In the welfare sector, an interesting case is provided by social housing organizations, which are looking for new dwellings and living solutions where different potential clients, unable to satisfy their housing needs on the regular market due to economic motivations or to the shortage of appropriate solutions, can be settled. These people include a wide variety of subjects such as singles, single-parent families, immigrants, temporary workers, off-campus students, elderly people and patients. In this case, social housing organizations could transform a temporary building into a permanent building to create new living spaces and grant the above people better living conditions, services and social actions.

The evaluation of the target market heavily depends on the flexibility level of the building itself. Obviously, the more flexible and versatile a structure is, under a design point of view, the wider and more diversified the target market will be. Hence, in case of modular and flexible design, a structure could fulfill, in its second-life, requirements that could also be very different from those of the first life users. Instead, if a building is more rigid (i.e. the design of the structure was intended for one specific purpose without considering alternative uses), the target market will be limited to those classes of actors that may have the same needs that the users of the structure had in its first life.

Going back to the examples of past mega-events, in the case of the Olympic Stadium, the target market was represented by different categories of actors: local sports teams, interested in a new playing field, or other public and private organizations, interested in obtaining rental fee and lease payments from sport events, concerts and other ceremonies. In the end, the Olympic Park Legacy Company (that was appointed by the Olympic Board to manage the Legacy of the Stadium) realized an agreement with a London football team for a long term renting of the Stadium.

Basic strategy to attract customers. We are here referring to the basic strategy to reach potential second-life users. The main issue concerns the assessment of the implicit and explicit needs of the potential customers in terms of living conditions and the attempt of adapting the structure in order to meet their needs in a more sustainable way than other building solutions. If the structure has been designed for an intended second-life use, the target market is somehow already defined and, consequently, the needs that the structure may aim to fulfill are set. On the contrary, if the structure has been designed to be temporary but without having considered how it would have been deployed in its second life, the proper identification of the potential needs is a crucial issue.

As we mention in the section about target market, the potential market segments are much diversified. Hence as follows, we will provide some examples of what strategies could be enacted in different cases. Consider for instance social housing organizations as an example of possible second life users. They deliver dwellings, services and social actions to those people that could not enter the regular market, such as singles, immigrants, temporary workers, off-campus students, elderly people and patients. By understating the housing needs of social housing organizations, it could be possible to customize the offering, adapting the structure to meet these requirements. For instance, a typical need of a beneficiary of a social housing structure include common areas for socialization and facilities with common services such as healthcare and social care services, home care for elderly and disabled, after-school, babysitting, etc.. In this sense, having a modular and adaptable structure allows to come out with a more valuable and targeted offering.

In defining the strategy that should be embraced to address the potential customer, it is worthy to consider possible reputational effects associated to the choice of relying on a reuse solution that could play a role in particular for large corporations. Reusing an existing structure is in fact a way to reduce wastes, refuse and emission-intensive activities and outcomes with a powerful image effect. Furthermore, depending on the strength of the brand of the mega event itself, the acquiring organization can exploit this choice for promoting its own image.

Block 2. **Value creation and value proposition**. The value creation and delivery system refers to how the company creates and delivers value to customers. It includes: (1) resources and capabilities, (2) internal organization, (3) position in the value network.

Resources and capabilities. Resources and capabilities include tangible and intangible resources disposed by an organization in order to ensure a second life to a temporary building. We are here referring to the capability of adapting and remodeling a building, the relationships within the network and the strength of the brand of a mega event.

The capability of adapting and remodeling a building for the second life functionalities represents a key resource that the organization should have in order to deliver a customized and targeted solution. If a building has been designed without taking into account its future use, a problem of adaptability may rise. Hence, to become suitable for its second-life functionalities, the building may require remodeling activities and other structural changes in order to enable the structure to meet the needs of the new purpose. In case of high level of adaptability, these re-manufacturing activities can be carried out preserving the integrity of the building, reducing the time lag and capital expenditure.

Network relationships include the formal and informal linkages with the other actors involved, such as the owner of the site where a building has been settled, the organizer of the mega event for whom the building has been designed, local authorities governing market trade and regulations, dismantling and decommissioning companies that conduct the disassembling of the building at the end of its life, market demand aggregator companies that enable the assessment of business opportunities and reuse scenarios. These relationships represent a key resource that is essential to ensure the matching between demand and offer.

The strength of the brand of a mega event refers to its ability to drive the market and attract customers. Many different factors concur in determining the strength of the brand of a mega event such as its history and tradition, the quality standards, the people and professionals involved, the wider societal role that the mega event plays, potentially becoming a symbol of the hosting nation. This factor could really help the owner of the building in the sale process.

In the case of the Olympic Stadium, the “label” of the Olympic Games played a considerable role in the process of finding a second life user. The possibility of using one of the venues of the most important sport events all over the world attracted the attention of many sport teams and event companies. The first-life use of the structure itself could in fact contribute to attract a higher number of visitors, captured from the charm and the history of the structure itself.

Internal organization. We are here focusing the attention on the key activities required in order to assure a second life to a temporary building. They are the design phase, the disassembling, the remanufacturing and the transportation of the structure itself.

The design phase represents the first critical activity. In order to enable a second-life use, this activity must be performed taking into account the possible future scenarios in which a building can be used. In this respect, the owner of the building could have already identified a second-life use in the early stage of the structure life or not. Accordingly, the design activities will be carried out in different ways. In the first situation, the functionalities of the building in both its first-life and the second-life should be taken into account. In this case, in order to maximize the structure ability to respond to the second-use requirements and minimize the costs associated to the remodeling and remanufacturing activities, a long term analysis must be carried out. If the second-life use is not known in advance, the design phase should be centered on how to allow flexibility and adaptability of the building itself, still preserving its ability to properly respond to the functionalities foreseen for its first-life use. This would enable the structure to be suitable for a wide range of reuse solutions, increasing the target market and reducing the remanufacturing outcomes.

The Olympic stadium of London provides an interesting example of a building thought with the future perspective of being transformed into a permanent building. The goal, in this case, was to think and construct a structure that could answer to the short term requirements of the Olympic Games (number of seats, security check, surrounding facilities), and, at the same time, fulfill the long term needs of being reused for different post-Olympic events. However, the second-life use was not yet defined at the time of the design phase. Therefore, the architect proposed a flexible and modular project that enabled the structure to be reused in very different fields and activities. The project included a lower semicircle surrounding the ground field that hosted the 25.000 permanent seats and uphold the upper circle, where the 55.000 temporary seats were settled. Moreover, the linkage between the different construction elements were bolted instead of weld, in order to allow the disassembling and remanufacturing activities. Exploiting these features, the Olympic board managed to find new users just after the end of the Olympic Games, reducing the closing time of the structure and the outcomes due to reconfiguring activities.

Disassembling represents another key activity that is critical from two points of view. On the one hand, activities should be performed preserving the original structure functionalities during this phase. In order to assure a second life to a building, its constitutive elements must not be corrupted or damaged. This issue is even more critical if a structure should be moved and rebuilt in a different site. In this case, moreover, the activity of disassembling is in a strong relationship with the issue of the site restoration. In fact, the spaces used for the first-life construction must be brought back to the initial conditions, ready to host new life and activities. On the other hand, disassembling activities generally require to follow strict safety protocols, and respect pollution and noise control standard, in order to preserve local communities from potential negative externalities. In this sense, the activities are heavily influenced by the size of the building, the shape, the materials adopted and surrounding structures to be protected and preserved.

Finally, when a building has to be moved in different places for its second life, transportation represents another key activity. This activity is again critical from different points of view, because it entails significant transportation costs and particular attention is required to avoid that the structure and its constituent parts are damaged when moved from one place to the other. From this point of view, it is important to properly estimate the main costs related to the different transportation modes and evaluate strengths and weaknesses according with the physical properties of the materials (size, fragility, etc..).

The Olympic Stadium, at the end of the Olympic Games, underwent relevant remodeling activities. These activities included disassembling and remanufacturing, mainly consisting in the reduction of the available seats, from 80.000 to 60.000. The upper part of the stage has been completely removed and readapted for the second-life use. Manufacturing activities needed also to be performed in order to turn the athletics track into a football playground. However, thanks to modular design, the lower part of the stage and the main constitutive elements of the Stadium, were only slightly affected by the renovation process. The Stadium is currently still closed and it will re-open to the public in 2016.

In the case of the Olympic Stadium, transport activities were not relevant, as the Stadium was designed to be reused in the original place, becoming a permanent structure.

Position in the value network. We are here referring to the key partners, who include public and private organizations that allow the second use of a temporary building: in this scenario, the decommissioning companies and the market demand aggregator companies play a crucial role.

The decommissioning companies are engaged in the whole process of disassembling the structure and restoring the site to the original condition. They conduct all the activities needed in order to enable a structure to be moved and transported with the proper means of transport.

Market demand aggregators play a key role for assessing the potential demand for temporary buildings since they aggregate many of the organizations that could be interested to embrace a solution based on the reuse of temporary structures. These organizations typically have wide visibility on different industries and can support the assessment of the market demand and the delivery to the most suitable second-life owner. Obviously, who these actors are depends on the specific industry field and can vary largely.

In the above section, discussing about the target market, we referred to actors operating in the education and private welfare sector as users potentially interested in a space solution based on a temporary structure. If we focus our attention, for example, on the field of social housing, we can find associations and public administrations engaged in planning, monitoring and coordinating the local social housing programs. On the one hand, they are aware of the local demand for developing projects and, on the other hand, they have generally a good understanding of the local legislative framework, local ongoing initiatives, urban analysis, etc… In this sense, they can foster and facilitate the matching between demand and offer of buildings able to answer to the social needs. In a similar way, if we consider the case of the education sector as in the case of kindergartens and nurseries, public entities with the task of coordinate the local structures could have visibility on the needs and the existing demand for new spaces.

If we go back to the example of the Olympic Games, introduced above, the Olympic Park Legacy Company was appointed to manage the post-Olympic activities of the Olympic Stadium and the surrounding areas, driving the redeveloping after London 2012. It oversaw the formal bidding process, receiving more than 100 expressions of interest. Each organization would have had six weeks to make its formal offer. At the end of the screening phase, two proposals were selected: a first joint proposal from Tottenham Hotspur F.C. and Anschutz Entertainment Group, that would have maintained the existing number of seats, and a second proposal from West Ham United F.C, that would have reduced the capacity to 60.000 seats. On February 2011, the Olympic Park Legacy Company selected West Ham United proposal as the most suitable concept for the second life usage of the Stadium.

Block 3. The value capture. The last building block, the value capture, describes how the company generates revenue and profit by reusing a temporary building. It includes: (1) revenue sources and (2) costs.

In the reuse scenario, we have considered four different alternatives. First, the structure can be reused in the original place - becoming a permanent structure – or it can be moved in another place and then rebuilt. Second, in its second life, the structure can conserve the same first-life purpose of use or assume new functionalities. According to these alternatives, the items included in the revenues stream generally remain quite similar, but the costs items can be very different. Here, we first present the case of reusing the structure in a different place with different functionalities, as it can be considered the most complex and expensive alternative. Then, for each cost item, we discuss the main changes that different alternatives imply.

Revenues sources. This element refers to the main revenue streams deriving from the reuse of a temporary building. Revenues are associated to the economic transaction of the structure's ownership: from its first-life owner to its second-life owner. This process could imply different solutions since a structure could be sold, rented or even donated.

Costs. This element refers to the cost items that the reuse of a temporary building may imply, as a result of the activities undertaken, the resources employed and the relationships of the owner organization in the value network. These costs can be linked to the following activities: (a) dismantling, (b) transporting, (c) remanufacturing and remodeling, (d) reconstructing and (e) site restoration.

Dismantling costs. The item includes costs related to the activities performed in order to dismantle the structure and enable its transportation to the new site. In case the structure is reused in the same site, dismantling activities involve only those parts that will not be exploited in the second life or those elements that are expected to be remanufactured and redesigned.

Transportation costs. The item includes costs related to the transportation of the building from its first-life site to its second-life site. Again, in case the structure is reused in the same site, transportation costs are not relevant.

Remanufacturing and remodeling costs. The item includes costs related to the activities performed in order to remanufacture and remodel the building elements coming from the disassembled structure. These activities enable the new structure to fulfill the functionalities required by its second-life. Remanufacturing activities can be also conducted on the reassembled structure. The effort deployed in the activity is related to how relevant the changes implemented are for making the structure suitable for the new life. As a consequence, the costs are generally less relevant if the second-life use of the structure is similar to the first-life use.

Reassembling costs. The item includes costs related to the reassembling of the building elements (remanufactured or not) with the second-life functionalities.

Site restoration costs. The item includes costs related to restoration activities that have to be performed at the end of the dismantling activities. This is due to the need of bringing back the land that hosted the first-life construction to the initial conditions.

The recycling scenario

The second scenario focuses on the possibility of recycling some constituting elements of a temporary building.

In particular, there are two main recycling alternatives. The first alternative refers to the possibility of recycling some building elements of the temporary structure for the construction of a new building (temporary or not). The second alternative refers to the possibility of recycling the raw materials composing the temporary structure and their consequent reprocessing. The following business model considers these two possible alternatives (Table 4).

Building blocks	**Elements**	**Description**
(1) Value proposition	(1.1) Offering	Building elements or raw materials composing the temporary structure
	(1.2) Target market	(a) Companies willing to use building elements coming from temporary structure as furnishing, interior design elements, equipment, facilities or exhibition element and (b) raw material remanufacturing companies
	(1.3) Basic strategy to attract customers	(a) lower purchasing cost (b) reputational effects associated to the choice of a recycling solution
(2) Value Creation and delivery system	(2.1) Resources and capabilities	(a) Relationships within the network, (b) capability of registering and keeping traced the physical characteristics of the building elements and (c) strength of the brand of a mega event
	(2.2) Internal organization	(a) Decommissioning, (b) reprocessing and (c) remanufacturing
	(2.3) Position in the value network	(a) Decommissioning companies and (b) market demand aggregator organizations
(3) Value Capture	(3.1) Revenue	Revenues related to the sale of the building elements or raw materials composing the temporary structure
	(3.2) Cost	Costs related to the activities that must be conducted: (a) decommissioning, (b) transporting, (c) reprocessing, and (d) remanufacturing and remodeling.

Table 4. Business model in the recycling scenario

Block 1. The value proposition. The value proposition depicts what a company delivers to customers and includes the offering, the target market and the basic strategy to attract customers and gain competitive advantages.

The offering. According to the above alternatives, different kind of products should be taken into account.

Under the assumption of recycling the elements of the temporary structure as a part of a new building, the products delivered to the clients could be different components of the building itself. They can be single elements, such as beams, girders, panels, or assembled elements, such as furnishing and interior design elements, equipment or facilities.

The Italian Pavilion built for the Universal Exposition of Shanghai 2010 can provide an interesting example of this situation. At the beginning, the original idea was of disassembling the entire structure and rebuilding it again in another geographical area of the city. At the end of the Universal Exposition, the structure was actually disassembled. The skeleton of the structure was assembled again and used as a permanent exhibition of the Italian culture, innovation, design and food. Part of the equipment was transferred in other public spaces and used like a brand of the Italian culture in China.

The Aichi International Exposition of 2005 provides another interesting example. As one of the main themes of the exposition was to minimize building waste, most of the buildings were built with the idea of being reused at the end of the event. The Aichi Pavilion Seto, settled in the Seto area was designed to be half temporary and half permanent. The temporary section of the exterior structure was made of pure and unrefined timber; the same timber was used for the interior walls and floorboard. Approximately $100m^2$ of these materials were nearly reused in the reconstruction work. An elementary school, relatively closed to the pavilion site and belonging to the geographical region where the timber were collected, expressed its willingness to be involved in the reuse plan. Another example is the Government Pavilion of Japan, settled in the Nagakute area. The pavilion was composed of thousands of elements, frame members, units, pieces and materials. At the end of the exposition most of these elements were recycled, sold by internet auctions and finally reused in new structures. The elements sold with the first auction were: the 100% of the elevators, the 63,9% of the Exhibition material, the 60,4% of the environmental material, the 50.6% of the electrical wiring and air conditioning ducts. In the second auction, the 100% of woods, kitchen facilities, equipment unit, and electric facilities were successfully sold.

In case of recycling of some building elements, the main source of complexity is the feasibility of reusing the disassembled component in order to meet the customers' requests. If a recycled element should be used as a structural element in a new building, its technical performance and physical characteristics are crucial. Furthermore when a building changes, many building elements must be adapted. It is very unusual to find the same element – with exactly the same features – in different buildings. On the contrary, the component might be used as an interior design element or exhibition item (like in the case of the Italian Pavilion in Shanghai). In this sense, the element will not be involved in the structure of the new building and the issue of the usability does not represent a critical issue.

In the case of recycling some raw materials, the offering includes materials such as iron, wood, plastic, glass, and all the other materials that constitute the structure. Before being recycled, these materials have to be reprocessed by the proper production company (e.g. steelworks for irons).

In this scenario, the main issue is to understand whether the raw materials can be recycled or not from a technology and cost effectiveness point of view. Concerning technological aspects, it's fundamental to understand if the materials used for the building can be somehow restored to their initial conditions (in terms of performance and physical characteristics), by their reprocessing. Concerning cost effectiveness, reprocessing costs related to the materials obtained from dismantling the structure (including the cost for materials' transportation and storage) should be compared against their market cost. If the reprocessing results are more cost-effective, the organization will likely to find a customer willing to buy the raw materials of the structure instead of turn to the market. Otherwise, the landfilling of the materials dismantled will become the most probable end of life scenario.

The target market. The evaluation of the target market starts from the analysis of the organizations that may be interested in the product offered and the needs that could be fulfilled.

In case of recycling some building elements, the target market includes those organizations that may reuse these elements. These actors could be organizations that might prefer to use the elements coming from a dismantled structure instead of turning to the market to acquire the new manufactured components. These actors, after having analyzed or tested the building elements, can use the component for the construction of a new building or as furnishing, interior design elements, equipment, facilities or exhibition elements, such as: museum, schools, universities, theatres, stadium, permanent exhibition halls or other structures for mega events.

In the case of the Italian Pavilion built for the Shanghai Universal Exposition, the target market included private and public organizations that could host the elements of the Pavilion. It represented an urban model. The idea was to combine the cities' requirements for renewal with the protection of history and the need to maintain a sustainable relationship with the territory. In this sense, the range of architectonical elements was broad and, as a consequence, the target market was wide. At end of the exposition, part of the elements in the pavilion were transferred and showed in the Chinese Universal Exposition Museum, due to their architectonical relevance.

In the case of the raw materials recycling, the target market depends on the type of material under consideration. After the decommissioning process, all the materials are ready to be reprocessed by a distinct reprocessing company (e.g. in the case of iron and steel, materials are to be reprocessed by steel-working companies). In some cases, other companies could operate, acting as an intermediary, between the decommissioning company and the final customer becoming customers themselves. This is, for instance, the case of the steel breakers that gather steel by buying it from the disassembled building and reselling it to the steelworks, obtaining a margin from it.

Basic strategy to attract customers. We are here referring to the basic strategy to address the building elements and the raw materials of a temporary building.

In the case of recycling of building elements, the customers could be very diversified and the basic strategy to attract the customers is somehow similar to that presented in the reusing scenario. It starts form the assessment of the implicit and explicit needs of potential customers, in terms of single or assembled elements, such as furnishing and interior design elements, equipment or facilities, in order to understand why the elements coming from a temporary building could result more suitable / appealing than new manufactured elements in fulfilling these needs. From this perspective an interesting driver could consists in the reputational effects associated to the recycling solutions, reducing wastes, and limit emission-intensive activities. On the other hand, the recycling choice could have some powerful implications, in terms of possibility to attract visitors and host a well-known symbol of a mega event in the new construction.

In the case of recycling of raw materials, the target customers are different companies / organizations that could use the raw material (such as steelworks reprocessing iron, glass, wood and plastic manufacturing companies reprocessing respectively glass, wood and plastic and other manufacturers interested in the materials composing the dismantled structure). In this case, the main competitive driver is represented by the lower cost related to raw materials purchase derived from a disassembled structure rather than other scrapping raw materials bought on the market. This issue is more relevant, if the reprocessing company apply to international market for its production requirement. Considering, for example, the case of steel; Italy is a net importer of steel scrap. This means that Italian steelworks must turn to the international market in order to obtain the raw material for their activities, with connected cost of gathering, storage and transportation of the materials. In this sense, steel coming from local dismantled structure represents a lower cost solution able to cover part of the production requirements of Italian steelworks. At the same time, the amount of raw material that will become available should be considered, to ensure that there is the interest in accessing these resources because they could cover a certain amount of the demand.

Block 2. **Value creation and value proposition**. The value creation and delivery system refers to how activities, resources and the position in the value network can be combined enabling the recycling of the building elements and the raw materials of the structure.

Resources and capabilities. Resources and capabilities include tangible and intangible resources that an organization deploys in order to ensure the recycling options. We are here referring to (1) the relationships within the network, (2) the capability of registering and tracing the physical characteristics of the building elements and (3) the strength of the brand of a mega event.

As in the reuse scenario, the relationships within the network play a relevant role in the implementation of the business model. The formal and informal linkages remain a key issue also referring to the recycling of building elements and raw materials.

The capability of registering and tracing the physical characteristics of the items and the specific use in the first-life structure plays an important role in case of recycling some building elements as structural elements in a new building. We refer to beams, girders, panels, etc.. This is because, for example, the loads that they must endure during their first life might modify the initial physical characteristics of the component itself, with the consequent obligation to be manufactured again before the second use. The issue is obviously less relevant if materials and components are supposed to be recycled as equipment or design elements.

Finally, as in the reuse scenario, the strength of the brand of a mega event is a key resource. Target customers are interested in hosting in their spaces (such as museum, schools, universities, theatres, stadium, etc..) an element coming from a mega event, since it could represent an attraction able to capture an higher number of visitors. The brand plays a more relevant role accordingly to how much the element is well-known and recognizable among the public.

Internal organization. We are here focusing our attention on the key activities to carry out in order to enable the recycling of the building elements and the raw materials. These activities are (1) decommissioning, (2) reprocessing and (3) remanufacturing.

Decommissioning represents a key activity in case of recycling. This activity refers to the complete process form the dismantling of a building to recover its raw materials. Again, this process should be performed according to safety protocols and in compliance with pollution and noise control standards, in order to preserve local communities. This activity could be influenced by the size of the building, its shape, adopted materials and the main characteristics of the surroundings to be protected and preserved. Furthermore, the decommissioning process includes separation, recovery and storage of the raw materials obtained after the dismantling phase. In fact, different materials should be separated and “sent” to the proper reprocessing industry.

Once the material has been separated, it is ready to be reprocessed. Each material follows a different process. In the case of steel, for example, after decommissioning, the material to be recycled is gathered by the local steel breakers that could stock and find a buyer, usually the steelworks. Steel, in fact, before being deployed in a new construction, must be completely reprocessed (from the beginning of the production process). This gives it back the initial performance and physical conditions, enabling the reuse with the same properties of the new raw material and without limitations and restrictions. Wood, in a similar way, is gathered and stoked at the end of the decommissioning and then reprocessed by the wood manufacturer. Wood waste collected on the national territory are mainly used to obtain chipboard panel. Wood reprocessing is more complicated than steel reprocessing. Initially, the material coming from the platforms is selected and cleaned again of foreign matters (metals, paper, various plastics, inert, ecc..). After this, it is shredded in small chips, whose quality is guaranteed by the high level of technology achieved by industrial processes and from the quality of the raw material. These chips, after drying process, required to contain the moisture levels, are pressed together with glues in order to achieve particle board used exactly as a new wooden board. The board can be then used in the production of furniture and furnishings for interior and exterior of houses, dwellings, offices and, in general, living spaces.

If we consider the recycling of building elements, remanufacturing activities can be needed. Before using these elements with an active parts in the construction of the new building or as an interior design element or exhibition item (like in the case of the Italian Pavilion in Shanghai), they must be adapted to the characteristics of the new building.

Position in the value network. We are here referring to the key partners of the organization, who include public and private organizations that allow the recycle of the building elements and the raw materials. In this scenario, (1) the decommissioning companies and (2) the market demand aggregator companies play a crucial role.

The decommissioning companies conduct all the activities needed in order to enable the raw materials to reach the proper reprocessing industry. They are engaged in the activities of disassembling a building, recovering, separate and store raw materials.

As in the reuse scenario, market demand aggregators play a key role. If we consider the alternative of reprocessing the raw materials, Manufacturers Associations work as demand aggregator on the market since they represent the manufacturers dealing with institutions, governments, and other organizations. They usually assist member companies about administrative, commercial, economic, fiscal, regulatory, technical and safety issues. For this reason, they can help the owner of the temporary structure in assessing the potential customers.

Block 3. **The value capture.** The value capture describes how the company generates revenue and profit by recycling building elements and raw materials. It includes revenue sources and costs.

In the recycling scenario, we have considered two alternatives. First, we can recycle the main elements of the temporary structure for the construction of a new building (temporary or not). Second, we can recycle row materials with their consequent reprocessing. In according with these alternatives, the cost items change.

Revenues sources. We are evaluating the main revenue stream deriving from recycling. They refer to the sale alternatively of the building elements to the new users or of the raw materials to the reprocessing companies.

Costs. This element refers to cost items that the recycle scenario may imply, as result of the activities undertaken, the resources employed and the relationships in the network. These costs, organized by destination, can be linked to the following activities: (a) decommissioning, (b) transporting, (c) reprocessing, and (d) remanufacturing and remodeling.

Decommissioning costs. The item includes costs related to the activities performed by the decommissioning company in order to dismantle the structure, decompose its main elements (such as beams, girders, panels, etc..), recovery, separate and storage the row materials (such as iron, wood, plastic, glass, etc..). The decommissioning costs include also the costs related to restoration activities that have to be conducted at the end of the dismantling activities. We consider all these costs categories in the same item since the activities that generate the costs are performed by the same company.

Transportation costs. At the end of the decommissioning, each element of the structure must be transferred from the first-life site to the new-life site or to the reprocessing companies. This cost category have a lower relevance here than in the reuse scenario.

Reprocessing costs. This cost item mainly refers to the raw materials recycling alternative. Before using iron, wood, plastic and the other materials they have to be reprocessed in order to give them the original functionalities and properties. This item includes the costs related to these activities.

Remanufacturing and remodeling costs. This cost item mainly refers to the building elements recycling alternative. Whether we use these elements with an active part in the construction of the new building or as an interior design element or exhibition item, they must be remanufactured and remodeled in order to become suitable for the characteristics of the new building. The costs will be more relevant as much as different are the first-use and the second-use structure.

	Recycling building elements	**Recycling raw materials**
Decommissioning costs	+	+
Transportation costs	+	
Reprocessing costs		+
Remanufacturing and remodeling costs	+	

Table 5. Cost comparison in the Recycling scenario

Conclusions

In this chapter, we tackled the issue of the design of a business model for the management of the end-of-life of temporary structures. We focused on two different scenarios: reuse and recycling. The need of identifying and representing in a structured framework all the organizational and managerial arrangements enabling the value creation is motivated by the configuration of the end-of-life of the structure: a multi stakeholder and multi-objective system. On the one hand, we are dealing with a multi stakeholder system that involves a network of different actors with their own decision-making processes and goals that should coexist and cooperate. On the other hand, the system is multi objective in nature, which means that each technical end-of-life solution leads to different levels of social, economic and environmental performance. We investigated the two scenarios referring to the framework designed by Richardson (2005).

The reuse scenario entails the reuse of the whole building, which can occur in its original place, becoming a permanent structure, or in a different place, after being disassembled, moved and rebuilt. In its second life, moreover, the structure can maintain its original function or it can be converted for a different purpose. In this scenario, the offering is represented by the temporary building itself. It can be delivered mainly to public and private organizations working in the social services industry (for example education and welfare, schools and universities, large corporations). In order to reach these organizations, the basic strategy includes the assessment of customer needs in terms of living conditions to understand how the structure can meet these needs and the exploitation of the reputational effects of a reusing solution.

With respect to how the business model can create and deliver value to customers, the resources exploited include the following: the capability of adapting and remodeling the structure to meet the second life functionalities, the relationships with the other network actors (the owner of the site, local authorities, dismantling and decommissioning companies, etc.) and the ability of the brand of a mega event to attract customers. The key activities to assure a second life to the structure comprise the design phase, the disassembling, the remanufacturing and the transportation of the structural elements to the new site. Finally, about the positioning in the value network, we focused our attention on the crucial role of the relationship with the decommissioning companies and the market demand aggregator companies.

The recycling scenario entails the recycling of building elements and materials. This scenario could include different recycling options, mainly the recycling of components in a new building and the reprocessing of components and materials into new materials. In this scenario, the offering is made of building elements and raw materials coming from the dismantling of the temporary structure. The building elements are delivered to companies willing to reuse them as furnishing, interior design elements, equipment, facilities or exhibition element. The raw materials are addressed to the remanufacturing companies. In this scenario, the main elements to attract customers are the lower purchasing cost and the reputational effects associated to the choice of a recycling solution.

From an internal point of view, the capability of registering and keeping traced the physical characteristics of the building elements, the relationships within the network and the strength of the brand of a mega event are the main resources exploited. The key activities are the decommissioning process, the reprocessing of the raw materials and the remanufacturing of the building elements. Finally, as in the reuse scenario, we investigated the relationship with the decommissioning companies and the market demand aggregator companies.

References

Amit, R., Zott, C., 2001, "Value creation in e-business", Strategic Management Journal Vol. 22, pp. 493-520

Barney, J.B., 1991, "Firm resources and sustained competitive advantage", Journal of Management, 17.

Geyer, R., Jackson. T., 2004, "Supply loops and their constraints", California Management Review Vol. 46, pp. 55–73.

Osterwalder, A., 2004, "The business model ontology - A proposition in a design science approach", Dissertation 173, University of Lausanne, Switzerland.

Osterwalder, A., Pigneur, Y., Tucci, C.L., 2005, "Clarifying business models: Origins, present and future of the concept", Communications of the Association for Information Science (CAIS), Vol 16: pp. 1-25.

Richardson, J., 2008, "The business model: An integrative framework for strategy execution. Strategic Change", Vol. 17, pp. 133-144.

Zott, C., Amit, R., 2010, "Business Model Design: An Activity System Perspective", Long Range Planning, Vol. 43 No. 2-3, pp. 216-226.

POLITECNICO di Milano

P.za L. da Vinci, 32 – 20133 Milano – Italy

CONVENZIONE TRA IL MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE ED IL POLITECNICO DI MILANO DEL 24 MARZO 2014 PER L'ATTUAZIONE DELLE METODOLOGIE DI CALCOLO DELL'IMPRONTA DI CARBONIO E DI COMPENSAZIONE DELLE EMISSIONI DI CO2 DI EXPO 2015

D.1.1.b Guidelines for the reduction of the environmental impact of temporary building and structures in mega events

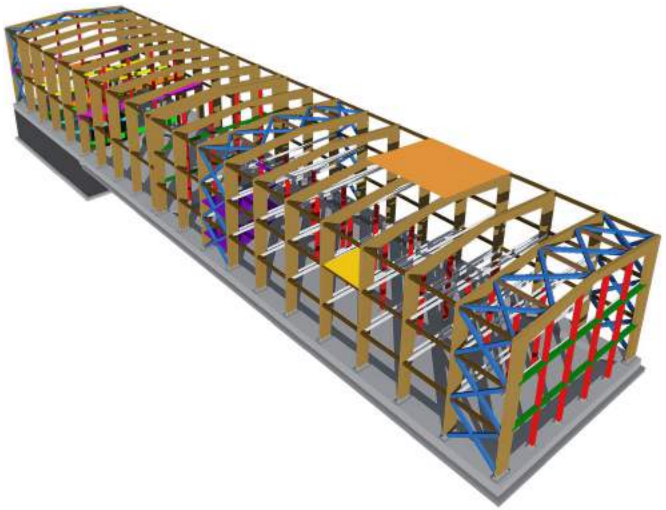
Annext A
Examples of re-use "out of site"

Dipartimento di Energia

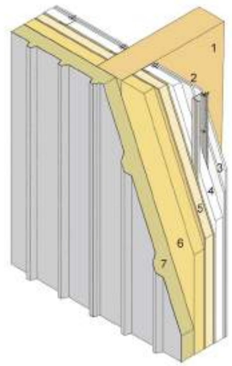
LCH-Lecco City Hostel
Hostel, exhibition area - Lecco
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Alberto Leoni, Karin Longhi, Andrea Valsecchi

LCH (Lecco City Hostel) is a building complex that includes a hostel, an exhibition area and a bioclimatic greenhouse. The project area, so called “La Piccola” in Lecco, has recently being the object of a competition for the redevelopment of the place. The building integrate this project and is placed in front of the square where the weekly market is held. The portals, which make up the structure, have enabled the creation of a simple geometry: a simple and linear distribution, with large windows facing south and the protruding shading, creates an intense dialogue with the context, consisting of two near shed. The distinctive element is the bioclimatic greenhouse, which not only acts as a central atrium connecting both environments, but it represents also an important source of passive energy gaining, making the building “active” and dynamic.

First floor plan



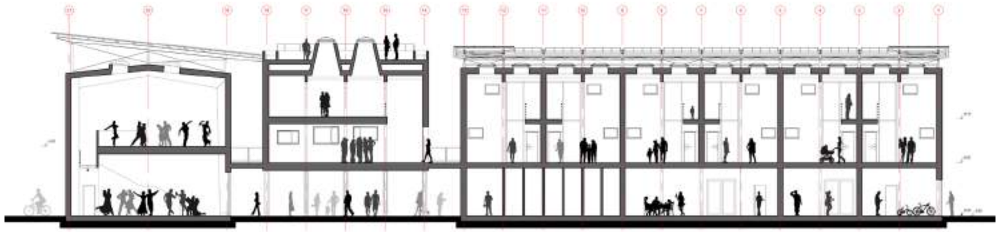
Structural scheme



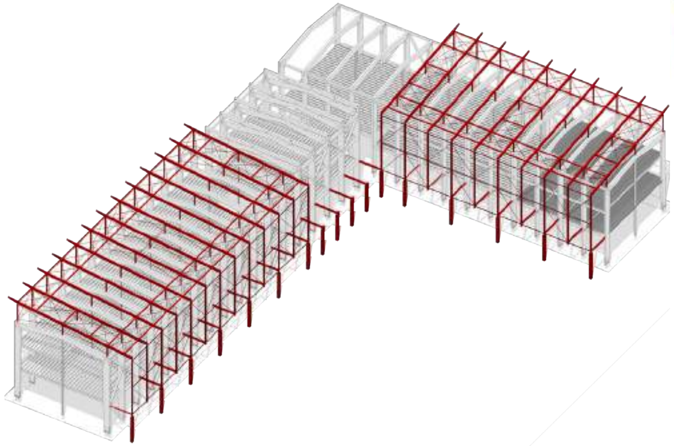
1. Wooden portal; 2. Interior lining with plasterboard panel, gypsum fibre board and interposed vapour barrier; 3. Cellulose fibre panels sp. 60 mm; 4. Wooden sandwich panel sp.79 mm; 5. Glass wool panels sp. 80 mm; 6. Coating and waterproofing with metal sandwich panels sp. 50 + 40 mm.

Martesana Social Hub
CoHousing and multicultural hub - Milan
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Eric Pitalieri, Andrea Redaelli, Danilo Tomasoni

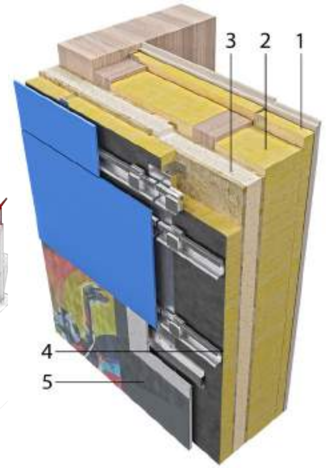
The project is located in the north-east suburbs of Milan, between via Padova and Naviglio Martesana where the cluster's structure has a second life as a multicultural hub covered in playful colours and underground street-art, bringing new life to the neighbourhood. The lightweight photovoltaic roof and the brise-soleil protect the three blocks characterized by multi-ethnic street-food restaurants that create a lively public space at ground level. The six CoHousing units are located in the west building and the two open-floors block with green terrace hosts the related shared services. The east part consists of public facilities: two ample rooms for different activities (dance, music, fitness...) next to a multicultural library that includes both spaces for exhibitions or classes and comfortable reading zones to study and relax.



Longitudinal section of CoHousing



Structural model



1. Gypsum board counter-wall with vapour barrier 75mm; 2. Wooden frame with rock wool 160mm; 3. SIP panel 90mm; 4. Galvanized steel structure and glass wool 80mm; 5. Recycled wooden panels or plastered cement board

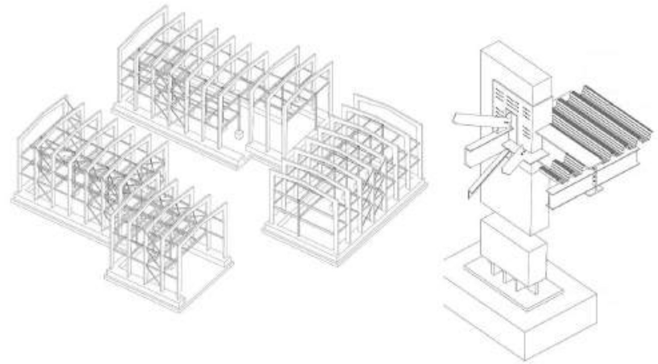
ActiVi – Coworking e Lab.

Coworking and Labs - Vimercate

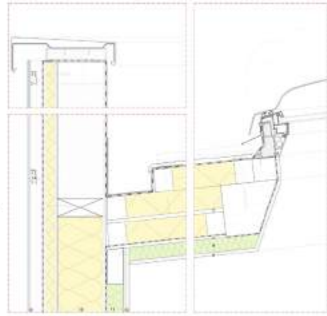
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Davide Cupani, Jolta Gurra, Enrik Kondo

The project proposes the re-use of the cluster's structure, creating a centre for business development of young people. The proposal involves the construction of a cultural centre, which is able to connect the resources of the area, local industries and young professionals. The territory of Vimercate where the building is supposed to be located, is able to provide a direct relationship with big companies in the field of technology that could also invest in this project. The idea is to create a space where workers can share ideas, knowledge, experience, tools and business opportunities. A virtuous circle that connects youth to community for mutual support. We wanted to propose an innovative concept of coworking "in art and music," that makes it possible to support creative activities with few individual resources, connecting different professions.

Elevation East - Intern



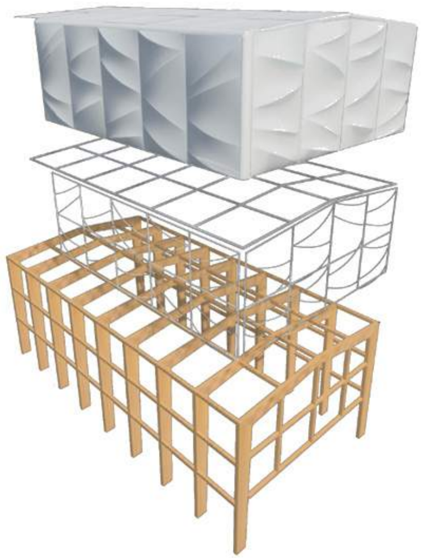
Structural scheme



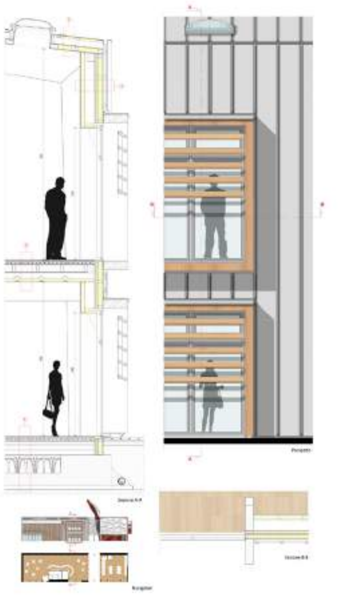
1. OSB - Oriented Strand Board; 2. Thermal insulation in hemp wool (fibre); 3. Natural gypsym board lightened with pearlite; 4. Rockwool insulation; 5. Gypsym fiber board; 6. High Pressure Laminate (HPL) panels; 7. Alluminium profiles; 8. Prefabricated wall

S3 Project
Youth centre: gym, fab lab, bar and library - Lecco
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Piergiacomo Acerboni, Domenico Arcadi, Marco Cucuzza

Elevation South-East



Light coverage in PVDF: assembly diagram

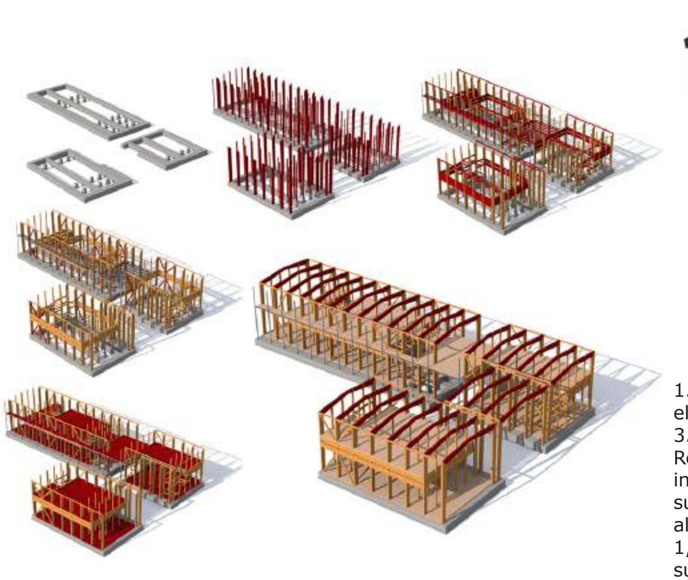


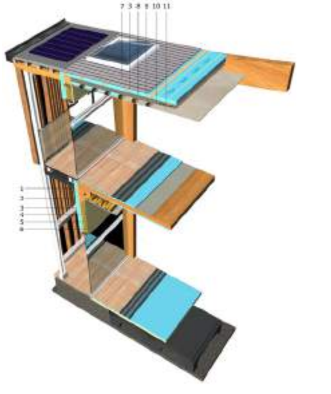
Shading detail

Sport, wellness and learn are the three ideas behind this youth centre located in Pescarenico (LC). The building's L-disposition protects the open space in front of the river Adda from noises coming from the ICAM factory. The three blocks place on the site have two passages for permeability. The gym facing the industry divides the public space from the road; the fab lab is squared and it has wood façades; the third body hosts the bar and the library, both facing Era square and the skate park that is directly connected to the cycle path leading to Bione sports centr. The materials used are metal, showing the industrial character of the area, and wood, symbolizing the surrounding natural context. The inner and outer space have the same importance, for this reason the façades of the gym also show its function with a climbing wall and a parkour route.

ABow
Multi-age cultural activities center - Milan
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Chiara Mariska Chiodero, Daria Pantò Mancuso, Cristiana Topo

South-West exposition study - Winter season





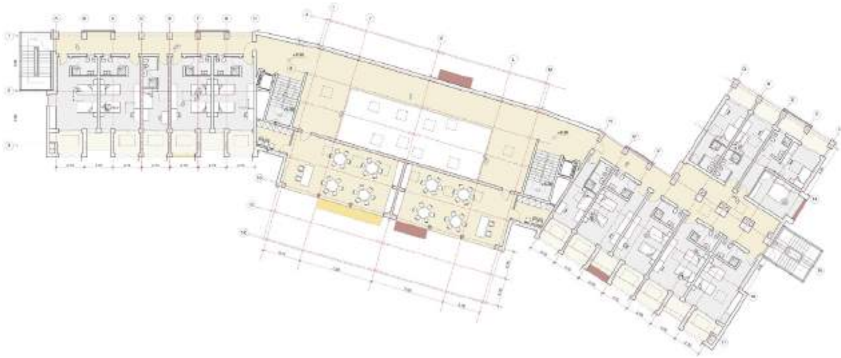
Building phases of structure

1. Polyurethane sandwich panel 10 cm; 2. SIP panel 7.2 cm; 3. Waterproofing; 4. Insulation Rock wool 10 cm; 5. Polyester insulation 7.5 cm; 6. Double gypsum board 2.5 cm 7. Corrugated aluminium sheet; 8. OSB panel 1,6cm; 9. Extruded polyester insulation 10 cm; 10. Mineralized wood wool insulation 7.5 cm; 11. Countertop with glass wool 7.5cm

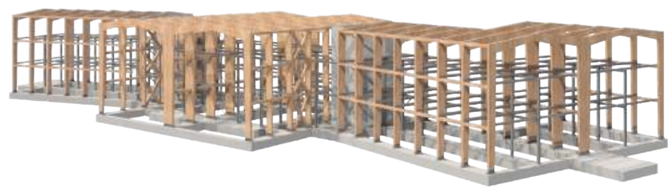
A-Bow is located in Milan Bovisa, an area which connects Polytechnic of Milan’s campus with the train station. The internal spaces are dedicated to educational activities and sports meant for people with differents ages, in addiction to relax and refreshment areas. Cluster’s portals are the structural part of the project and draws the entrance to the buildings, which is why it is named “Activity Bow”. The interior spaces are designed to keep a high level of light, thermal and acoustic comfort. Shading systems are studied according to the different exposures, to maximize natural light use. Thermal insulation wrap minimizes energy wasting. Furthermore we used Expo 2015’s theme, “Feeding the Planet”, adding a bioclimatic greenhouse, including a green wall and gardens, used as a heat storage to maintain thermal comfort in winter.

2H - HOMELESS' HOME

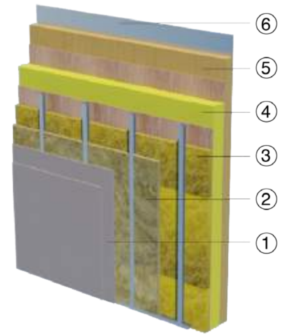
Homeless care facility - Milan
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Caterina Nogara, Roberto Pezzutto, Benedetta Rota



Second floor plan



Structural scheme

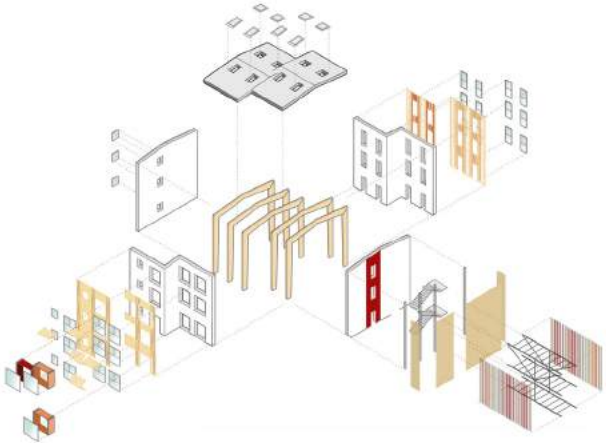


1. Double gypsum board with vapour barrier, 25 mm 2. Rock wool panel, 40 mm 3. Glass wool panel, 40 mm 4. Sandwich panel with extruded polystyrene core, 190 mm 5. Wood fibre insulating panel, 60 mm 6. Layer of plaster, 2 mm

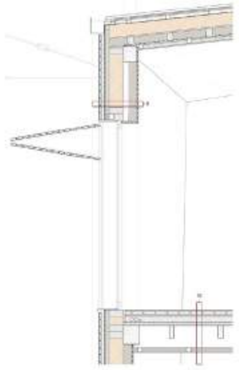
The project is located in Milan, close to Porta Nuova, in via Fatebenesorelle. The North-facing side is affected by the presence of a hospital, while the South-facing side looks toward a new playground. The wooden structures were reused for the construction of a homeless shelter, to provide assistance and social reintegration. The space is organized around a triple-height central core, that connects two long terrace-style buildings with shared areas on the ground floor (reading room and dining hall) and 25 rooms on the first and second floor. The horizontal distribution element evokes the typical Milanese houses with common balconies that characterize the north elevation of the building. The south facade, with mainly glazed surfaces, is composed of alternating loggias and extruding volumes, which identify the rooms' solar greenhouses.

PoliNET
Students residence - Lecco
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Federica Marchesi, Alessandra Oberti, Giuseppe Tucci

South elevation, building E-F facing Adda river and Viscontea island.



Isometric explosion of a designed building module in which are highlighted the primary structural elements, around which were then added the façade's walls with their own coatings, the bioclimatic greenhouses, the roof with glazed openings and the staircase with the steel foot-bridge.

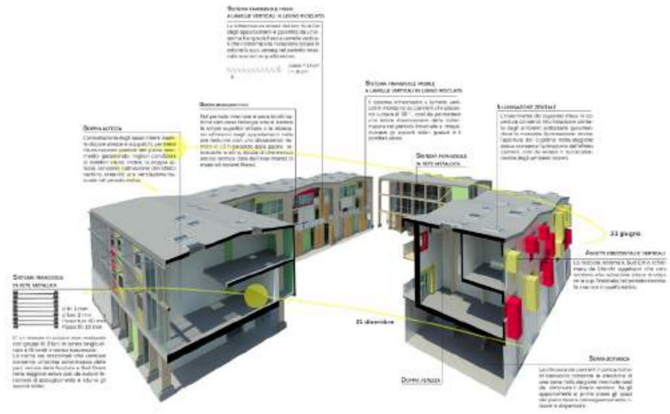


Portion of the south facade in which are highlighted the roof/wall and inner floor/wall connections, besides the presence of the screening system adopted, that is a knee sunshade coated with larch boards. Are visible also the wooden structure and the thick insulating layers.

The designed building is located in an abandoned industrial site of 5670 sm located in Lecco, between Corso Martiri della Liberazione and Via dell'isola. The area overlooks Adda river and there is a direct visual connection with the Viscontea island and its natural beauties.
The project is developed around the idea of connecting two different city places. One strictly urban characterised by the buildings curtain of Corso Martiri while the other represented by the irregularity and heterogeneous forms of the riverbank. The project's site also wants to be a new landmark for the Politecnico's students and the city itself, as a prosecution of the brand new built Campus of Via Previati. It hosts common and service areas for the students, as a small library/reading room, as well as new and functional student residences.

CARA CASA centro accoglienza richiedenti asilo
Homeless shelter - Milan
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Giulia Chessa, Sofia Fondelli

Internal South-East elevation, courtyard



Lighting and energy strategy

Detail of South-West facade

C.A.R.A. CASA is a homeless shelter that has the purpose to integrate itself in urban and social contest, trying to give value to a degraded area occupied by a ramshackle building. The project is located near Rogoredo railway station in Milan suburbs. Design main aim is to reuse and recycle "Island, Sea and Food" Cluster's structures and technological elements.
C.A.R.A. CASA homeless shelter does not limit to provide assistant during the night but it wants to offer to people in need common spaces and flats where families can find their intimate dimension. The building, developed around a courtyard, is characterized by hermetic skin on the outside, like a protective shell, and by more articulated volumes facing the court, with bioclimatic greenhouses, balconies, galleries, filtering spaces and botanical garden that allows hosts to participate in the community life.

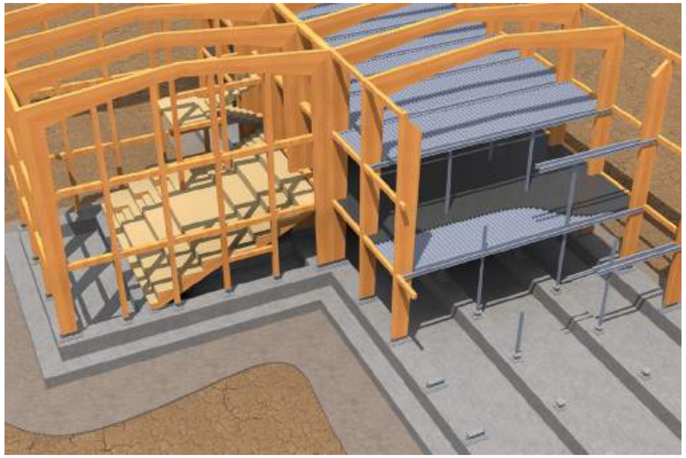
WDML - Wood Dormitories Metal Labs

Student dormitory and Ateliers - Lecco

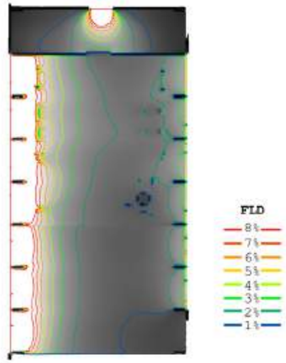
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Emanuele Maiorano, Fabio Molaro, Francesco Rota

The project is located in Lecco, in ex Faini's factory area. The aim was to reuse all the wooden structures of "Islands, sea and food" Expo's Clusters. The ensemble is divided into three blocks developed around a central public square. Building A: Art and Craft Ateliers (north side) and bar and social aggregation space (south side) on the ground floor. Student dormitory on the first and second floor; Building B: kids craft laboratory on the ground floor, double high relax area on the first floor; Building C: double high gymnasium on the ground floor and gym on the second one. The wooden framework building was covered with a metallic bronze skin, that recall Lecco's metallurgic history . The southern facade in characterised by a curtain wall, properly screened with aluminium flaps, that cut down the incident solar radiation on the summer season.

First floor plan



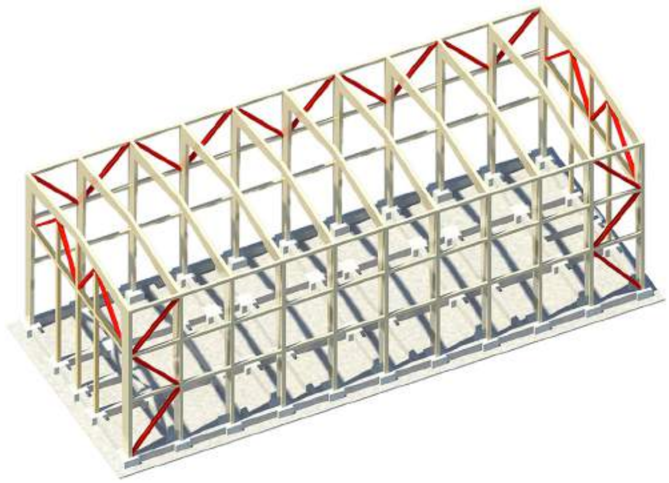
Structural model



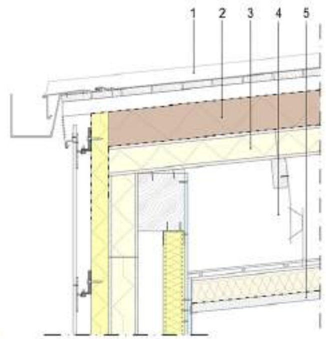
Lighting study of the interiors

noMade
Residential complex and multipurpose building - Cremona
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Salvatore Nastasi, Silvia Spallina

Residential building - first floor plan



Structural model - wood elements



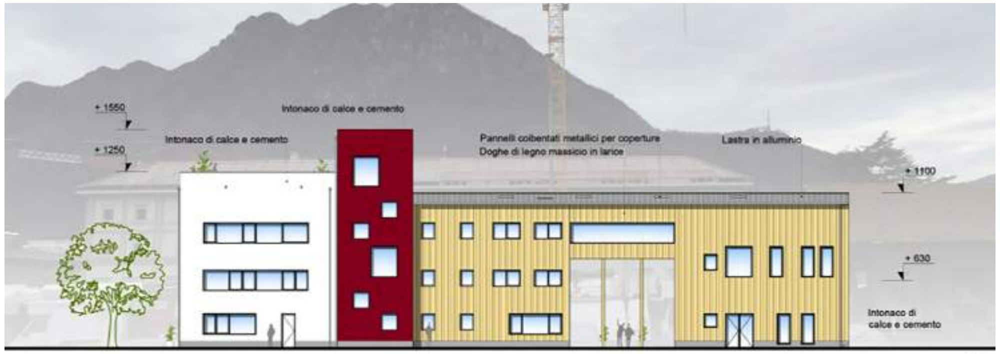
1. Metal roof panels fixed on larch wood laths; 2. Fibre wood thermal insulation panels with vapour barrier and breather membrane t. 80 mm; 3. SIP panels t. 80 mm; 4. Wood frame; 5. Countertop made of gypsum boards fixed on galvanized steel structure with kenaf acoustic insulation t. 30 mm

The project consists in a courtyard placed in Cremona countryside, near the city centre, defined by three buildings arranged in a C shape. The entire ensemble aims to provide housing and services to the local Roma community. We choose the courtyard typology as our proposal of community life. Two of the three buildings host the residences; each apartment, for large families, spreads on three floors and integrates a stables for a small cattle farming at ground level. The concept of the barn-house, which starts from the traditional Lombardy farmhouse, is reinterpreted with the goal of environmental sustainability and energy efficiency where the animal has a fundamental role in the building energy balance. The third building presents services for the community such as a common laundry, study rooms, a kindergarten and hobby-rooms.

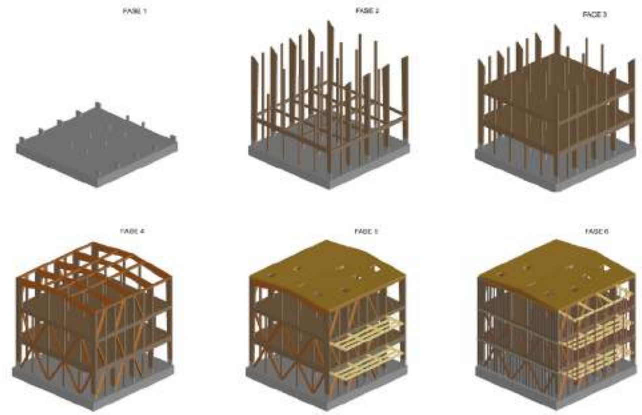
I.S.H. - INTERNATIONAL STUDENT HOUSE

International student residence - Lecco
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Dong Zhihui, Gu Hao, Yves J. Soh Tela

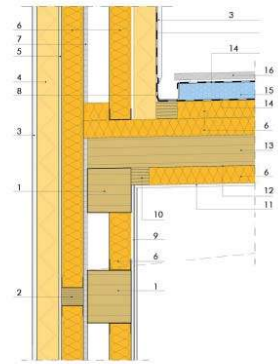
ISH is a dormitory with a capacity of 30 students located in the area where there was a railway storage in Lecco. One of the objectives of this project is to reuse the glulam structure that have been used for the pavilions during EXPO. The frames are fixed on the CLS pillars that are set on a CLS plate. The substructures and bracing beams are also made from recycled glulam from EXPO site. The roof and floor boards consist of Xlam panels. The balconies designed with an overhang of 2 m are sustained by stainless steel tie rods. The appearance of the building is a combination of the larch wooden part, which represents the public areas, the white plastered part, which represents private areas, and the red plastered part, which represents the stairway areas, whose colour recall the castle’s towers of Lecco.



North-East elevation



Building phases

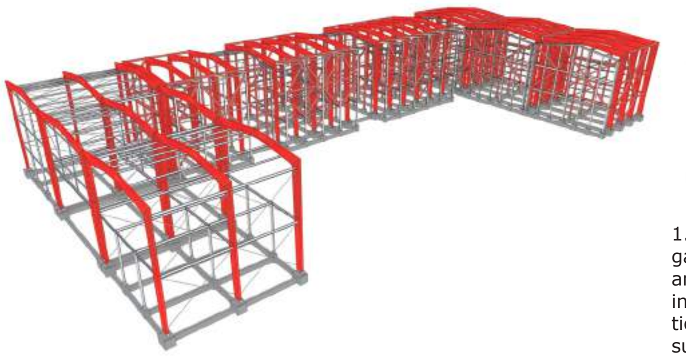


1. Wood structure 2. Wood substructure 3. Plaster 4. Insulation 5. Aquapanel 6. Insulation 7. OSB 8. Eaves copper 9. Double plasterboard sheet with vapour barrier 10. Wood substructure 11. Plaster 12. Vapour barrier 13. X-LAM wood panel 14. Waterproofing layer 15. Insulation 16. Cement mortar block

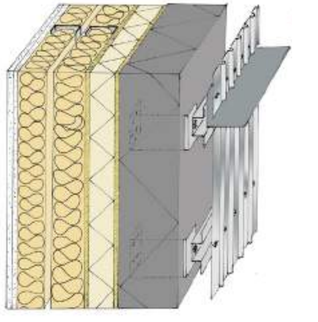
LinkAge - Residenza intergenerazionale
Intergenerational Housing - Lecco
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Julien Bossard, Aubin Cortale, Pierre-Hugo Romain

The LinkAge project develops three main themes. First, linking Lecco city with its natural surroundings: Adda River, mountains and Viscontea Island. Second, creating a lively and welcoming space for a mixed community of seniors and students. Third, reusing the wood structure from the EXPO Clusters. The building creates a private courtyard, and recalls the close historical district of Pescarenico, with its balconies and external distributions. The nodes within the buildings are thought of as points of encounters between seniors and students. Long and massive, the North side is cut by small bio-climatic greenhouses. The south instead, facing Viscontea Island, is more porous and attractive for the public. Wherever possible, the wood structure from EXPO is shown and emphasized, both inside the apartments as libraries, and outside as supports for the louvres.

North-West elevation - Public park



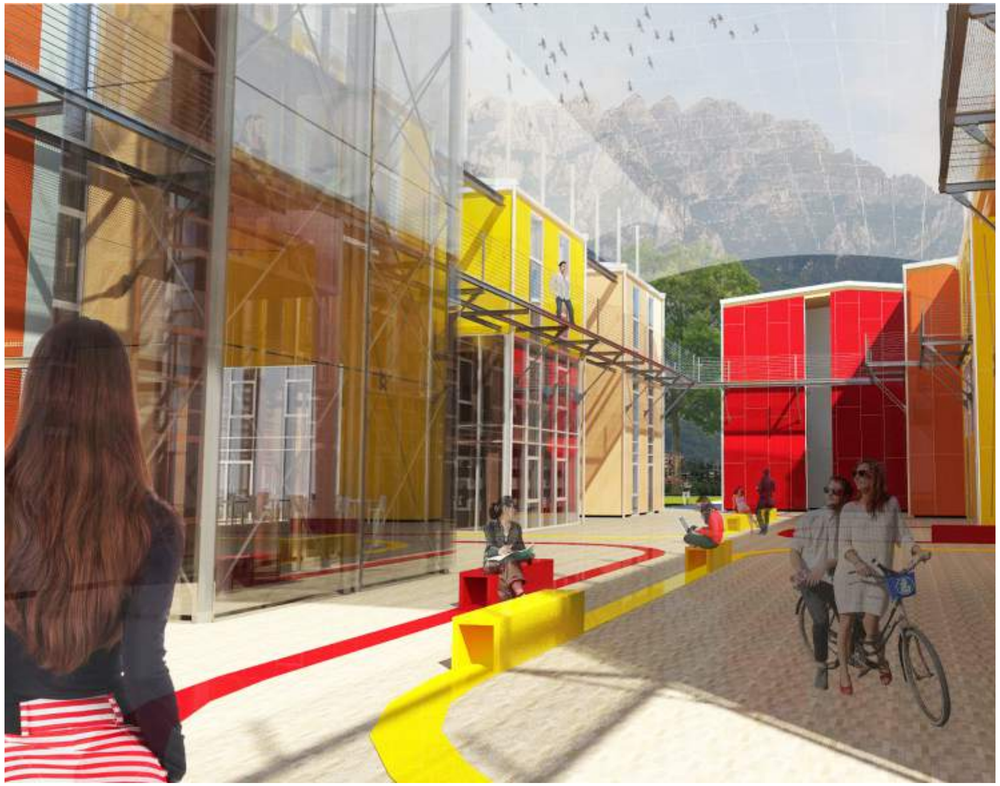
Structural model



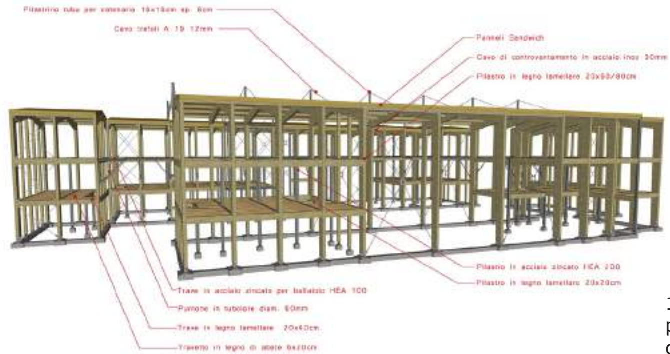
1. External panels in pre-lacquered galvanized steel, micro-waving and coloured; 2. Under-structure in aluminium Ω profiles; 3. Insulation panels in EPS w. 14 cm 4. Insulated sandwich panels; 5. Rock wool acoustic insulation panels; 6. Structure of galvanized steel profiles; 7. Internal finishing in double plasterboard with an integrated vapour barrier

Lecco In Bosco

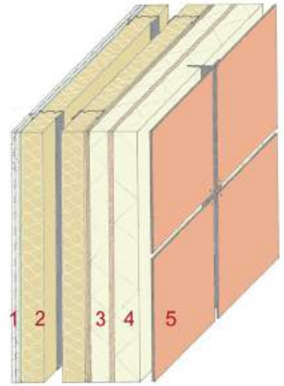
Students housing - Lecco
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Damien Alias, Louis Lallemand, Charles Perchaud



Longitudinal section

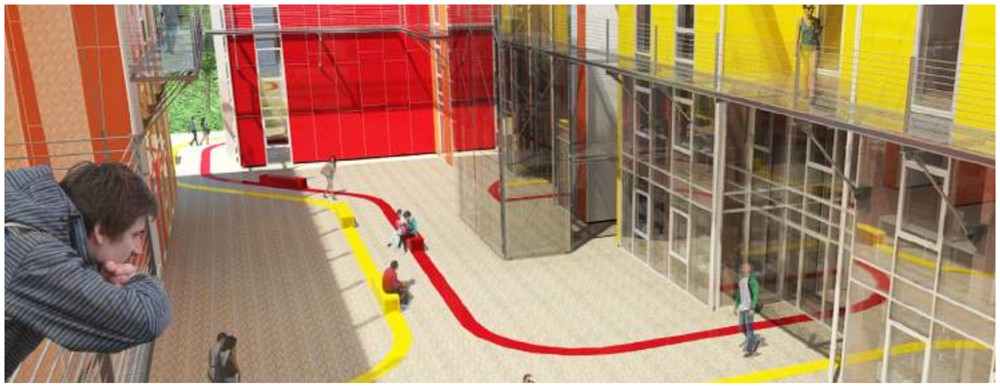


Structural diagram



1. Internal coating in double plasterboard plate; 2. Internal counterwall in metal framework isolated in rock wool; 3. Reused Sandwich panel; 4. Insulation in expanded polystyrene; 5. Ventilation and coating in panels of compacted resin sheets

Our project is located in the Northern part of Lecco along the Gerenzone torrent, in a remote site of the city even though close from town center. It consists of a student residence that is an addition to the current one in Gorizia street. As well as accommodations, it proposes services adapted to the users like a library, a bar, a park along the river and a central square. The 36 portals of the EXPO cluster are reused together with its wooden beams, the sandwich frontage and roof panels as well as the catenary structure that covers the street joining the buildings. This light structure holds the semi-transparent fibre glass and silicone membrane aimed to protect the street from both the sun and the rain. External balconies in metal-framed grid on a steel structure made of beams and struts connect the higher level housing.

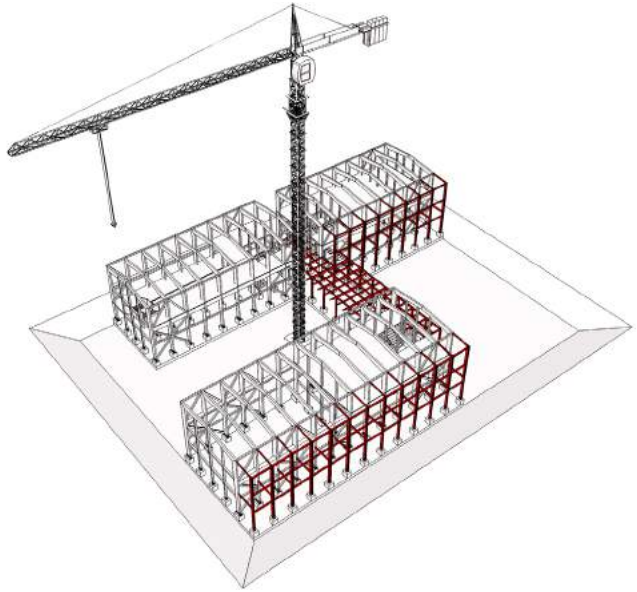


NEXT

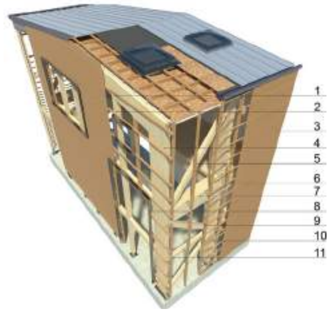
Multipurpose spaces for social activities, library and fab lab - Milan
Politecnico di Milano - Polo territoriale di Lecco
Lab Progettazione e Innovazione Tecnologica - Prof. M. Imperadori
Micol Borsa, Era Fejzo, Marco Sangiorgio

The project is located in a green area in the Bovisa university campus, north west of Milan. This part of the city lacks of services for the inhabitants, especially for young people and families with children. The project aims to create a multifunctional building for the whole neighbourhood and the Polytechnic of Milan itself. The final idea is to build a library, a fab-lab and new spaces for the association Coltivando, that has been running a garden for several years on the building site promoting two main EXPO's ideals: the need to increase our sense of responsibility towards the environment and its products and the importance of sharing the. The main objective for the project is to maintain the natural qualities of the site; this resulted in the preservation of the existing vegetation and in the use of wood as the main material for structures, finishings and shieldings.

North elevation



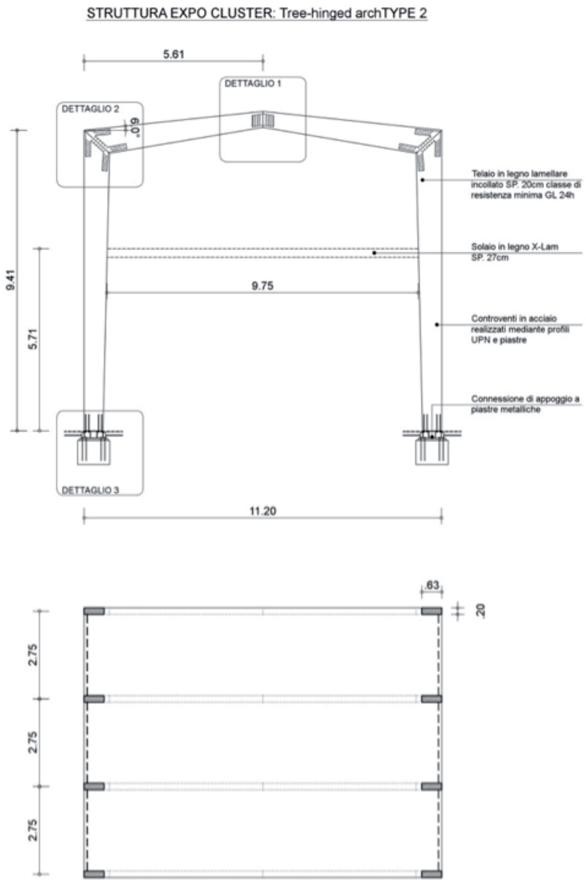
Structural model

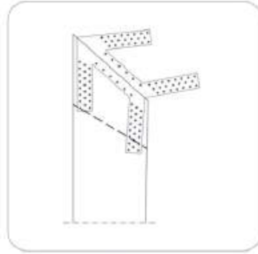


1. Horizontal rafters; 2. Laminated wooden pillar; 3. Vertical rafter; 4. Laminated wooden structural frame sp. 200mm; 5. Laminated wooden brace; 6. Coupling stirrup; 7. "L" beam Glula; 8. Steel tubular; 9. Vertical rafters; 10. Horizontal rafters; 11. Wooden laminated beam

EXPO 2015 Cluster Pavilions - After EXPO 2015
Thesis by: Stefano Bonetti, Anna Colombo, Stefania Franzelli - Politecnico di Milano
Tutor: Prof. Marco Imperadori - Politecnico di Milano

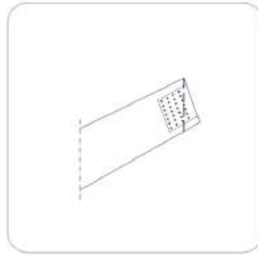
EXPO provides for cluster pavilions three types of wooden structure. The project developped in this thesis is about the possible re-use of the wooden structures of EXPO 2015 “Sea, islands and food” cluster pavilion (three hinged arch TYPE 2) to create new residential solutions, studied for a specific quarter in Lecco.
This structure can be re-used in the original conformation , paying particular attention to the joints during disassembly and transport. For the design of his “ second life “ it will be rechecked the characteristics of every single element , the connections and the stability of the overall system.
Being replaced in a completely different environmental and functional context, the geometry of the structure has to be readapted.
Climate analysis has putted in evidenced that the slope of the roof pitches did not meet the local regulatory requirements, so cuts in the connection between the column and beam have been studied to increase the inclination, paying particular attention to the optimization of waste , in accordance with the provisions of the “Guidelines” . This led to a consequent reduction of internal span.
Depending on the architectural design the structure can be differently cut at the bottom or at the top of the pillar, always considering that, not having pillars of straight section, cut in one end section causes significant differences affecting the bearing capacity of the frame.





Taglio pilastro in sommità

Taglio trave al piede



Taglio trave in sommità

CARATTERISTICHE DEI MATERIALI

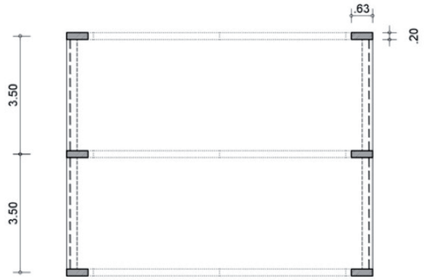
Legno lamellare di conifera classe GL24h (rif. EN1194)

Resistenza (MPa)		
flessione	$f_{m,g,k}$	24,0
trazione parallela alla fibratura	$f_{t,0,g,k}$	16,5
trazione perpendicolare alla fibratura	$f_{t,90,g,k}$	0,40
compressione parallela alla fibratura	$f_{c,0,g,k}$	24,0
compressione perpendicolare alla fibratura	$f_{c,90,g,k}$	2,7
taglio	$f_{v,g,k}$	2,7
Modulo elastico (GPa)		
modulo elastico medio parallelo alle fibre	$E_{0,g,mean}$	11,6
modulo elastico caratteristico parallelo alle fibre	$E_{0,g,05}$	9,4
modulo elastico medio perpendicolare alle fibre	$E_{90,g,mean}$	0,39
modulo di taglio medio	$G_{g,mean}$	0,72
Massa volumica (kg/m³)		
massa volumica caratteristica	$p_{,g,k}$	380

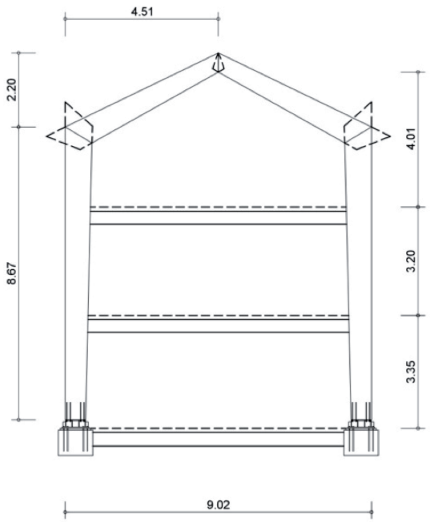
Pannello strutturale in abete a fibre incrociate Xlam classe C24

Resistenza (MPa)		
Modulo elastico (GPa)		
Massa volumica (kg/m³)		
massa volumica caratteristica	$p_{,g,k}$	450

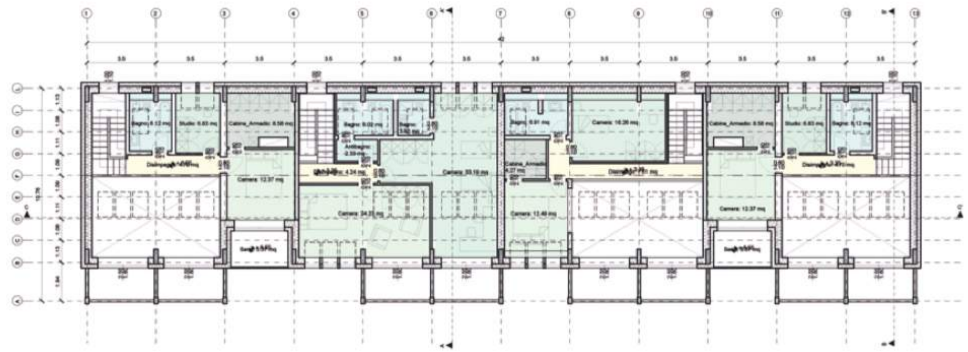
CASE STUDY 1
3 story residence



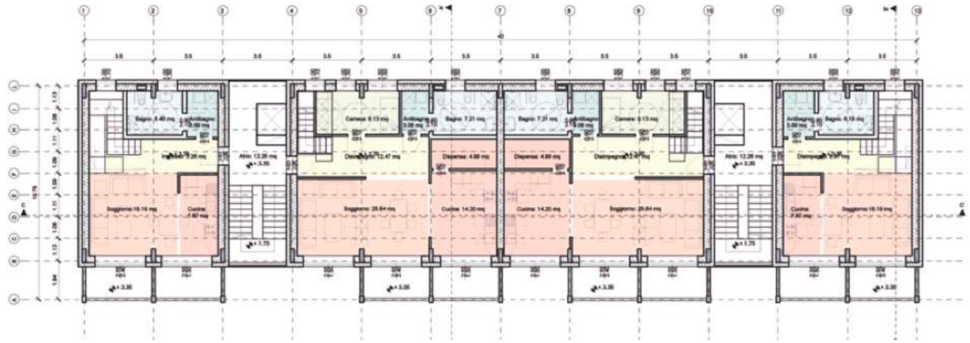
STRUTTURA ADATTATA



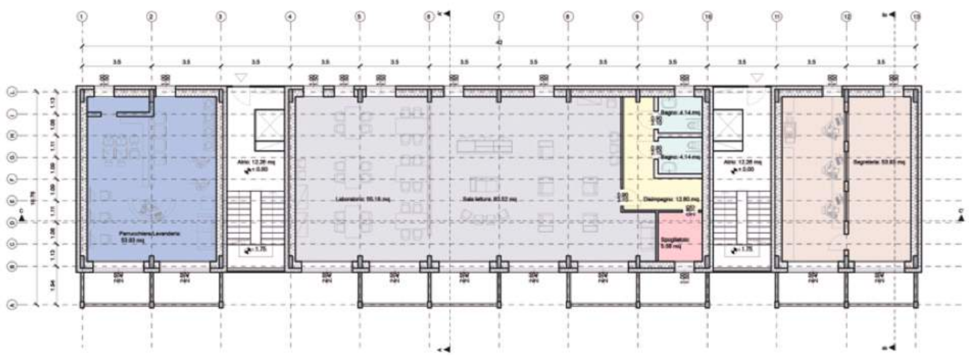
PIANTA PIANO SECONDO + 6.55 M.



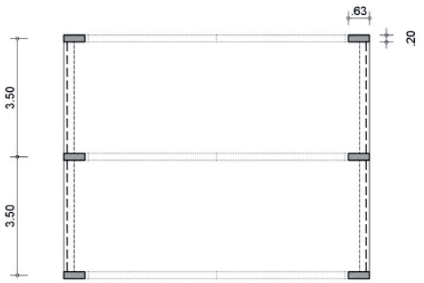
PIANTA PIANO PRIMO + 3.35 M.



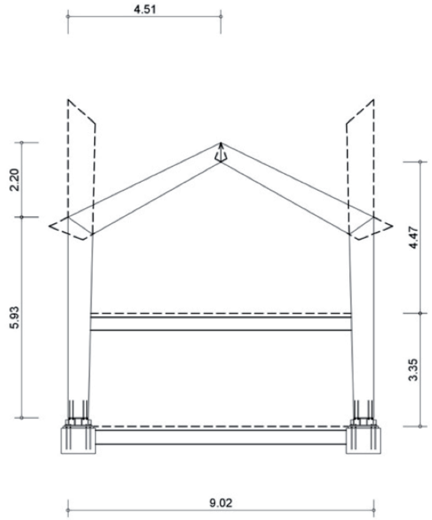
PIANTA PIANO TERRA + 0.00 M.



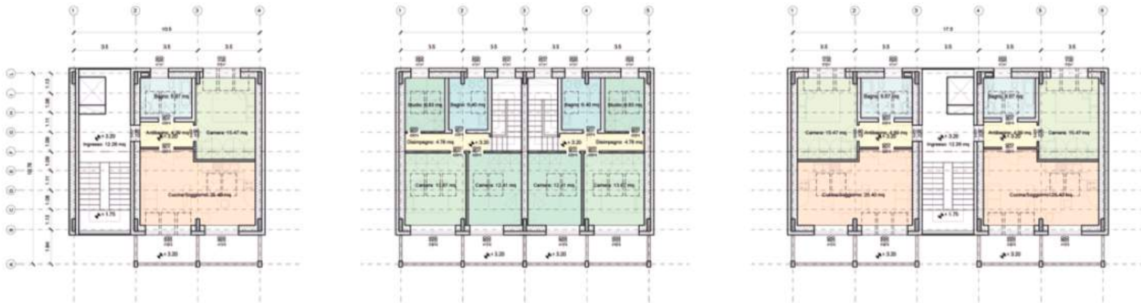
CASE STUDY 2
2 story residence



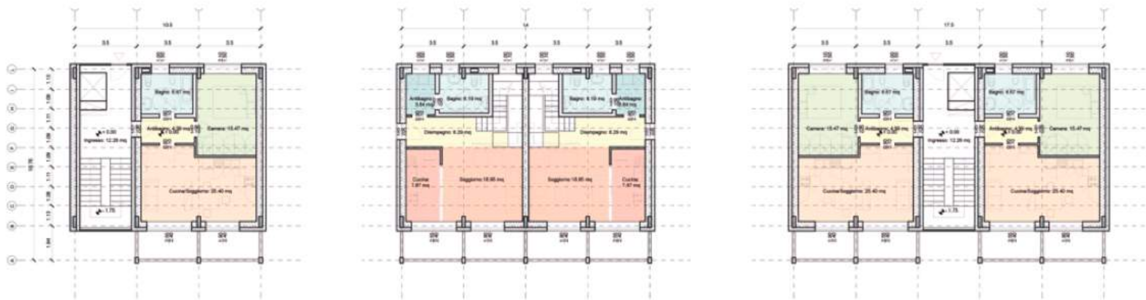
STRUTTURA ADATTATA



PIANTA PIANO PRIMO + 3.35 M.

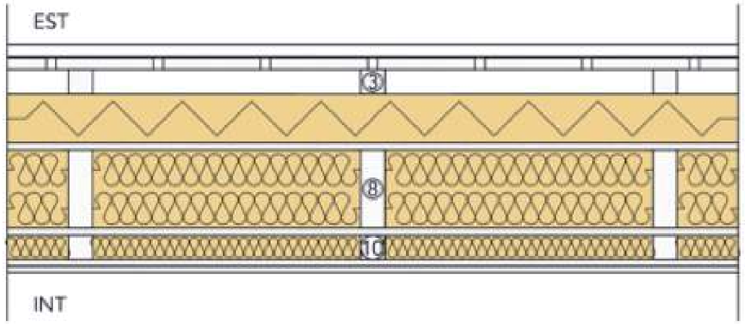


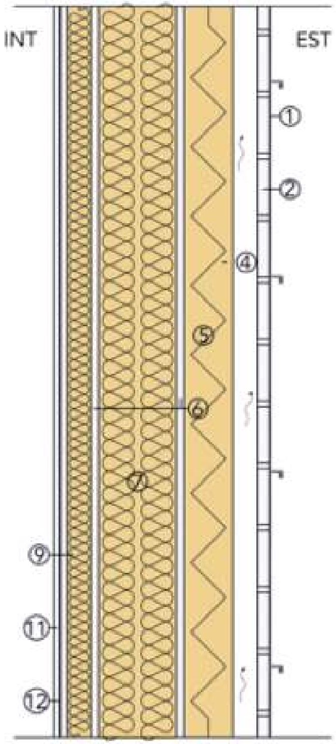
PIANTA PIANO TERRA + 0.00 M.



CHIUSURA VERTICALE

Trasmittanza termica: 0,1156 W/(m²K)
Attenuazione: 0,0412
Sfasamento: 16h 28'
Trasmittanza termica periodica: 0,0047 W/(m²K)
Capacità termica areica periodica interna: 18,1 kJ/(m²K)

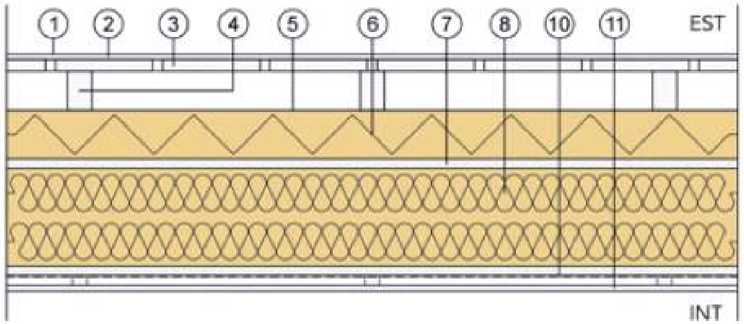


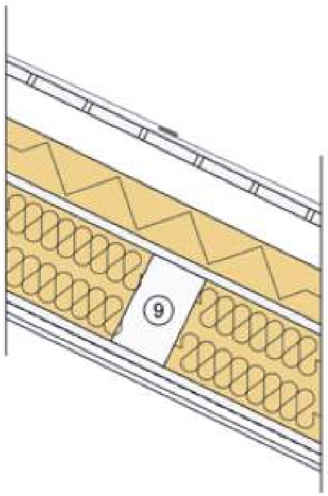


1- Rivestimento di parete in zinco-rame-titanio tipo zintek prepatinato, spessore 8/10 mm, con sistema di aggraffatura angolare orizzontale di altezza 24 mm, con passo 400 mm.
2- Assito in tavolato di legno di abete grezzo di spessore 24 mm, largo 100 mm, distanziato tra le tavole 10 mm e posato inclinato di circa 30°.
3- Listelli in legno di abete grezzo di dimensioni: 50x50 mm con funzione di ventilazione e supporto per il rivestimento.
4- Membrana impermeabile all'acqua e al vento ad alta traspirazione di bassa grammatura (115 g/m2) tipo Riwega USB Wall 120.
5- Pannello termoisolante rigido in fibra di legno di densità 160 kg/m³ tipo Bauwood 160 spessore 100 mm.
6- Pannello strutturale di legno a scaglie orientate (OSB) di spessore 15 mm e densità minima 650 kg/m³.
7- Pannelli termoisolanti flessibili in fibra di legno di densità 50 kg/m³ spessore 80+80 mm.
8- Sottostruttura a telaio in legno di abete grezzo di dimensioni 200x80 mm e passo 600 mm.
9- Pannello isolante termoacustico in lana minerale di densità 40 kg/m³.
10- Sottostruttura controparete in listelli di abete grezzo 50x50 mm.
11- Doppia lastra in gesso rivestito spessore 12,5+12,5 mm tipo Knauf GKB con interposta barriera al vapore.
12- Schermo freno al vapore multistrato termosaldato in polipropilene tipo Riwega USB Micro 100/20.

CHIUSURA ORIZZONTALE DI COPERTURA

Trasmittanza termica: 0,118 W/(m²K)
Attenuazione: 0,0526
Sfasamento: 17h 41'
Trasmittanza termica periodica: 0,0062 W/(m²K)
Capacità termica areica periodica interna: 19 kJ/(m²K)





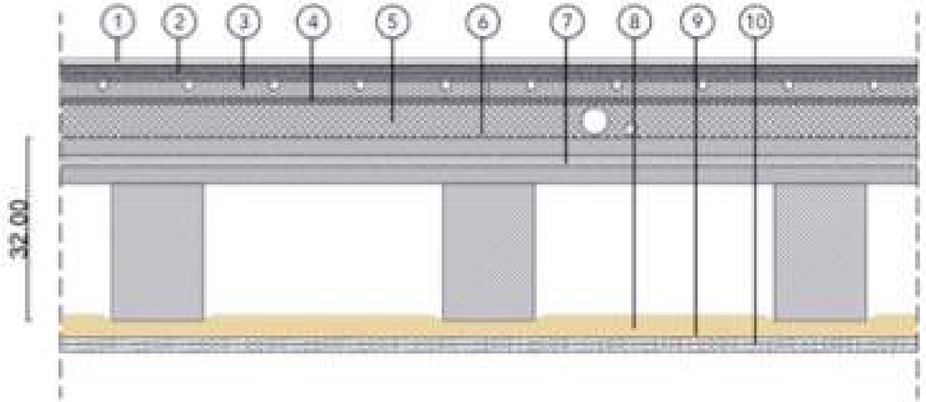
1- Rivestimento di copertura in zinco-rame-titanio tipo zintek lucido da laminatoio (naturale), spessore 7/10 mm con sistema di aggraffatura semplice trasversale, con passo 400 mm.
2- Membrana multistrato fonoassorbente, impermeabile, ad alta traspirabilità, antirombo per coperture metalliche tipo Riwega USB Drenlam Diff SK
3- Assito in tavolato di legno di abete grezzo di spessore 24 mm, largo 100 mm, distanziato tra le tavole 10 mm e posato inclinato di circa 30°.
4- Listelli in legno di abete grezzo di dimensioni: 50x80 mm con funzione di ventilazione e supporto per il rivestimento.
5- Membrana multistrato impermeabile all'acqua e al vento ad alta traspirazione di tipo Riwega USB Classic.
6- Pannello termoisolante rigido in fibra di legno di densità 160 kg/m³ tipo Bauwood 160 spessore 100 mm.
7- Pannello strutturale di legno a scaglie orientate (OSB) di spessore 20 mm e densità minima 650 kg/m³.
8- Pannelli termoisolanti flessibili in fibra di legno di densità 50 kg/m³ spessore 100+100 mm.
9- Travi secondarie in legno lamellare di dimensioni 200x120 mm.
10- Schermo freno al vapore multistrato termosaldato in polipropilene tipo Riwega USB Micro 100/20.
11- Lastra in gesso rivestito spessore 12,5 mm tipo Knauf GKB.

PARTIZIONE ORIZZONTALE - Ipotesi 1

Carico variabile (Q): 2 kN/m²
Carico permanente (G2): 2 kN/m²
Peso proprio struttura (G1) : 0,636 kN/m²

Isolamento del suono aereo R'w: 56 dB
Isolamento del rumore di calpestio L'n,w: 63 dB

Classe di reazione al fuoco: REI 60



1 Finitura superficiale incollata (parquet o piastrelle).

2 Doppia lastra in gessofibra tipo Fermacell 2E22 spessore 12,5+12,5 mm.

3 Sistema radiante a secco tipo Jupiter Ideal Eco comprensivo di pannello portatubi in lana di legno densità 260 kg/m² spessore 30 mm, conduttore metallico e tubazioni multistrato diametro 16 mm.

4 Lastra di ripartizione dei carichi in gessofibra tipo Fermacell spessore 10 mm

5 Livellante granulare minerale per sottofondo impiantistico a secco tipo Fermacell livellante granulare spessore 7 cm.

6 Strato di separazione e contenimento del livellante granulare in carta kraft

7 Solaio prefabbricato in legno lamellare costituito da travetti di dimensioni 160x240 mm passo 58 cm incollati a pannello in legno lamellare a 3 strati incrociati di spessore 80 mm.

8 Isolante termoacustico in lana di vetro densità 21 kg/m³ spessore 4 cm

9 Sottostruttura lignea per controsoffitto

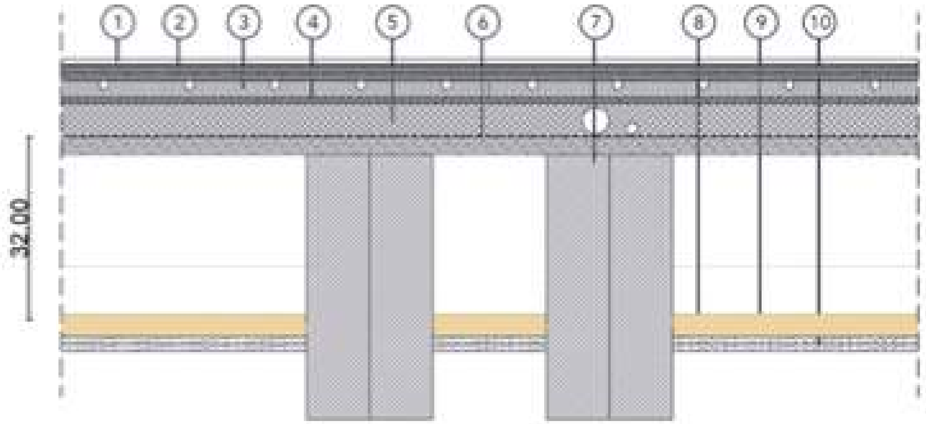
10 Doppia lastra in gesso rivestito spessore 12,5+12,5 mm tipo Knauf GKB

PARTIZIONE ORIZZONTALE - Ipotesi 2

Carico variabile (Q): 2 kN/m²
Carico permanente (G2): 2 kN/m²
Peso proprio struttura (G1) : 0,635 kN/m²

Isolamento del suono aereo R'w: 54 dB
Isolamento del rumore di calpestio L'n,w: 63 dB

Classe di reazione al fuoco: REI 60



1 Finitura superficiale incollata (parquet o piastrelle).

2 Doppia lastra in gessofibra tipo Fermacell 2E22 spessore 12,5+12,5 mm.

3 Sistema radiante a secco tipo Jupiter Ideal Eco comprensivo di pannello portatubi in lana di legno densità 260 kg/m² spessore 30 mm, conduttore metallico e tubazioni multistrato diametro 16 mm.

4 Lastra di ripartizione dei carichi in gessofibra tipo Fermacell spessore 10 mm

5 Livellante granulare minerale per sottofondo impiantistico a secco tipo Fermacell livellante granulare spessore 7 cm.

6 Strato di separazione e contenimento del livellante granulare in carta kraft

7 Solaio costituito da travetti di dimensioni 120x196 mm passo 150 cm incollati a pannello in legno lamellare a 3 strati incrociati di spessore 30 mm e trave principale doppia 2x220x464 mm.

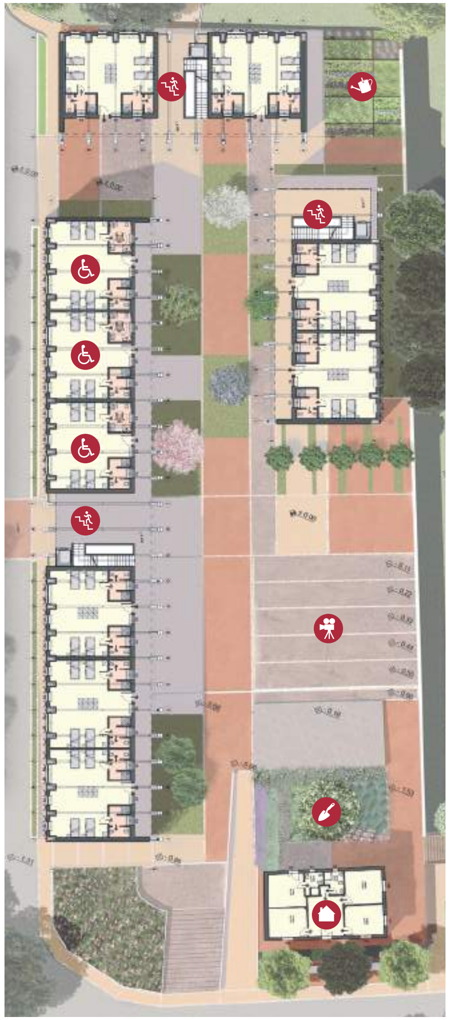
8 Isolante termoacustico in lana di vetro densità 21 kg/m³ spessore 4 cm

9 Sottostruttura lignea per controsoffitto

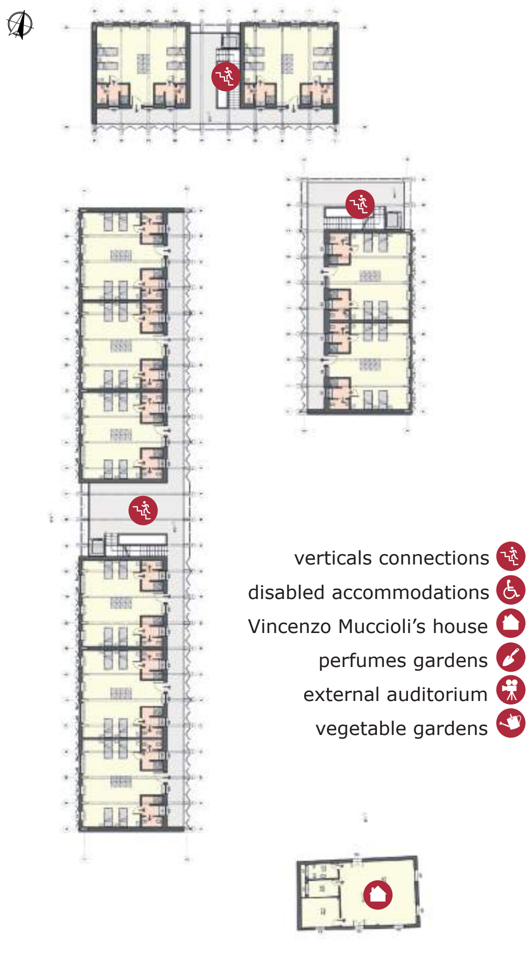
10 Doppia lastra in gesso rivestito spessore 12,5+12,5 mm tipo Knauf GKB

HUG

Housing Unit Group, San Patrignano community - Coriano - Rimini
Politecnico di Milano - Polo territoriale di Lecco
Thesis project- Prof. M. Imperadori
Barbara Frigerio, Giulia Fumagalli, Matteo Pasqualotto



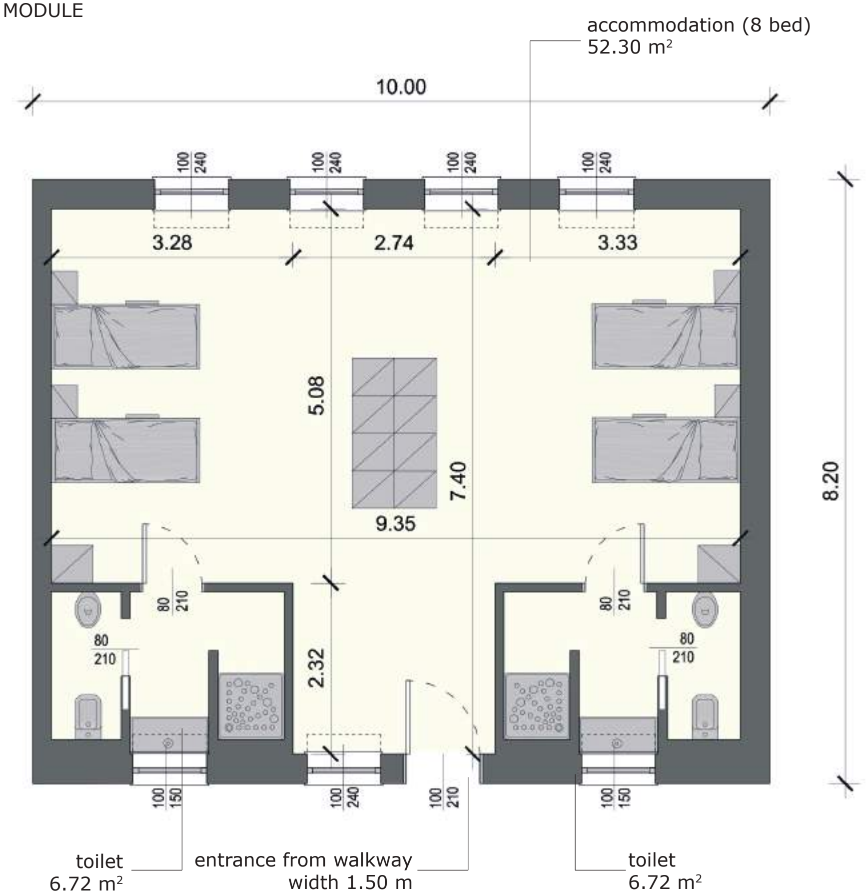
Ground floor plan



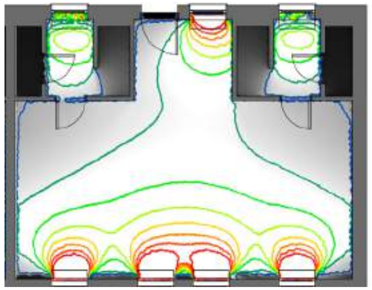
First floor plan

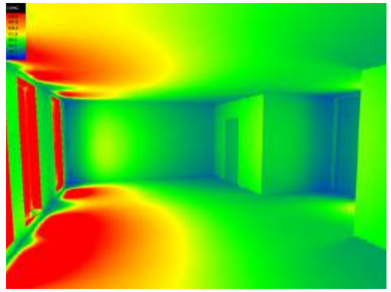
HUG project is a combination of housing facilities and space designed for sport and cultural activities. It's placed inside the San Patrignano therapeutic Community, of which the residential and production centre are located in Coriano, a small town in Rimini's district. The reuse of the glulam structure allows the realization of three volumes with a simple and regular geometry, disposed in order to create a more private courtyard that represent the core of the community life as a place of aggregation and sharing. The buildings have two floors above ground level and reach a maximum height of 11,20 m. Vertical open-air stairs connect the square with the residential part located at the upper floors through exteriors corridors that run in front of every unit. On the ground level are located all the cultural and leisure facilities. This layout provides shelter for 240 people .

LIVING MODULE



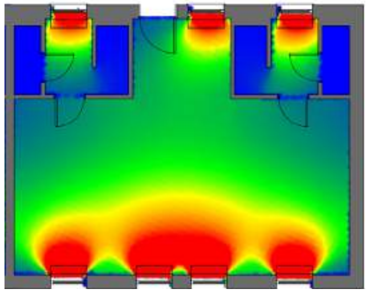
1-2. Typical interior solution for the accommodations, where the choices of the material finishes and the arrangement of the rooms create a comfortable location for community's needs: hopper windows, toilet designed for three contemporary users and tailor-made furniture for the highest comfort achievable.

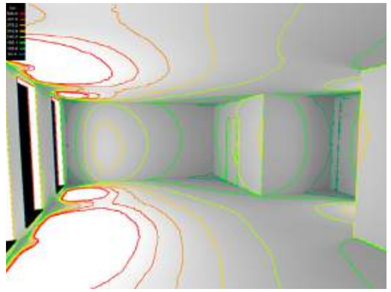




3. FLD analysis _ daylight factor
JUNE 12:00 p.m.

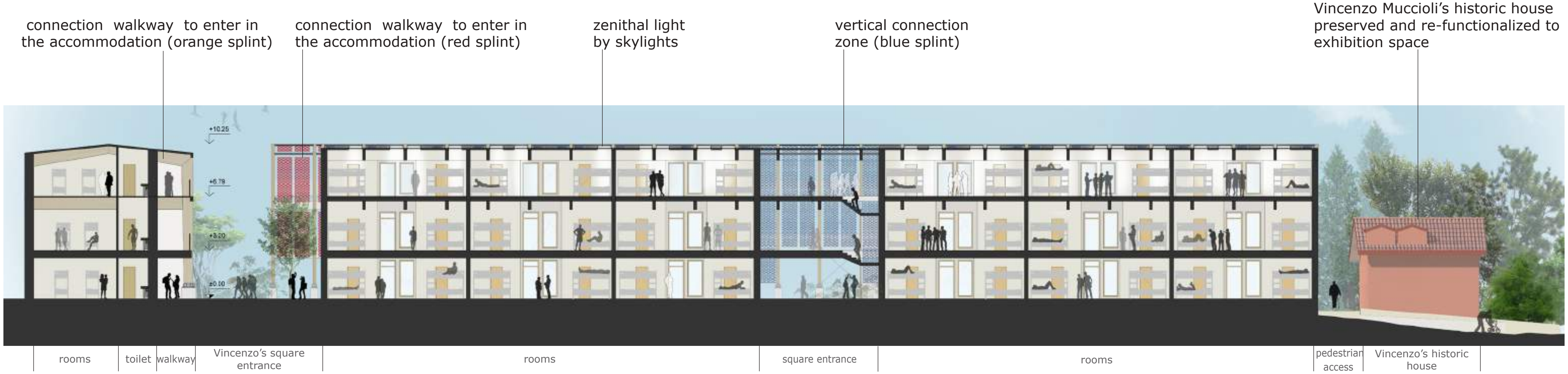
4. Luminance levels analysis
JUNE 12:00 p.m.





5-6. Natural lighting levels analysis
JUNE 12:00 p.m.

LONGITUDINAL SECTION



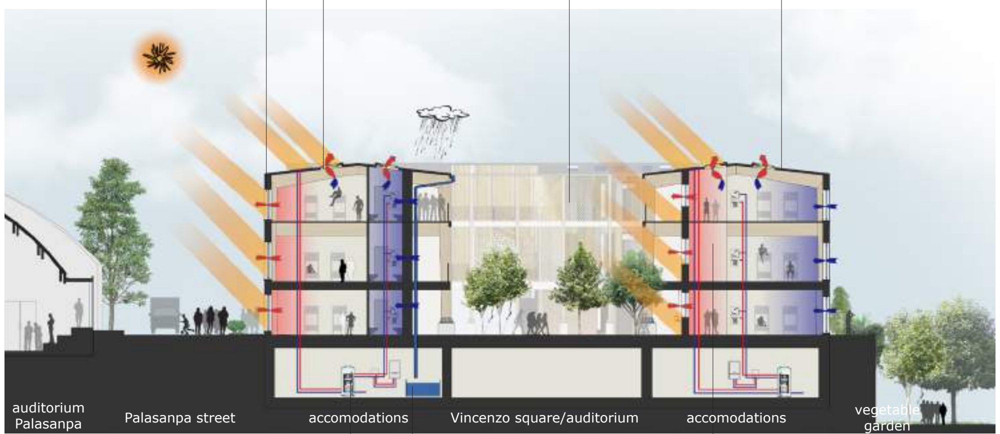
CROSS SECTION _ INTERMEDIATE SEASON

aluminium windows with double glazing U=0.88 W/m²K

'stack effect' of natural ventilation thank to skylights

shading elements realized with expanded metal to protect from solar radiation

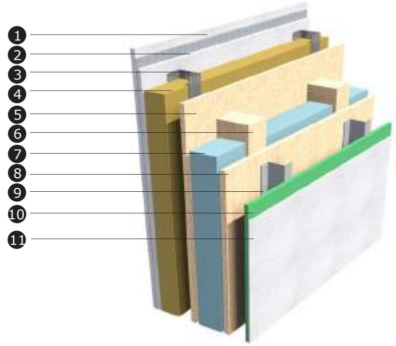
photovoltaic panels and solar thermal system



hot water's storage tank integrated with heat pump

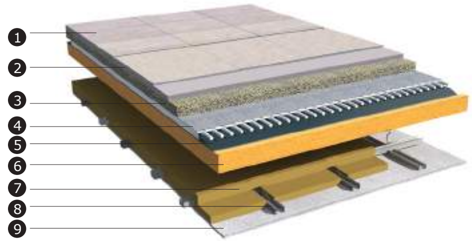
tank of storage and reuse of meteoric water

cross ventilation for natural air changes of the internal rooms



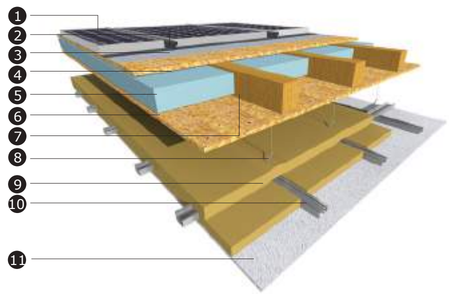
VERTICAL CLOSING

1. Plasterboard panel sp.12.5 mm 2. Plasterboard panel with aluminium micro foil sp. 14.5 mm 3. Vertical galvanised steel C section dim. 75 x 0.6 mm 4. Glass wool panel sp.60 mm 5. OSB panel sp.16 mm 6. Spruce wood strips sp.100 mm 7. Rigid insulation panel in extruded expanded polystyrene sp.100 mm 8. Multilayer wooden panel with three layers sp.13 mm 9. Aluminium profile Z to anchor 10. Recycled glass panel sp.12 mm 11. Plaster sp.3 mm



HORIZONTAL PARTITION

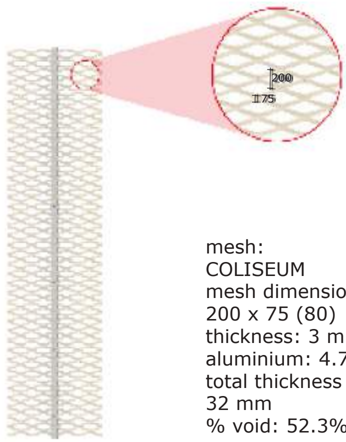
1.Ceramic tiles 2.Double dry subfloor panels sp.2 x 12.5 mm 3. Dry Layer of granular materials perlite or expanded clay sp.50 mm 4. Layer of detachment with TNT in needle-punched polyester sp.2 mm 5. Radiant heating system over expanded polystyrene base with a special needle-punched fibre sp. 5 mm 6.Structural wood panel X-LAM sp.85 mm 7. Glass wool panels sp.2 x 45 mm 8. Double steel structures 9. Modular plasterboard panels for ceiling sp.12.5 mm



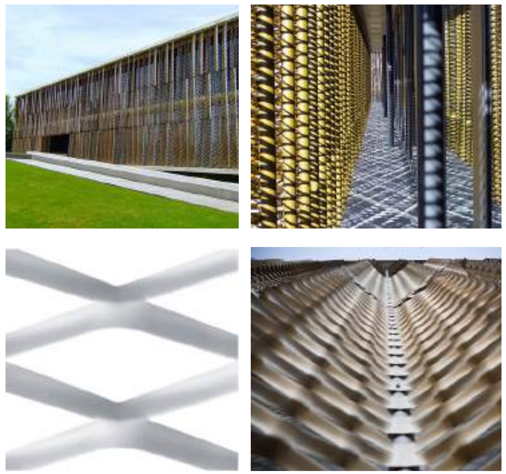
HORIZONTAL CLOSING

1.Photovoltaic panels dim. 1520 x 672 x 40 mm 2. Laminate of alloy zinc-copper-titanium sp.0.7 mm, crimping height 24 mm 3. Sound-absorbant membrane sp. 0.75 mm 4. OSB panel sp.16 mm 5. Rigid insulation panel in extruded expanded polystyrene sp.80 mm 6.Lamellar wood panel with three layers sp.13 mm 7. Spruce wood strips sp.100 mm 8. Hook with spring for C section, Ø 4 mm 9. Glass wool panels n.2 x dim.600 x 1350 mm cad., sp.45 mm 10. Double galvanised steel C section dim.50x270.6 mm 11.Modular plasterboard panels for ceiling sp.12.5 mm dim.600x600 mm

FACADE PANEL FEATURES



mesh:
COLISEUM
mesh dimension:
200 x 75 (80)
thickness: 3 mm
aluminium: 4.70 kg/m²
total thickness panel:
32 mm
% void: 52.3%



TOTAL RE-USED ELEMENTS

ROOF MODULES

Islands, Sea and Food Cluster
24 roof modules

Tasting and Events Area Cluster
8 roof modules

Cereals and Tubers cluster
10 roof modules

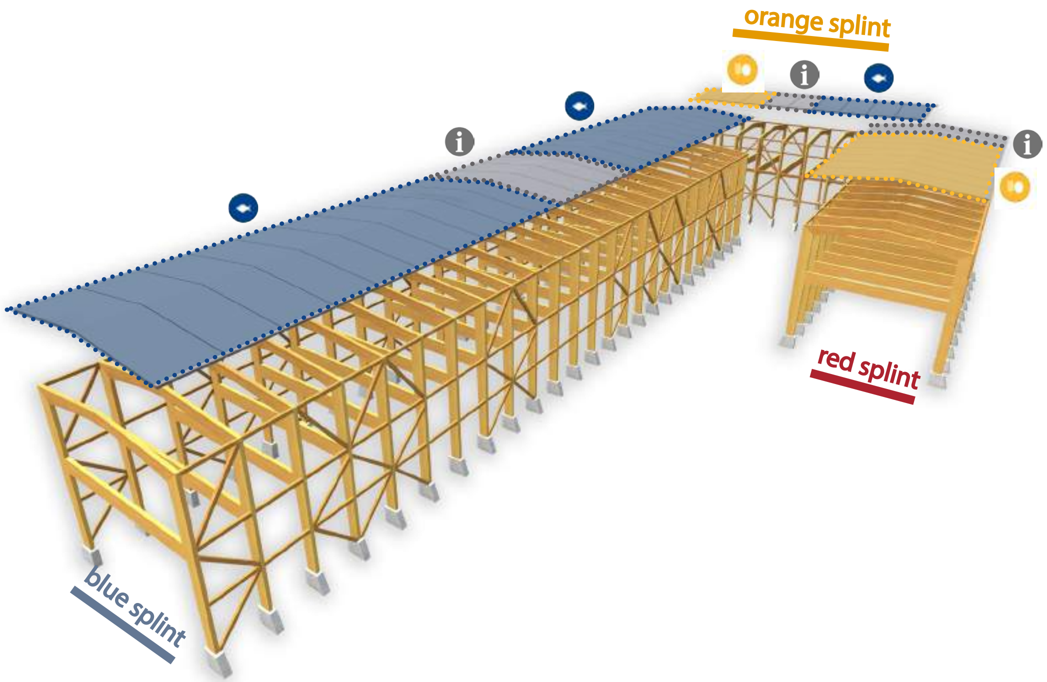
CLUSTER'S PORTALS:

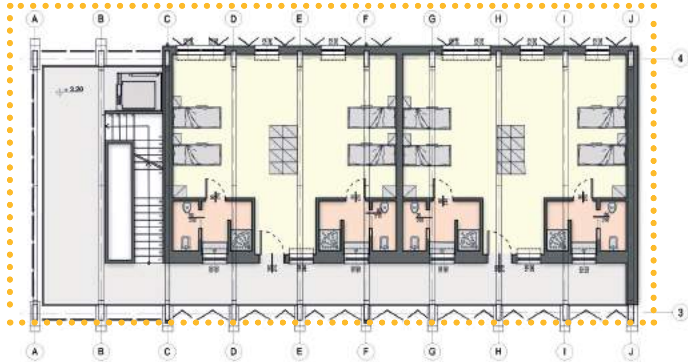
Islands, Sea and Food Cluster
26 cluster's portals

Tasting and Events Area Cluster
9 cluster's portals

Cereals and Tubers Cluster:
8 cluster's portals

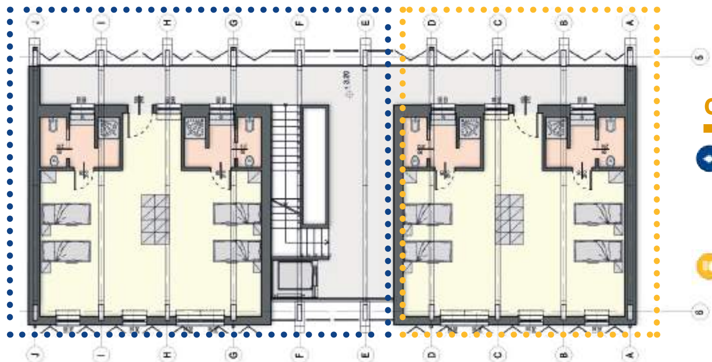
Due to project's extension it has been necessary not to consider only "Islands,sea and food" Cluster as a reuse matter, but also the other ones and part of the Rubner project. This way, once run out "Island,sea and food" Cluster structures, it's been supposed to use in addition the ones of "Cereal" and "Tuber" Cluster for a total amount of 43 gates and 42 cover panels. A lot of attention has been paid to the positioning of the panels in order to avoid the skylights holes used in the pavilions, without the need to change any dimension. This way it would have been only a matter of moving the panels due to the needs of the project reducing also material wastes.





red splint

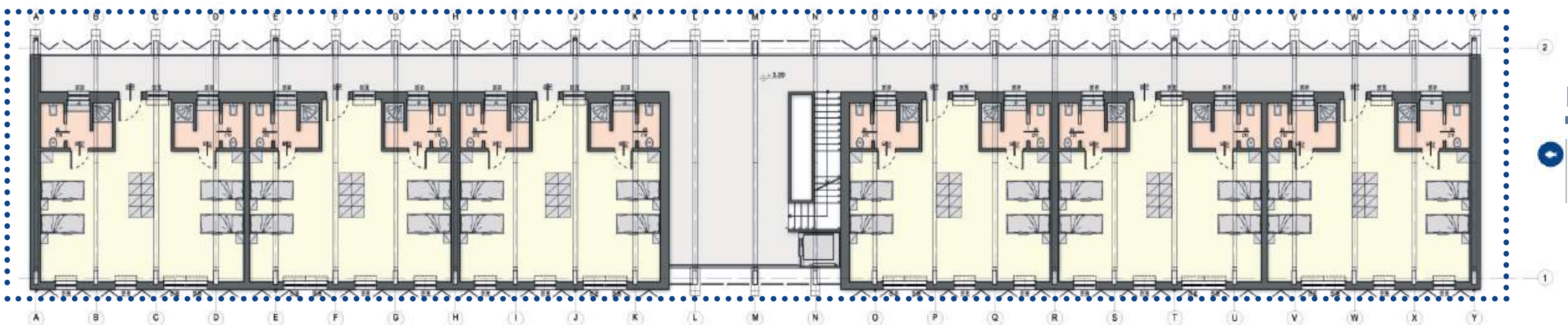
cereals and tubers cluster
10 cluster's portals



orange splint

islands, sea and food cluster
4 cluster's portals
2 tasting and events area portals cluster

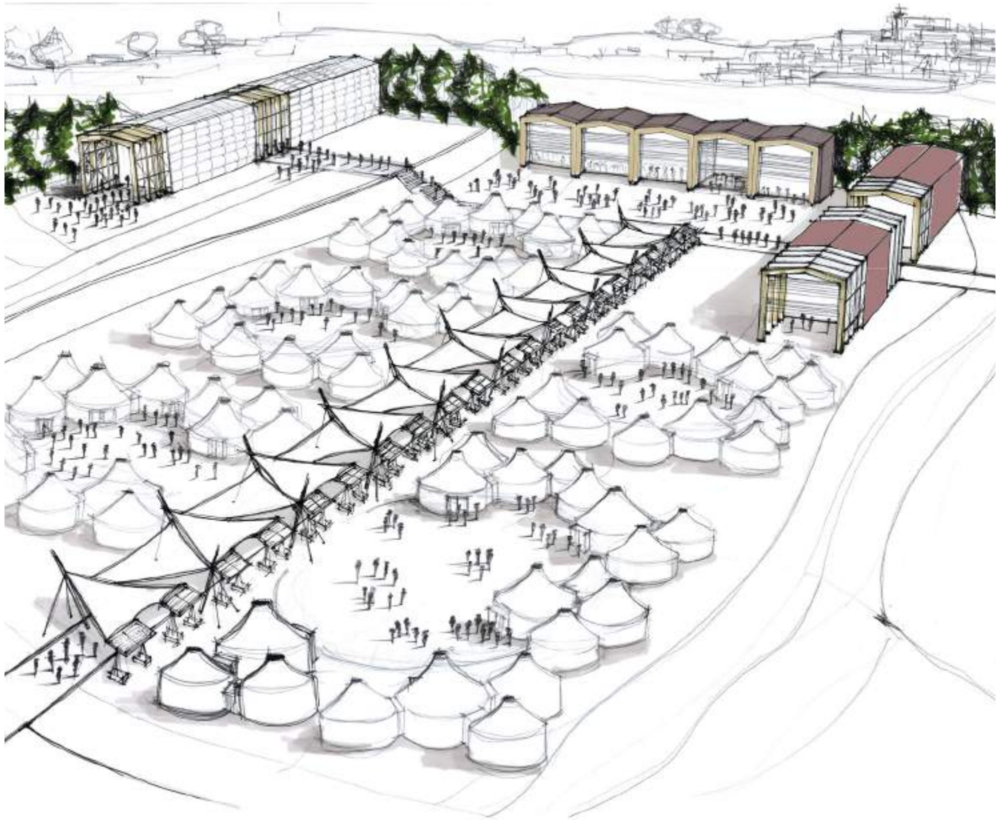
cereals and tubers cluster
4 cluster's portals

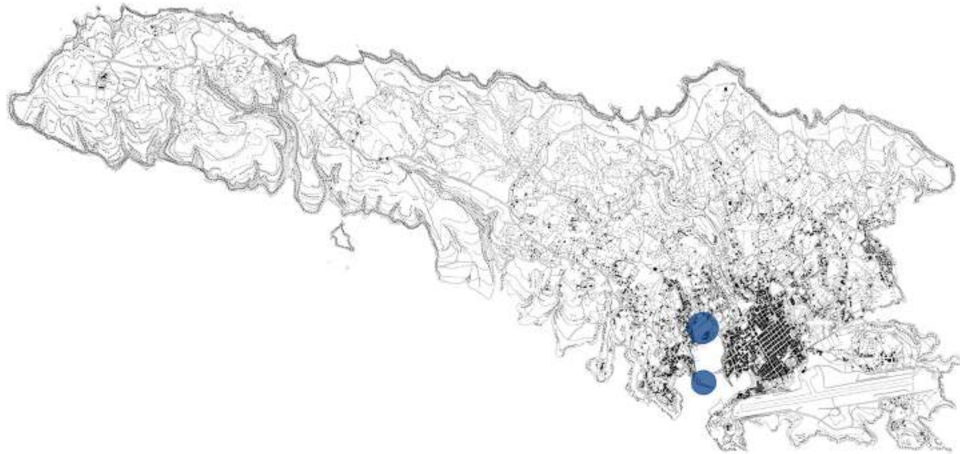


blue splint

islands, sea and food cluster
22 cluster's portals
3 tasting and events area portals cluster

A.R.C.A. Project
Centro di Accoglienza e Primo Soccorso per immigrati - Lampedusa
Politecnico di Milano - Polo territoriale di Lecco
Tesi di Laurea in Ingegneria Edile-Architettura - Prof. M. Imperadori
Lumina Federico, Muti Elisa, Polese Ilaria

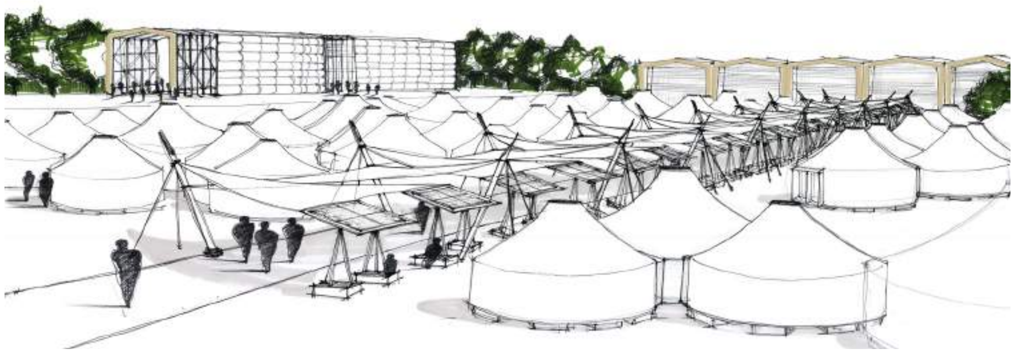


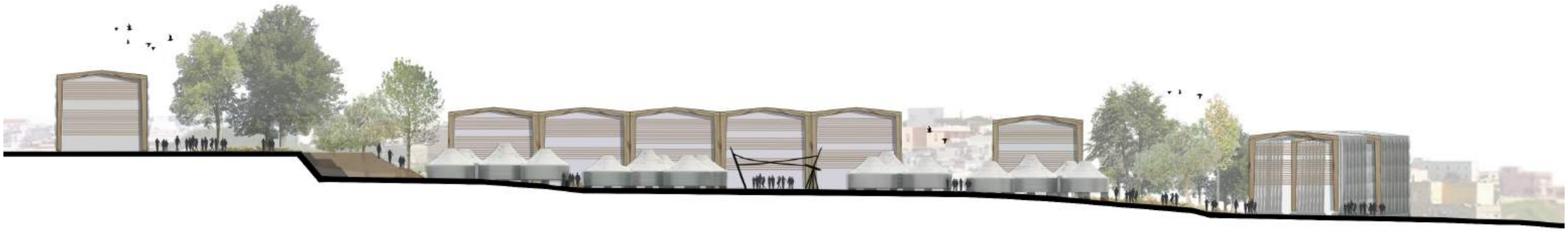


Project area: Lampedusa Island

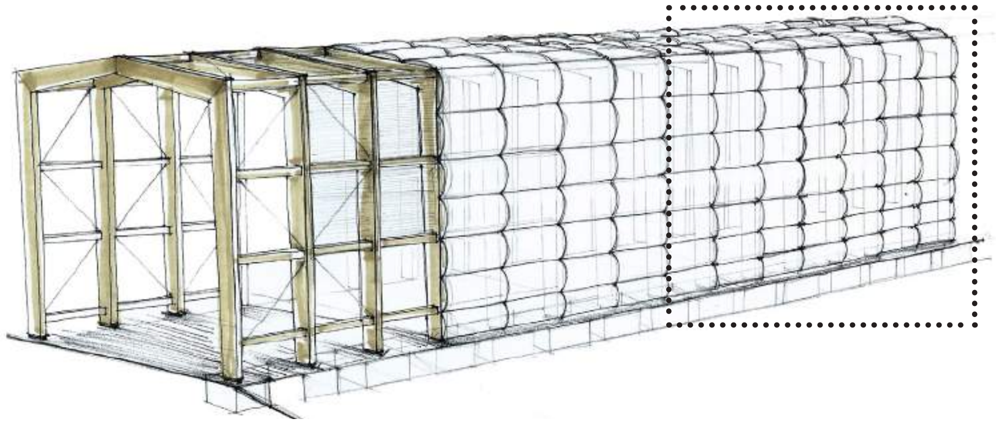
The A.R.C.A. Project (Architecture for Resilience and Community Accommodation) aims to provide asylum and first aid services to the migrants who land in large number on the Italian island of Lampedusa.
The centre is located in a disused area of about 35 thousands square meters, close to the new harbour of the island. This location meets the two main objectives of the project: firstly it is strategic in terms of logistic, moreover it can favourite integration and mutual human relationship between cultures, as it is also close to the centre of the city.
The project is composed of two main kind of buildings: the service areas, made recycling the timber structures of the Islands, Sea and Food Cluster from Expo 2015, and the accommodation shelters.

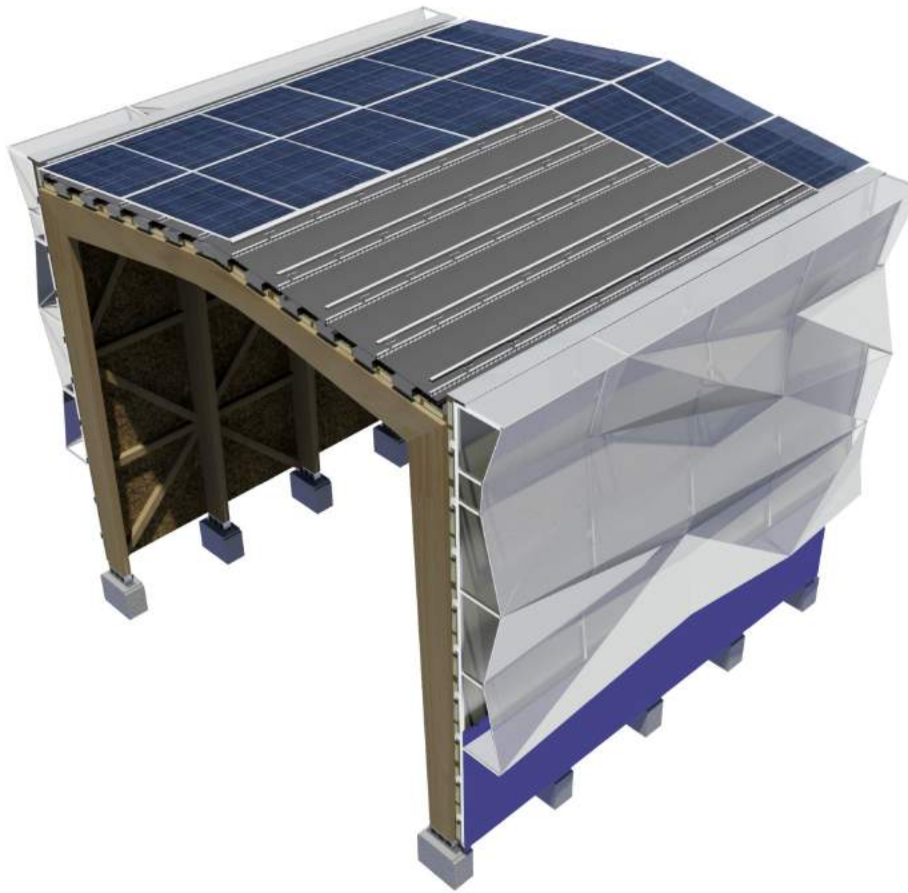
The configuration of the area arises from an analysis of the surrounding urban context, that is severely regular and consists basically in two orthogonal axes around which all the buildings take place.
In particular, the north-south axis leads to the main building that includes the refectory and common areas. At the side of this avenue are placed all the other functions, including the first aid point, security services and personal services.
The guests can reach the accommodations through the west-est avenue, which is surrounded by shelters arranged in order to create common squares, like in African villages.





The structure of the clusters is made of two vertical pillars and a central beam all made of glulam timber. These are covered by sandwich wooden panels (identical for the roof and for the walls).
On the covering it is laid a further layer of insulation that supports photovoltaic panels which also contribute to create an high ventilated overlay.
The walls are covered with metal sandwich panels on the lower section and with a textile layer on the higher. There are two options (as shown in the pictures at the basis of the page) about the shape of the textile layer, which is supported by steel structures in both cases.
Inside can be inserted up to 3 glulam wooden panels in order to create 2 more inner levels.





POLITECNICO di Milano

P.za L. da Vinci, 32 – 20133 Milano – Italy

CONVENZIONE TRA IL MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE ED IL POLITECNICO DI MILANO DEL 24 MARZO 2014 PER L'ATTUAZIONE DELLE METODOLOGIE DI CALCOLO DELL'IMPRONTA DI CARBONIO E DI COMPENSAZIONE DELLE EMISSIONI DI CO2 DI EXPO 2015

D.1.1.b Guidelines for the reduction of the environmental impact of temporary building and structures in mega events

Annext B
Examples of re-use "on site"

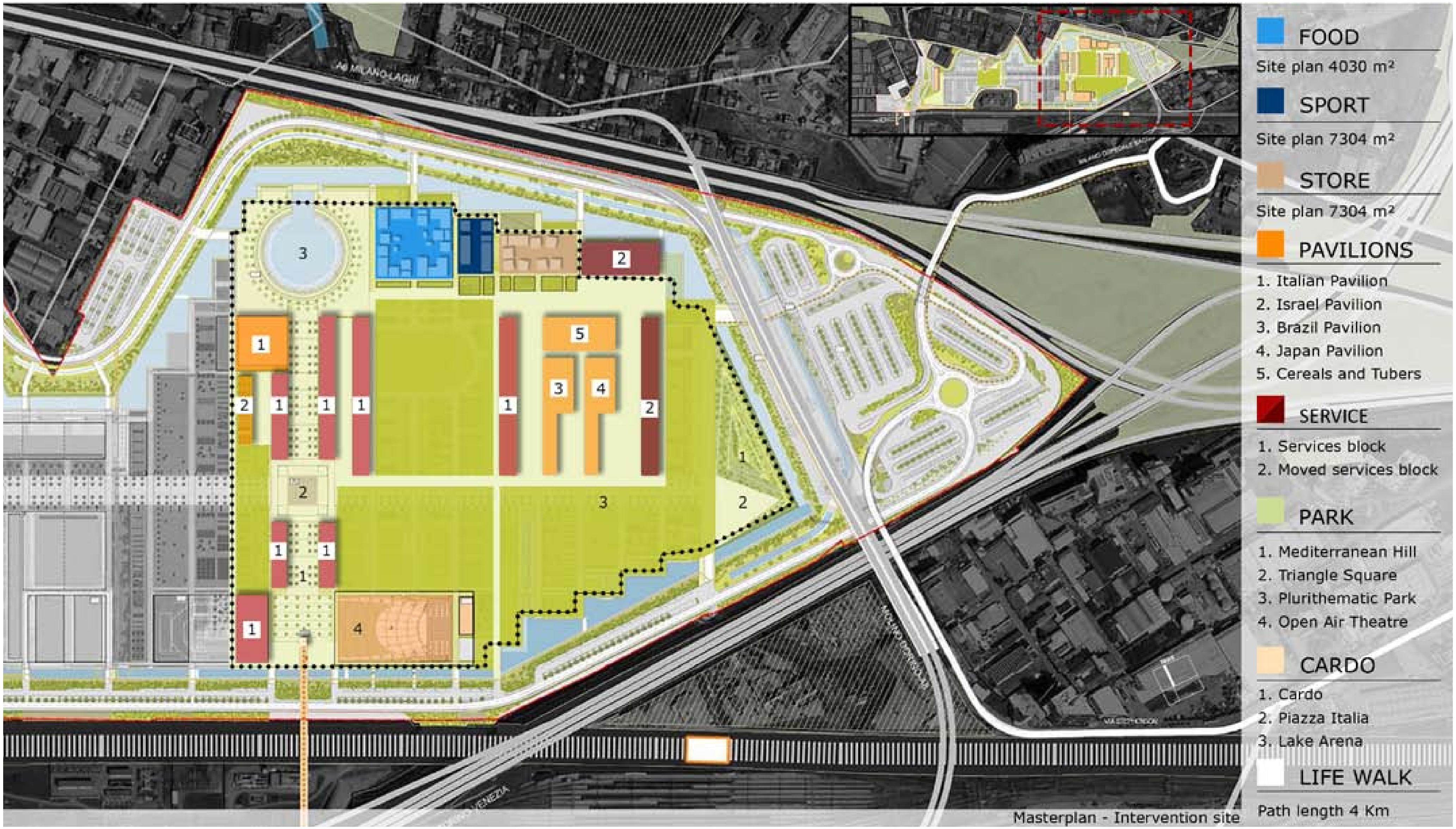
Dipartimento di Energia

Masterplan
Arrangement of design proposal
Politecnico di Milano - Polo territoriale di Lecco
Re-thinking Expo - Prof. M. Imperadori
Michele Amadori, MArtino D'Alberto, Firino Roberta, Sofia Fondelli

The configuration of the post EXPO solutions led to the formulation of different and in constant evolution scenarios. In particular, the idea of being able to reuse on site a largely part of buildings could facilitate a series of processes of pro-gressive re-employment, also partial, of the area dedicated to the EXPO. Between the end of the event and the general rearrangement of the area, passing through Fast Post scenarios that allow not to vanish the achieved results (in terms of maintenance and construction), the progressive redevelopment of the area and the guidelines for possible development scenarios have been suggested in earlier studies (see for example the document "EXPOST – Riconvertire, Recuperare, Riusare, Linee guida per la predisposizione delle proposta progettuale, allegato 2 - Masterplan e linee Guida per la pre-disposizione della proposta progettuale"). On the complex possibilities of development and promotion of the site, the areas that will be left to the city and will re-main on site per-


General view - Cluster area


Masterplan - Expo area



Masterplan - Intervention site

manently have been identified, Cascina Triulza and garden, Palazzo Italia and water square, Collina Mediterranea and triangular square, Outdoors Theatre, Cardo and Piazza Italia and West access and sloping square. On the remaining areas, besides the development of a theme park, are admitted functions related to equipment and services of public or general interest at municipal and/or supra-municipal level, also owned and/or managed by private, and destinations of use typical of city context, such as residence, also in the types of housing based on municipality agreements and/or subsidized, and compatible functions including medium commercial structures. The area of the event has been divided into three development sectors A, B and C. For sectors A, containing West access, sloping square, Cascina Triulza and garden spaces, and B, free of areas already "identi-

Masterplan - Cluster area

fied", the real intended use seems more uncertain, instead for sector C proposals for intervention have been al-ready drawn up, primarily related to the theme park and the "city of sport". Starting from these initial ideas of the area revaluation some project proposals have been drawn, linked to the actual masterplan, which have focused their interest on the sector C, which extends from the Cardo to the southeast, to the edge of the lot of competence. This portion of the area has been designed considering the redevelopment of spaces and buildings already studied with the idea of reuse on site (Palazzo Italia and water square, Collina Mediterranea and triangular square, Outdoor Theatre, Cardo and Piazza Italia) and including in the general masterplan the reuse on site, in their actual location, some Cluster (Biomediterraneum Islands and the Arid Zones), the services architectures and some Self built pavillons (Israel, Japan and Brazil). For the last two categories of buildings was assumed a renovation of building functions both in the exact current location that through disassembly and reassembly, however on the site of the

project, giving the ability to reuse structures insistent on areas B and C in areas to be cleared for future different uses.
From the planimetric-distributive-functional point of view, the proposed solution is thus intended to implement services (according to the guidelines) already present in the spaces adjacent the Cardo and on the far north-east of the area. From the technical and technological point of view, however, the transformation designed for the pavilions, as well as appropriate verification of the sub-systems suitability and the compliance with applicable regional and national rules, involved the study of the energy performances of buildings (broadly speaking) and the adjustment of vertical and horizontal, opaque and transparent envelope elements. Overall, the proposed solution aims, through a technical and functional adjustment, to look for a good balance between green/open or free spaces and constructed spaces that could be the support for the residential areas to be developed on the EXPO site (potentially in areas A and B) and in the neighboring areas of the municipalities of Rho and Milan.

Bio-mediterraneum cluster -> Food Court
Arrangement of design proposal
Politecnico di Milano - Polo territoriale di Lecco
Re-thinking Expo - Prof. M. Imperadori
Michele Amadori, Martino D'Alberto, Roberta Firino, Sofia Fondelli

The individual units of the cluster are arranged along the perimeter of the area in keeping with a "geographical" order that produces four islands that are homogenous in their morphological charac-teristics underlined by a light grey external pavement. The layout permits each group of units to share a more intimate public space that converge in a large central sea, a metaphoric space, a plaza for gathering and interaction, with a pavement in draining concrete, in four shades of blue. The Bio-mediterraneum cluster, characterized by its big central square, is suitable to be adapted as a food court with restaurant at different levels (from refined to street restaurants). Such choice has been motivated by the pre-existent installation different kitchen units and service zones, which ma-ke easier the adaptation for a new utilisation. Furthermore, the different sizing of each module gua-rantees the inclusion of different types of catering services, going from the big restaurants of the bigger blocks, to the bars of the smaller units, through the insertion of cafeterias, ice-cream parlors and bistrots in the kiosks. The original layout of the units provided for the Expo was maintained adding only a few connecting path/bridges; subsequent divisions are proposed. Six big areas were created, each one specialized in a different activity and endowed with an outdoor area for eventual table service during hot season. For the small sized units, it has been suggested a possible connection with the adjacent ones, such that outdoor spaces designated for table service are extended. According to the regulations, each activity has been dotated with spaces for cooking and preparing dishes, for conservation of raw and finished products and their respective distribution, as well as ar-eas devoted to dish-washing, technical equipment, and waste. Each unit has its own toilet areas, se-parated for the personnel and clients. Specifically, the latter have been divided by gender, with the addition of a service for differently abled clients.

RESTAURANTS

1. Kitchens 219 m²
2. Dining rooms 1469 m²
3. Toilets 110 m²
4. Technical rooms 132 m²

BAR

1. Kitchen 22 m²
2. Dining room 58 m²
3. Toilets 9 m²
4. Technical room 41 m²

MULTIPURPOSE HALL

1. Kitchen 22 m²
2. Dining room 181 m²
3. Toilets 9 m²

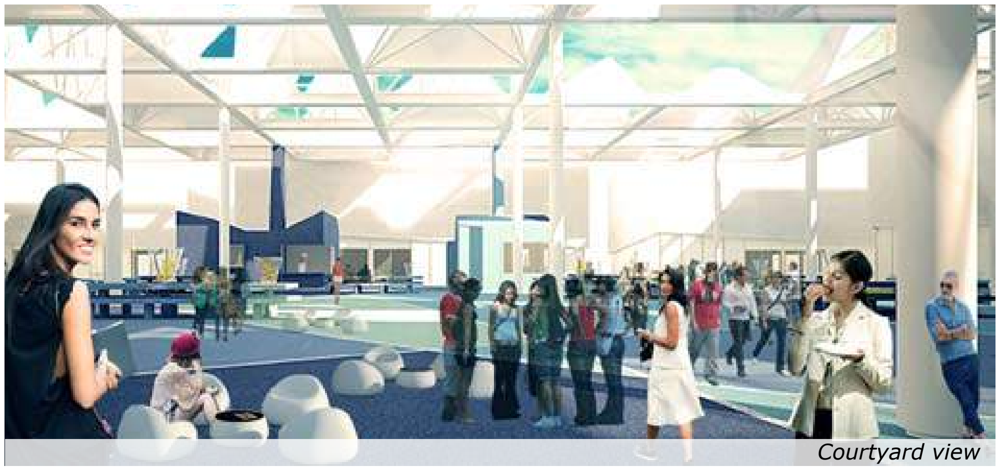
STREET PERFORMER

OUTDOOR

1. Courtyard 5147 m²

Surface area 7304 m²

Ground Floor



Courtyard view

Bar - Internal view

Restaurant - Internal view

RESTAURANTS

1. Dining rooms 1469 m²
2. Toilets 110 m²
3. Technical rooms 146 m²

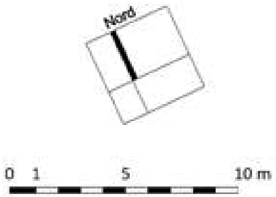
BAR

1. Dining room 74 m²
2. Toilets 15 m²
3. Technical room 56 m²

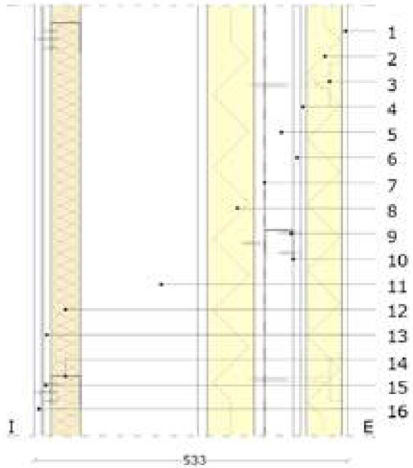
MULTIPURPOSE HALL

1. Dining room 109 m²
2. Toilets 15 m²
3. Technical room 5 m²

Surface area 2147 m²



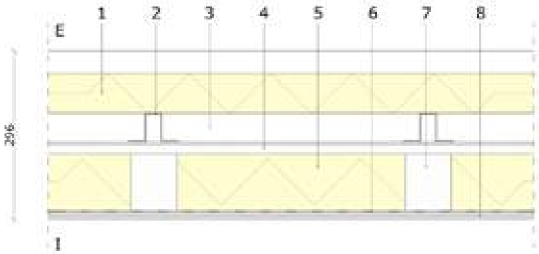
First Floor



FACADE DETAIL

s = 533 mm U = 0,2 W/m²K

1. 15 mm acrylic topcoat
2. 60 mm XPS insulation panel
3. Insulated panel wedge
4. 10 mm glue layer as SM 700 Knauf
5. 50 mm ventilation cavity
6. Aquapanel Outdoor board as Knauf
7. Waterproofing and breather membrane as Tyvek
8. 16+80+16 mm SIPS as Kingspan
9. Aquapanel maxi screws
10. 50x50x0,6 mm C metal profile, distance 60 cm
11. 200 mm plants cavity
12. 40 mm glass mineral wool insulation panel
13. 12,5 mm plasterboard as Knauf GKB
14. 50x50x0,6 mm C metal profile,distance 60 cm
15. Phosphated screw
16. 12,5 mm plasterboard as Knauf GKB



ROOF DETAIL

s = 296 mm U = 0,18 W/m²K

1. 70+40 mm sandwich panel polyurethane insulation
2. 30 x 50 x 30 mm, 2 mm thick, omega metal profiles
3. 50 mm air layer for facade ventilation
4. 16 mm OSB wood panel
5. 80 mm polystyrene insulation panel
6. Vapor barrier
7. 100 mm fir wood strips
8. 13 mm 3-layer glulam

Island, Sea and Food Cluster -> Sport Arena
Arrangement of design proposal
Politecnico di Milano - Polo territoriale di Lecco
Re-thinking Expo - Prof. M. Imperadori
Michele Amadori, Martino D'Alberto, Roberta Firino, Sofia Fondelli

The Island cluster composed but double height level building is particularly suitable to be trans-formed in sport activity hall.
Is re-adaptation for complementary sports activities will be possible only for non-agonistic activities (by its given dimensions that sill not complain current regulations). The spaces are then been devoted to the practice of sports related to recreation and physical well-ness.
The design has been developed following the guidelines approved by Consiglio Nazionale of CONI (n. 1379 del 25 june 2008), in order to guarantee the functioning and security of sports facility.
Four units compose the pavilion: the two main modules allocate a fitness area, a climbing wall.

EVENTS AREA
1. Events area 124 m²

BAR
1. Room 50 m²
2. Outdoor 61 m²
3. Deposit 4 m²
4. Toilets 6 m²

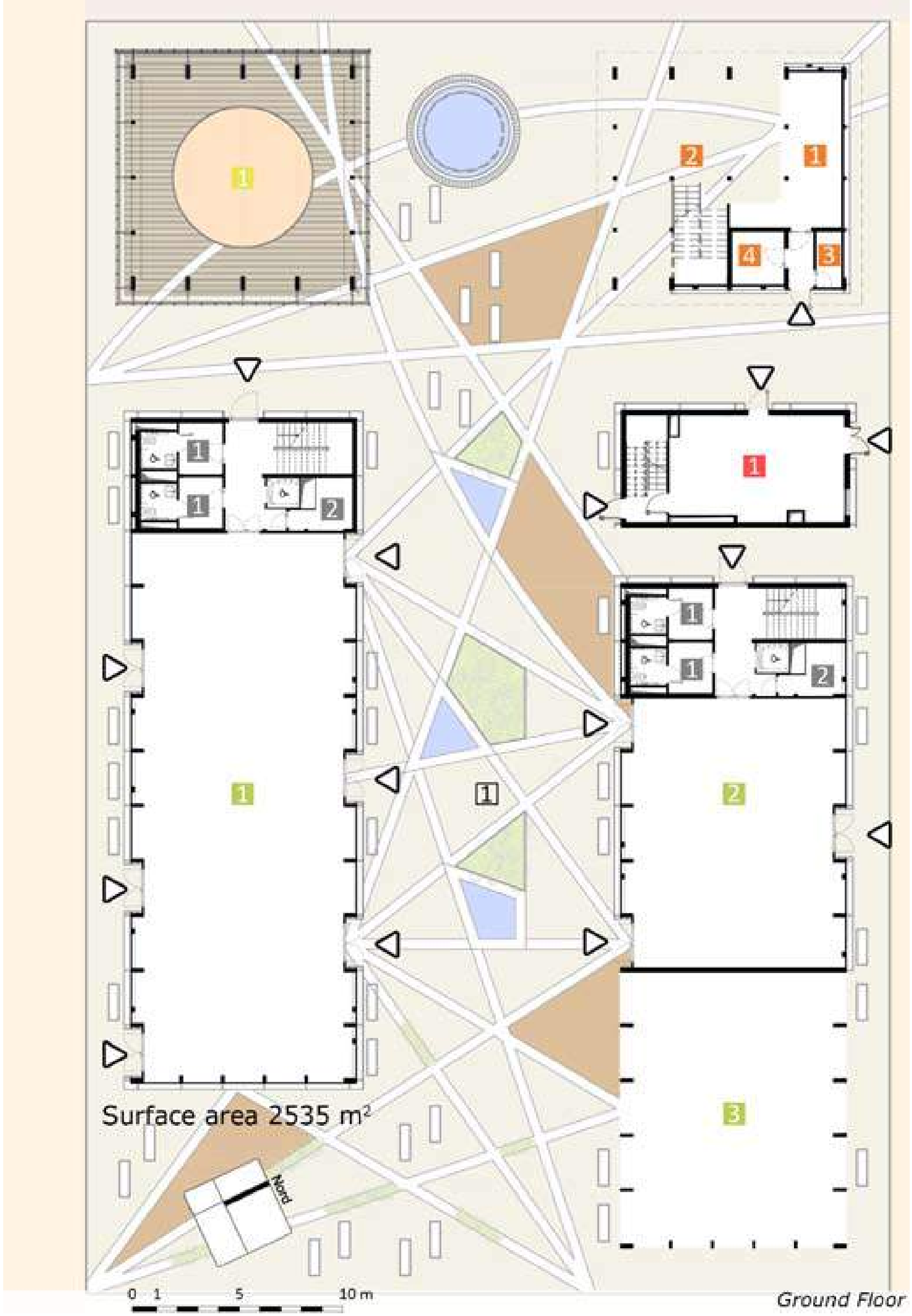
GYM
1. Gym 600 m²
2. Gym 300 m²
3. Climbing wall 300 m²

CHANGING ROOMS
1. Changing room 56 m²
2. Instructor changing room 8 m²

TECHNICAL ROOM
1. Technical room 37 m²

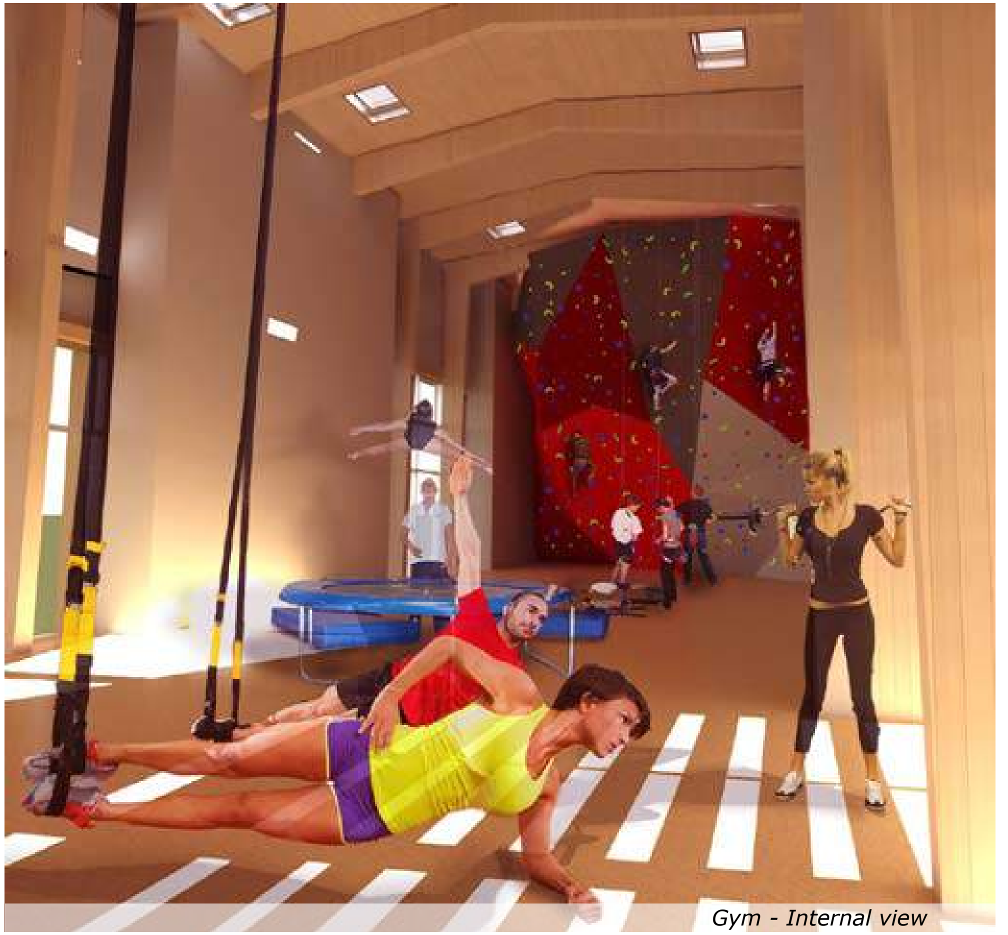
OUTDOOR
1. Courtyard 1527 m²

Gym - Internal view



Ground Floor

This is both internal to ensure the practice and the courses during the winter, both external, still covered, to give the opportunity for users to practice this activity at open air protected in case of rain or other adverse weather events. In addition to the environments mentioned above relative support and facil-ities are provided all around the main buildings. The latter include a deposit, a medical first aid room, dressing rooms for the staff and technical rooms. The dressing rooms for the users are located in each unit. In addition, two more areas are provided: one for a bar and the second (characterized by double height) dedicated to exhibitions or other events.



Gym - Internal view

Climbing Wall - External view

Arid Zone Cluster -> Store Plaza

Arrangement of design proposal
Politecnico di Milano - Polo territoriale di Lecco
Re-thinking Expo - Prof. M. Imperadori

Michele Amadori, Martino D'Alberto, Roberta Firino, Sofia Fondelli

Arid zone cluster is composed by seven squared units and a additional larger building. Al blocks are facing toward a courtyard with irregular paths. Square unit are double floor and they have been transformed and re-adapted.. Units are mainly designed as temporary shops, laboratories for workshops or space for weekend sells. They are equipped with large spaces for sale or expositions and also small deposits on each floor.
According to the secluded position of one the blocks, it has been designed to contain management offices for the whole area.
The larger module has been adapted in a multi-purpose hall becoming a versatile space able to host various activities at different levels both for public and private events or destination of use. According to that, such module may be equipped with movable partition walls, such that different requirements/purposes can be satisfied simultaneously.

STORE

1. Store 75 m²
2. Toilets 6 m²
3. Deposit 15 m²

OFFICE

1. Open space 75 m²
2. Toilets 6 m²

STORE

1. Open space 150 m²
2. Deposit 35 m²
3. Changing room 15 m²

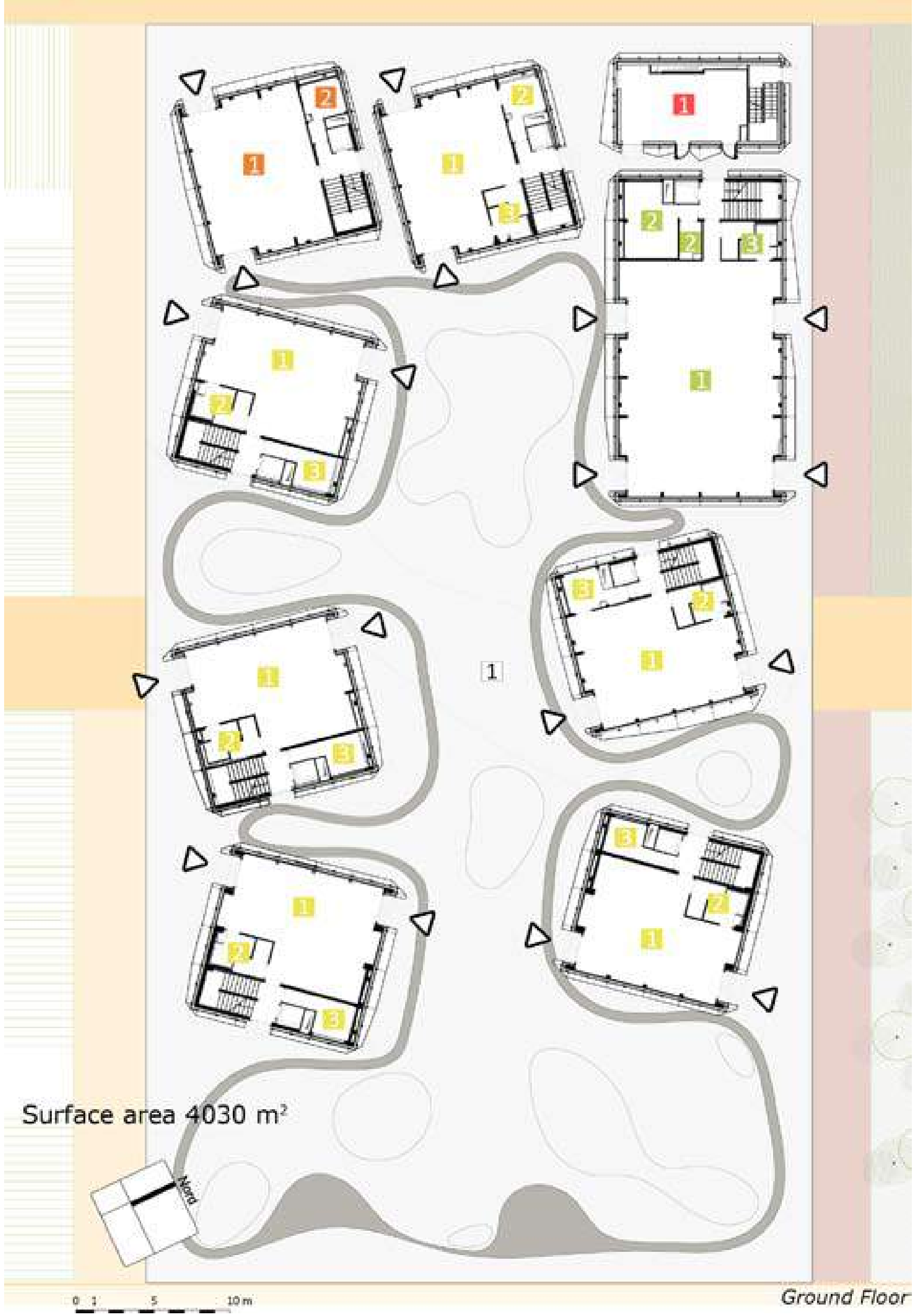
TECHNICAL ROOM

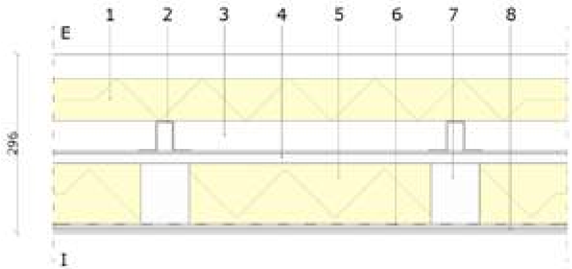
1. Technical room 35 m²

OUTDOOR

1. Courtyard 3104 m²


Courtyard view





CEILING DETAIL

s = 296 mm U = 0,18 W/m²K

1. 70+40 mm sandwich panel polyurethane insulation
2. 30 x 50 x 30 mm, 2 mm thick, omega metal profiles
3. 50 mm air layer for facade ventilation
4. 16 mm OSB wood panel
5. 80 mm polystyrene insulation panel
6. Vapor barrier
7. 100 mm fir wood strips
8. 13 mm 3-layer glulam

STORE

1. Store 75 m²
2. Toilets 6 m²
3. Deposit 15 m²

OFFICE

1. Open space 75 m²
2. Toilets 6 m²

STORE

1. Open space 150 m²
2. Deposit 35 m²
3. Changing room 15 m²

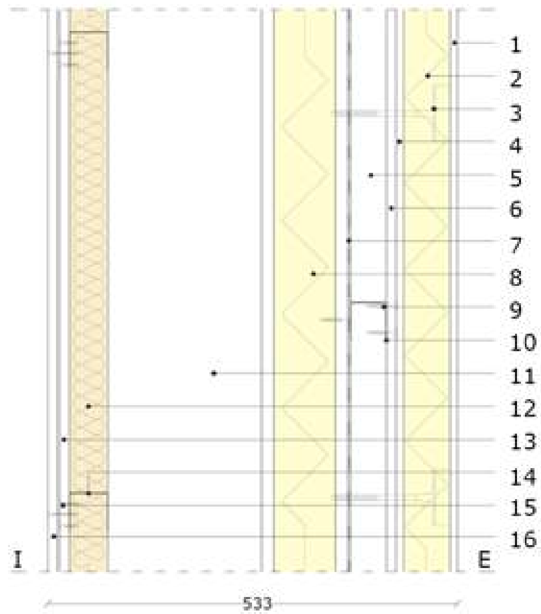
TECHNICAL ROOM

1. Technical room 35 m²

Fab Lab - Internal view

First Floor

Store - Internal view



FACADE DETAIL

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1. 15 mm acrylic topcoat
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3. Insulated panel wedge
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8. 16+80+16 mm SIPS as Kingspan
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10. 50x50x0,6 mm C metal profile, distance 60 cm
11. 200 mm plants cavity
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13. 12,5 mm plasterboard as Knauf GKB
14. 50x50x0,6 mm C metal profile,distance 60 cm
15. Phosphated screw
16. 12,5 mm plasterboard as Knauf GKB

Intervention has the purpose to offer a second life to the structures, by using Expo available tools, bringing spaces up to standard, designing façades and roofs with annual technological performance through increasing thermal insulation in addition to SIPS structural insulation sandwich panel. Temporary structures, design to meet the need for hot climate, could be moved elsewhere or, if it is possible, modified to support snow loads. Wall layering refers to Regione Lombardia DGR VIII/5018 in order to provide thermal U-values limit for the facade (U=0,34 W/m²K) and for the roof (U=0,33 W/m²K). Vertical and horizontal enclosure have been transformed and implemented to reach the required performances adding a series of layer both on the external and on the internal side.
Concerning the roof it has been used in all cases a sandwich panel that guarantee waterproofing characteristic and good U-Value performance.