Description of SDEurope 2010 Houses
by the participating universities

Virginia Polytechnic Institute & State University, United States of America
Hochschule Rosenheim University of Applied Sciences, Germany
Hochschule für Technik Stuttgart, Germany
École Nationale Supérieure d'Architecture de Grenoble, France
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University of Valladolid, Spain
University of Nottingham, United Kingdom
Tianjin University, China
Instituto de Arquitectura Avanzada de Catalunya, Spain
Universidad Politécnica de Madrid, Spain
Introduction and Main Objectives of the Project

The LOW3 (low energy – low impact – low cost) is a prototype we, the UPC-Barcelona Tech, developed for the Solar Decathlon Europe 2010. It is a self-sufficient solar house based on three main principles: a low energy demand, a low impact on the environment, and a low cost architecture with a strong focus on the economy of means. LOW3 explores the thermal capacity of intermediate spaces in contributing to low energy architecture as well as it explores their spatial qualities, creating in-between spaces for innovative ways of living.

Our alternative housing concept is based on existing low-tech solutions: we aimed at creating an affordable but sophisticated solar house. The design process was driven by economic aspects from the beginning: we were searching for the maximum available volume at minimum cost, which led to the use of an off-the-shelf agricultural greenhouse, adapted to residential needs. Well integrated standard solar technologies allow energy self-sufficiency at a reasonable price.

Our holistic sustainability approach led to the implementation of a two step grey water recycling system, a dry toilet, and a vegetable garden that provides food self-sufficiency for the occupants.

Our "house-in-a-house" concept generates additional, "temporarily useful" floor spaces and volumes at a very low cost, as well as it improves the overall energy balance of the building.

Architectural Design

Today’s flexible and changing social conditions, new ways of living and working, as well as frequent changes in uses inspired our design. We explored an alternative, growing housing concept based on modularity in space, structure and installations; as well as the combination of interior highly insulated housing modules with a lightweight microclimatic building shell. Resulting intermediate spaces enrich the spatial concept of LOW3 and create, through their bioclimatic optimization, additional spaces and volumes available for the uses of the occupants.

The three main concepts of LOW3 are:
- Low energy: passive solar architecture and effective bioclimatic design minimize the energy demand of the LOW3 house.
- Low impact: the use of sustainable and reusable materials minimizes the environmental impact of the project, in terms of construction and duration of use. LOW3 aims at fulfilling the important objective of “closing” water and material life cycles.
- Low cost: low-cost and low-tech solutions, all together with dry construction methods, allow quick modular assembling. It converts a green house structure into an innovative solar housing concept.

Exterior design. LOW3 is a highly insulated, minimum housing unit of 42 m². The outer shell of the building is based on an industrialized greenhouse structure featuring a lightweight polycarbonate skin. Such a microclimatic skin modifies the thermal behavior of the
The interior is actively conditioned through a radiant heating and cooling system, as well as a ventilation system with heat recovery. The intermediate space of LOW3 is designed to create comfort conditions exclusively through passive strategies.

On the north side, an independent row of installation boxes contains all the necessary equipment for active climate system, hot water supply, fresh water tanks and grey water recycling. Due to their accessibility, these installations can easily be modified or upgraded according to specific location and/or uses.

**Interior design.** The inner living modules of LOW3 form a minimum housing unit of 42 m², according to the basic requirement of the competition. Three living modules and one wet module containing the bathroom, the kitchen and all the main installations of the prototype are strategically located inside the greenhouse. The building shell generates a microclimate and supports solar hot water and electricity generation.

Small window openings and one main access door located on the north side contrast with the south facade, which is completely glazed.

The kitchen module adjoins an intermediate space, allowing the evacuation of internal thermal loads from cooking, and giving access to the wet module. This intermediate space is the core of the house: it is a shared infrastructure available for a variety of use.

**Construction and Materials**

Constructions and industrialization systems. The microclimatic skin of LOW3 employs a standard industrialized greenhouse structure, based on galvanized steel profiles and polycarbonate panels as skin. Every structural element can be demounted and reused, or adapted over the life cycle of the house.

The living modules consist of micro laminated KERTO wood structures, in combination with lightweight Fiji wood beams and OSB board cladding. No mineral-based construction material is used for the inner housing unit. The modularity of the inner living modules, as well as the outer green house structure (with a standard width of 2.5 m) convert the LOW3 concept into a modular growing housing system. It allows many possible configurations ranging from low cost, minimum housing to larger projects (co-housing, living and working spaces, etc.) which can be modified over the life cycle of the house.

**House Envelope.** The polycarbonate panels used for the outer building shell are specially treated for resistance against UV radiation. They are 12 mm thick, have four layers (three chambers) and a U-value of 2.2 W/m²K with a visual light transmission of 42% and a solar factor of 0.52 for white or "opale" modules. Their visual light transmission is of 72% and they have a solar factor of 0.77 for translucent or "crystal" modules. Special constructive solutions allow an elevated air-tightness of the building shell, in comparison with standard agricultural green houses.

The inner living modules are highly insulated with 160 mm of wood fiberboards (walls), cellulose panels (floor and roof) and a low-e double glazing (south facade), for an overall average U-value of about 0.43 W/m²K and high air-tightness.

The south facade of the inner living modules captures direct solar radiation in winter, whereas in summer, glazed areas of the inner modules are shaded by the geometry of the construction and additional shading devices.

**Interior Comfort HVAC and House Systems**

The intermediate spaces of LOW3 are thermally regulated through basic bioclimatic mechanisms (mainly adapted from the agricultural sector) like movable sun protections, evaporative cooling, cross ventilation via extensive openings and passive solar use. Their period of use is extended throughout the year without any kind of additional energetic or economic cost.
Depending on weather conditions — according to the activities users want to perform — the intermediate spaces expand the space of the dwelling itself. The design and function of each facade or roof segment contribute to this objective.

The translucent collector south facade of the LOW3 prototype can open up and provide a porch for the house. Three out of four facade segments can be opened (by folding doors). Automated sunscreens protect the intermediate and interior spaces from excessive, direct solar radiation. The screens are made of resistant glass fiber, have a solar transmission value of 7%, and a visible light transmission value of 8% (see figure 11). The facade segment corresponding to the wet module (contains the bath and the kitchen) integrates solar flat plate collector of 7.2 m². Due to their vertical integration and to their dimension, reaches 87.3% of domestic hot water demand.

The combination of opened or closed facade, as well as opened or closed sun screens, allows the greenhouse to act as either an open and ventilated shading roof, or as a closed buffer space which captures solar energy. The north facade of LOW3 consists of a fix polycarbonate cladding, which is only interrupted by small window openings and the door. A 20 cm air gap between the inner living modules and the outer building shell allows all the main installations to be located between modules, making them easily accessible from the outside. No shading devices are needed. Thermal loads are evacuated through the roof opening.

The north part of the roof consists of a curved polycarbonate surface on metal substructure, with a standard green house opening mechanism. It is based on one central single phase motor and a horizontal mechanical axe which allows very slow lifting and closing of the whole roof segment. A movable outer shading device would be the most effective strategy to prevent overheating. Inside, easily accessible and movable solar protection has been planned. In combination with an opened roof and a cross ventilation, heat evacuation is considered sufficient, and easy maintenance is assured.

For technical reasons, shading devices couldn’t be installed during the competition week in Madrid.

Temperature sensors, sensors for relative humidity, as well as a meteorological station inform a domotic system which automatically controls the shading devices as well as the roof opening or adiabatic cooling devices. It optimizes the microclimatic building shell, and contributes to the overall energy performance and comfort of the prototype.

We installed an evaporative cooling system in the intermediate space. In the context of Madrid’s dry summers, the effectiveness of adiabatic cooling seemed especially relevant.

**Solar Systems**

LOW3 integrates a 4.2 kWp photovoltaic installation which annually produces 6,000 kWh of electricity — enough to make the house self-sufficient. According our initial low cost and low impact principles, we used a standard polycrystalline PV technology.

The PV modules are integrated into the roof structure. We used a galvanized steel framework which double skin allows the free circulation of the air (through a gap of 20 cm between the inner polycarbonate roof cladding and the PV array).

The photovoltaic installation is oriented towards the south, with an inclination of 19º — close to the optimum. A PV array shades the roof surface (on the south side) and avoids overheating of the intermediate space below. A natural stack effect induces high back ventilation: heat is carried away, and the temperature and efficiency of the modules are optimized.

PV modules are organized in strings of six, so they can easily be pre-assembled on the ground. They also enable an efficient roof installation, the electrical connection points (in the lower part of the roof) being accessible from the facade.
Sections 1

Construction details

Sections 2

Elevations

Modules Construction system
**TECHNICAL DATA OF THE HOUSE**

**Project name:**
LOW3

**Construction area:**
74 m²

**Conditioned area:**
42 m²

**Conditioned Volume:**
101 m³

**ENERGY BALANCE**

**Estimated energy balance:**
+120 kWh/a

**Estimated CO₂ emissions:**
No emissions during use due to energy self-sufficiency based on solar energy.
CO₂ emission related to grey energy of building materials and installations during lifecycle of 50 years: approx. 3.8 kg/m²a, a [20% of standard housing in Spain, solar systems not included]
Solar Energy systems avoid CO₂ emissions of about 100 Tn over lifespan which results in an overall positive CO₂ Balance over lifespan

**Estimated energy production:**
6,000 kWh (PV), 2,830 kWh (Thermal)

**Photovoltaic system:**
Installed PV power (kW): 4.2 kW
Types of PV Modules: 24 polycrystalline modules SCHOTT-POLY-175

**ENERGY CONSUMPTION**

**Estimated energy consumption:**
5,800 kWh/a

**Estimated electrical consumption:**
140 kWh/m²a

**Characterization of energy use:**
Appliances 2,550 kWh
Heating and Climatization 1,450 kWh
Ventilation 225 kWh
Lighting 850 kWh
Domotic system 180 kWh
Water cycle 425 kWh

**CONSTRUCTION ENVELOPE**

**Insulation types (type and thickness):**
Wood fibre board GUTEX 160 mm (facades)
Cellulose panels HOMATERM 240 mm (floor and roof) together with exterior building shell Polycarbonate AISLUX ARCOPLUS 6124 12 mm

**Constructive Systems thermal transmittance:**
Floor 0.15 W/m²K
Ceiling 0.15 W/m²K
Facade 0.24 W/m²K
Exterior building skin 2.2 W/m²K

**SPECIAL AND INNOVATIVE SYSTEMS**

Very low energy building system based on industrialized green house structure.
Microclimatic building skin with integrated solar technologies as ventilated shadow roof [summer] or greenhouse [winter]
Low energy heating and cooling system through radiant ceiling panels in combination with heating and cooling coils for faster response and dehumidification and mechanical ventilation system with heat recovery. (NAC Comfort)
2-step grey water recycling system and rainwater storage for irrigation of a vegetable garden [self supply]
Dry toilet without use of chemicals or water.

**COSTS**

**Construction Cost:**
402,000 € (total project budget)
240,000 € (prototype construction cost, material and manpower)

**Industrialized Estimate Cost:**
163,000 €