Layered dry envelope insulated with sheep wool-lime mix.

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This poster describes the results of a research aimed to design and assess a new layered envelope component that might be implemented on buildings of the Mediterranean area, in order to improve the energy efficiency and the environmental sustainability. These goals have been achieved by means of the use of local and natural building materials or arising from renewable resources. In particular, thermal insulating has been realized utilizing a mix of natural and mineral materials, obtaining a biocomposite with comparable building physics and mechanical properties to commonly used building materials. Among natural materials, the sheep wool was chosen since it is, on a hand, a waste to exploit and, on the other hand, it has a good behavior towards heat, moisture and indoor air pollution. Several samples have been realized mixing sheep wool, at different granulometry, with lime in different weight percentages. For each sample, thermal tests have been performed by means of a heat flow meter. The U value, Yie, mass and time lag have been evaluated for the whole designed system according to the Italian standards. In order to compare the environmental impact of the designed system with a similar commercial product, a Life Cycle Assessment has been carried out. Finally, thermal performance of the envelope system was evaluated by simulating its use in the retrofit of the old structure of a factory both in wall and in floor elements. The results was good in terms of energy balances of the building, while LCA results are contradictory, being one of the main issue the lack of data for local materials not directly investigated by authors.

Experimentation on sheep-wool mix

▸ WHY SHEEP-WOOL?

- good insulating properties
- absorbtion up to 30% of moisture
- reduction of indoor pollution
- unused waste
- recyclable
- regenerable

Conductivity	W/m°K	0,037-0,04
Heat capacity	J/kgK	1300-1700
Density	kg/m	20-50
Moisture resistance	µ	1-5

(literature data)

▸ MATERIALS PREPARATION

Sheep wool flakes from local flocks have been cleaned only with water in order to separate wastes from fibers without changing chemical properties.

Lime is a traditional material with well-known hygroscopic properties; two types of lime have been used in order to reduce environmental impact and provide mechanical resistance.

Water, used to mix the composite, has been weight in proportions with the others material.

▸ SAMPLES PREPARATION

Grinding: sheep-wool and lime have been grinded by knife milling machine. Particularly, sheep-wool flakes have been reduced to fiber of mm 20 (as a preliminary step), mm 6 and mm 4 (final steps).

Mixing: sheep-wool and lime have been weight in assigned proportions. Then, a composite of sheep-wool and a matrix of lime and water has been amalgamed in a 100l cement mixer for about 10 minutes.

Molding: the mixtures have been poured into mm 300x300x30 wooden molds and named with a code. Then, they have been dried both naturally (15 days) and into a climate chamber (4 days).

▸ MEASUREMENTS AND RESULTS

LEGEND
ρ density [kg/m³]
λ conductivity [W/mK]

Mixture no.1

L20-F4-A

Sheep wool	20%
Lime	16%
Hydraulic lime	64%
Water	g3583

ρ kg/m³ 747,90
λ W/mK 0,15

Mixture no.2

L20-F6-A

Sheep wool	20%
Lime	16%
Hydraulic lime	64%
Water	g3583

ρ kg/m³ 747,90
λ W/mK 0,14

Mixture no.3

L30-F6-A

Sheep wool	30%
Lime	14%
Hydraulic lime	56%
Water	g5323

ρ kg/m³ 660,70
λ W/mK 0,13

Mixture no.4

L40-F6-A

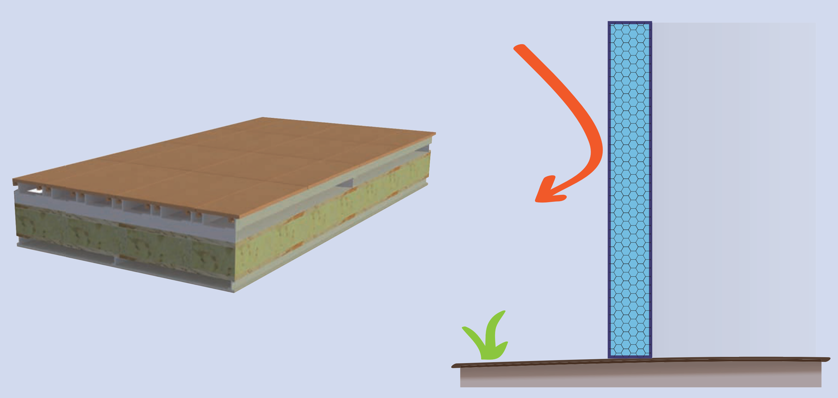
Sheep wool	40%
Lime	12%
Hydraulic lime	48%
Water	g5664

ρ kg/m³ 573,40
λ W/mK 0,11

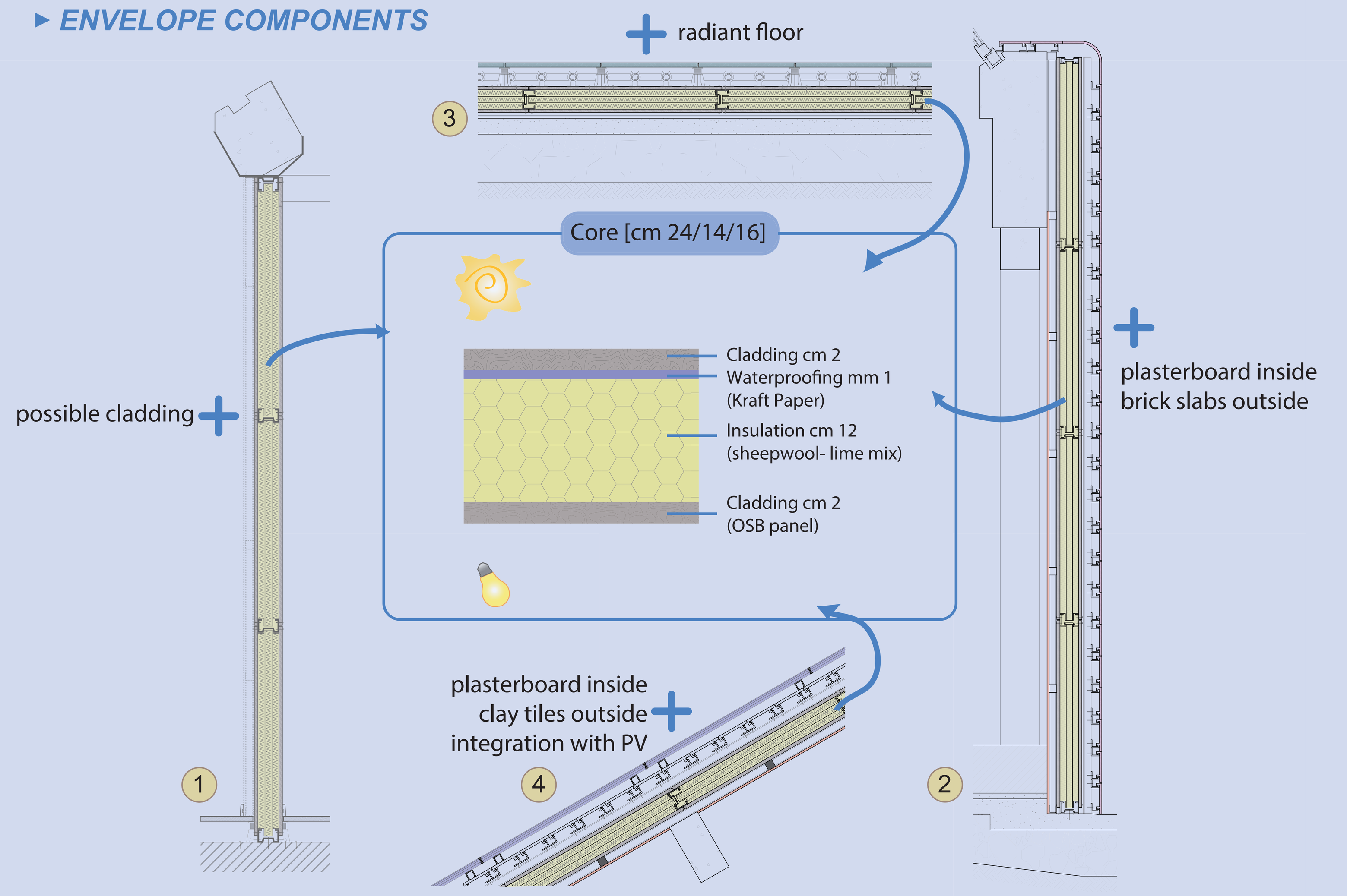
Envelope design

▸ WHICH FEATURES?

- dry built
- layered
- easy to install and versatile
- insulated
- hygroscopic
- low embodied- energy



▸ ENVELOPE COMPONENTS



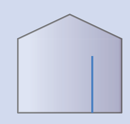
▸ PHYSIC PROPERTIES

LEGEND
U thermal transmittance in steady state [W/m²K]
Y_{ie} thermal transmittance in dynamic state [W/m²K]

Component 1

Partition

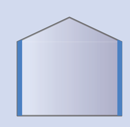
Thickness	cm 17	U W/m²K 0,35
Surface mass	kg/m² 122	Y_{ie} W/m²K 0,089
Time lag	h 11	



Component 2

Facade

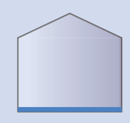
Thickness	cm 23	U W/m²K 0,43
Surface mass	kg/m² 167	Y_{ie} W/m²K 0,098
Time lag	h 12	



Component 3

Floor

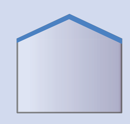
Thickness	cm 42	U W/m²K 0,46
Surface mass	kg/m² 717	Y_{ie} W/m²K 0,054
Time lag	h 16	



Component 4

Roof

Thickness*	cm 24	U W/m²K 0,35
Surface mass	kg/m² 166	Y_{ie} W/m²K 0,056
Time lag	h 14	



* photovoltaic panels excluded

Enviromental impact (LCA)

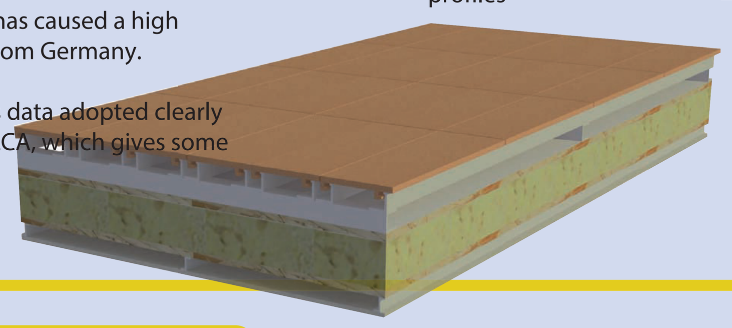
Ref.: ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework

▸ FUNCTIONAL UNIT

- Comparison between 1 m² of facade, providing an U value equal to 0,45 W/m²K, of the solution designed and reference one.

▸ CONSIDERATIONS

- Sheep wool supply represents the most polluting process because of the influence of data on pastoralism and land management, which were not similarly included in the other processes. On the other hand, if we consider that sheep wool is basically a waste, a specific LCI should be performed not considering the impact of farming activities but only the ones related to the processes realized "outside the farm gates" which are related to its use as raw material for the panel construction (washing, refining, cutting, handing, transport, assembly of the biocomposite).
- Although materials from recycled sources (Kraft paper, OSB panels) have been chosen to reduce dissipation of raw materials, this has caused a high impact of transports coming from Germany.
- The amount of heterogeneous data adopted clearly represents a weakness of the LCA, which gives some incoherent conclusions.



▸ INVENTORY OF THE DESIGNED SOLUTION

Element	Transportation [km]	Raw material consumption [kg]	Not renewable energy consumption [MJ]
Brick slabs	212	21	0.68
OSB panels	2487	91	5370
Kraft Paper	1576	0.009	1.4
Sheep-wool insulation	114	132	1333
Plasterboard	2366	24	133
Metal profiles	60	50	919
		319 kg	7757 MJ

▸ INVENTORY OF THE REFERENCE SOLUTION

Element	Transportation [km]	Raw material consumption [kg]	Not renewable energy consumption [MJ]
Brick slabs	212	21	0.68
Plywood	1531	22	5903
Kraft Paper	1576	0.004	0.7
Polyethylene	1531	170	236
Rock-wool insulation	1531	16	164.5
Plasterboard	2366	24	133
Metal profiles	60	50	919
		304 kg	10486 MJ

▸ LIFE CYCLE IMPACT

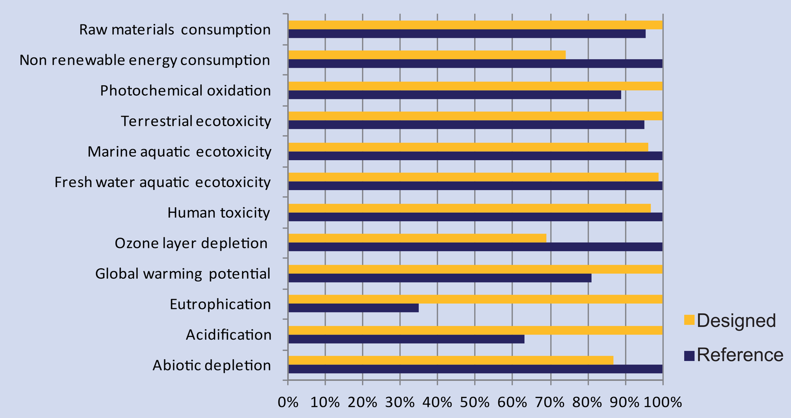


Chart 1. Environmental impact assessment - comparison between both solutions.

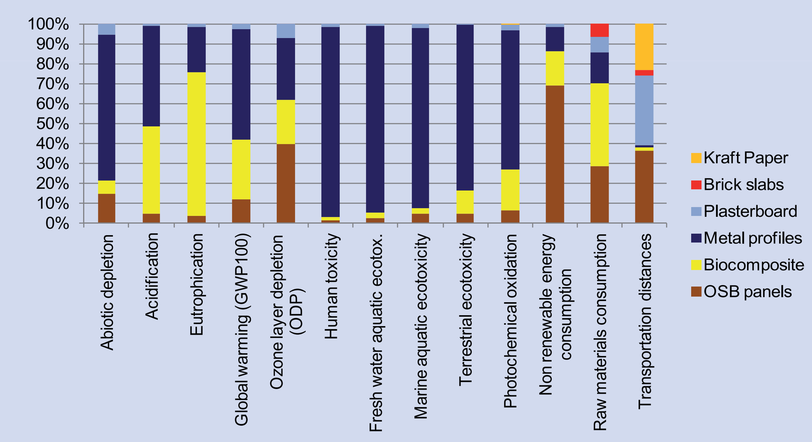


Chart 2. Relative environmental impact assessment of each material of the designed solution.

- An improvement of the environmental performances of the design product may arise from the possibility of increasing the provision of local materials and elements.
- The production of metal profiles is the most polluting process and Chart 2 confirms this.
- The production of both OSB panels and biocomposite, negatively affects the environment.
- Biocomposite production strongly affects the category of eutrophication due to the addition of nutritive substances during the sheep farming.

Energy demand for heating

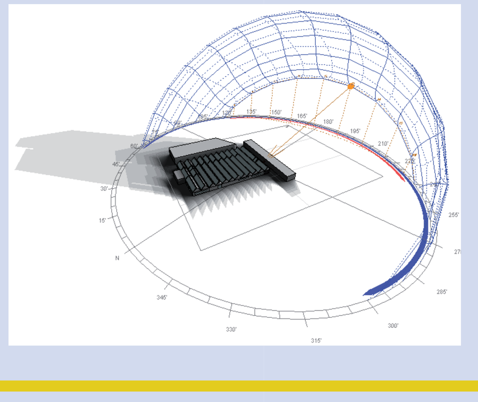
Energy simulations with Autodesk Ecotect Analysis.

▸ WHICH EVALUATIONS?

- Possible renovation of the envelope in an existing building as designed.
- Energy need for space heating.
- Possible development of RES, installing PV panels on shed roof (30°, south-west).

▸ WHICH CONSIDERATIONS?

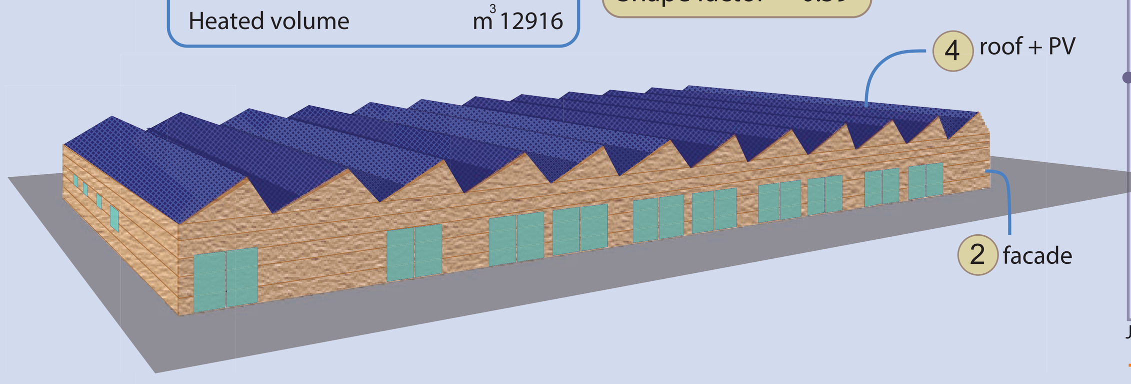
- Natural and local insulating materials ensure a good decrease of energy losses.
- Synergies between efficient conditioning systems and renewable energy sources are essential.



▸ BUILDING CHARACTERISTICS

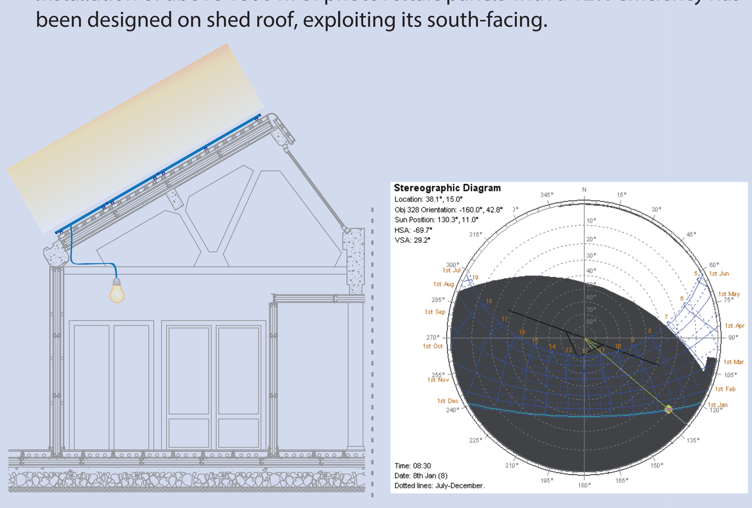
Floor surface	m² 2479
Surface area	m² 7620
Heated volume	m³ 12916

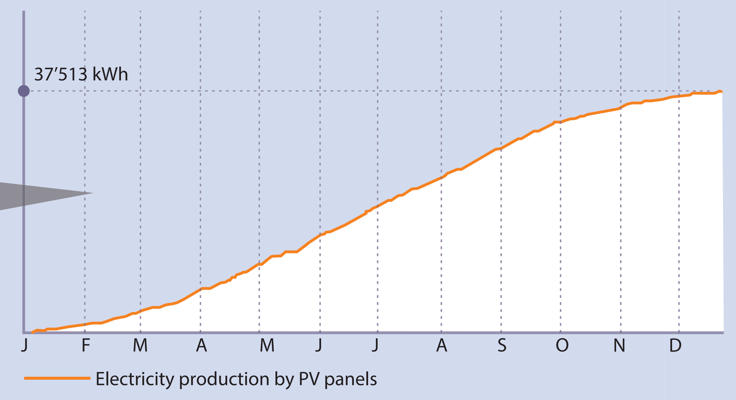
Shape factor 0.59



▸ INTEGRATION WITH PHOTOVOLTAIC PANELS

Installation of above 1800 m² of photovoltaic panels with a 12% efficiency has been designed on shed roof, exploiting its south-facing.





▸ ENERGY BALANCE

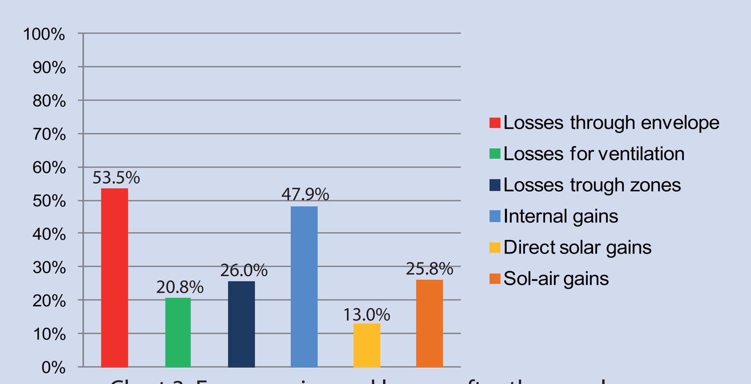


Chart 3. Energy gains and losses after the envelope renovation.

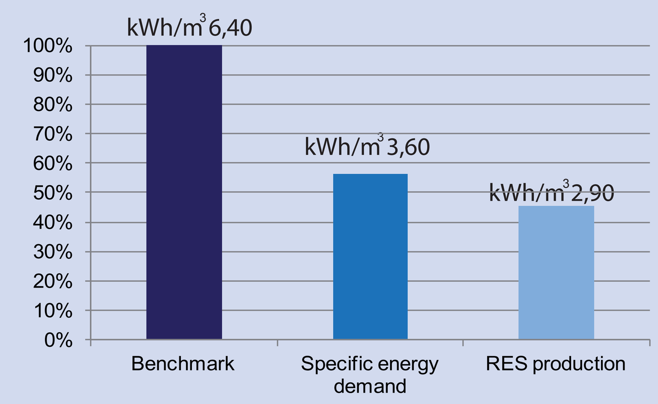


Chart 4. Energy need and production after the envelope renovation.

- Good results have been achieved thanks to the more efficient envelope that has optimized an existing good orientation of the building decreasing thermal losses (Chart 3).
- Heating need widely complies with national limits in force which correspond to 6,4 kWh/m³ year for an exhibit building having a shape factor equal to 0,59 and located in the B climate zone (Chart 4).
- As an additional proof of the existing favorable orientation of the building, the installation of PV over the roof gained a high efficiency supplying almost 80% electric energy of the overall need (Chart 4).