

1 Publishable summary



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1.1 Introduction

Although, the European citizens are becoming increasingly familiar with the concept of energy in use – that is the energy required by the occupants of an existing building, primarily for space heating, water heating and lighting – and of the need to reduce it, they have not realized yet that energy is needed not only to run a building but it also takes considerable amount of energy to create the building products and the building itself.

The embodied energy of a building, defined as the total energy required to produce the building components, transport them in place and construct the building, is a significant component of its lifecycle impact and can be the equivalent of many years of operational energy. An average household contains about 1,000 GJ of energy embodied in the materials used in its construction, which is equivalent to about 15 years of operational energy consumption. Moreover, it is important to point out that when increasing the level of energy performance of buildings in operation, which is the current trend in the construction of new buildings dictated by many EC (EPBD 2010/31/EU) and member state directives, the embodied energy of the building materials represents a much higher percentage of the energy spent in the whole life cycle of the building.

Therefore, the development and use in construction works of building materials of low embodied energy will directly reduce the overall environmental impact and improve the sustainability of the building sector.

1.2 Project Objectives

A review of the embodied energy values of the various building materials shows that the embodied energy of the most widely used insulation materials in construction applications is characterized by very high values. This mainly results either from the energy intensive conditions applied for the manufacturing of the mineral based insulation materials or from the high embodied energies of the oil- based raw materials used for the production of the organic based ones. Moreover, conventional insulating materials can suffer from various disadvantages including not stable thermal and acoustic performance overtime, combustibility, shrinkage and setting, and pollution of the indoor building environment.

In this frame the objective of the project is the development of a new generation of inorganic insulation materials and building insulation masonry components, that will have 70-90% lower embodied energy, 20-25% lower unit cost than the synthetic organic and mineral based ones, like EPS, XPS, Stone and Glass Wool, and at the same time they will not present their technical, health and/or environmental drawbacks. New formulations and products will be called “3I” materials, since they will be Inorganic, Insulating and Incombustible.

This objective will be achieved through the development of innovative technological routes for the production of the 3I materials, combining:

a) use of appropriate inert, natural alumino-silicate raw materials, originating from “zero-embodied energy” wastes of industrial mineral exploitation (i.e. perlite, bentonite, amorphous silica and other volcanic minerals) and other industrial wastes and by-products;

b) application of novel low energy consuming synthesis processes based on inorganic polymerization and thermal expansion that take advantage of the unique and favorable chemical and mineralogical composition of the above wastes;

c) addition of appropriate mineral by-products (fluxes) that easily react with the above wastes through highly exothermic reactions forming inert stable structures.

The assessment of the environmental sustainability of each one of the new insulation components will be performed with life cycle assessment studies.

Within this overall framework, the main research areas covered within the project are the following:

1. Definition and quantification of the technical specifications of the new insulation components (3I loose-filling material, 3I formed products - foam boards, EPBs, fibre and non-fibre boards - and 3I polymer bricks) proposed to be developed in order to meet the market requirements and comply with the EPBD and the technical, safety, health and environmental performance standards. The properties that have to be measured and the relevant methodology for the characterisation of the wastes to be used as raw materials for the development of the new components and also the evaluation of the new insulation components performance will be studied (WP1);
2. Development of various formulations of inorganic precursor polymers, which upon suitable processing will lead either to the direct synthesis of formed insulation products (in the frame of WP4) and insulating polymer bricks (WP5) or to an easily expandable precursor material that will be used for the production of bulk insulating materials (WP2)
3. Development of 3I loose-filling materials with superior performance, reduced embodied energy and lower cost compared to the currently applied bulk insulation products (expanded perlite, stone and glass wool, polyurethane bubbles) to be used to fill cavity walls, to cover the space between soil and concrete floors and under flat green roofs in retrofitting works, but also in new buildings to provide thermal insulation and protection from water drainage, as filler for plasters, mortars, paints and joint compounds and for wrapping ducts to provide thermal insulation and fire resistance. The solid inorganic precursor polymer developed in WP2 will be used as primary material for the synthesis of the new 3I loose-filling materials. The development of the 3I loose-filling material will include two stages: a. expansion of the precursor inorganic polymer and b. surface coating of the expanded particles to render them completely hydrophobic (WP3);
4. Development of new 3I formed products (foam boards, EPBs, fibre and non-fibre boards) with similar thermal performance to the currently available products for similar applications, but also with good acoustic insulation and mechanical properties, chemically inert, stable over time and fire resistant to be used as insulating boards in new or retrofitted buildings, to cover roofs and walls (external and internal); additionally, the insulating boards will be also used to cover ventilation pipes, wire networks, steel constructed buildings, etc. For the synthesis of the new 3I formed products, the inorganic

polymer paste developed in WP2 will be used as primary material, while different low embodied energy and cost processing routes will be applied for its further processing, depending on the type of the final board to be developed (WP4);

5. Development of new bricks, with improved thermal and acoustic insulation properties, reduced embodied energy and mechanical properties similar to those of special insulating clay bricks currently available in the market, by using: a. the solid polymer material, developed in the frame of WP2, for binding perlite in order to create a composite brick body; b. the 3I loose-filling or foamy material, developed in WP3 and WP4 respectively, to fill the brick cavities (WP5);
6. Evaluation and assessment of the technical performance of the new 3I products under real weather conditions in order to be used in the building sector and testing of the new 3I products with all the relevant EN standards in order to prove their compliance with technical, safety, health and environmental standards and the targets set by EPBD (WP6);
7. Assessment of the environmental impact related to the production and application of the new 3I products through a detailed Life-Cycle Analysis, and comparison to that of the most widely applied insulation materials, aiming to demonstrate the energy benefits and the environmental sustainability of the proposed insulation products (WP7);
8. Technical and environmental evaluation of the new processes and 3I products developed in the frame of the project (WP8);
9. Evaluation of the economic feasibility (pre-feasibility study) of the new processes and products developed in the frame of the project and development of a realistic preliminary business plan for the industrial application of the new production processes and a market penetration strategy for the exploitation of the new 3I products (WP9).

1.3 Work performed and main results achieved within the 2nd reporting period

Based on DoW, the WPs foreseen to be active in the period from month 18 to month 36 of the project are: WP2 (Development of inorganic precursor polymeric materials), WP3 (Development of 3I loose-filling materials), WP4 (Development of 3I formed products), WP5 (Development of 3I polymer bricks), WP6 (Field tests of the new 3I components – Certification), WP7 (Life Cycle Analysis), WP8 (Technical evaluation of new products), WP9 (Business plan). Finally, WP10 (Project management) and WP11 (Project scientific coordination) are active throughout the whole duration of the project.

1.3.1 Activities and main achievements per WP

Within this respect the activities carried out and the beneficiaries involved in them are the following:

1.3.1.1 WP2: Development of inorganic precursor polymeric materials

- The proper types of silicate/alumino-silicate waste materials have been identified and fully characterized by NTUA. Selected waste materials are perlite tailings (cyclones, μ -Silica), Bentonite tailings (Ca and Na-bentonite), recycled glass cullets (Soda-lime glass, Borosilicate glass) and kaoline. Moreover, a study of the compatibility between the silicate/alumino-silicate wastes available across EU and the market expectations – technical requirements has been performed.
- NTUA performed a detailed study of the chemistry of the inorganic polymerisation reactions and identified the optimum process conditions aiming to the formation of precursor inorganic polymers with optimum composition and properties for the development of the new 3I products. Research has been performed in parallel for the different 3I products; Loose Fill materials, inorganic polymeric binders for compact boards and bricks, and foam boards. The key parameters have been identified for each case, and the lab scale synthesis of the different 3I products has been optimised.

- 3I Loose fill materials (3I LFM):

Various formulations for 3I Loose Fill Materials (3I LFM) have been developed yielding granulate samples with LBD ranging from 14 up to $> 100 \text{ kg/m}^3$. The key parameters that affect the properties of the final products have been identified, and the lab scale synthesis process has been optimised. Appropriate formulations have been selected and fine-tuned according to the specifications set for each different application (cavity walls, 3I EPBs, 3I fibre – non fibre boards, 3I bricks and facades).

- Inorganic polymer binders for 3I compact boards and polymer bricks

Various formulations for inorganic polymer binders have been developed. The key parameters have been identified, and the lab scale process has been optimised. Optimum formulations based on perlite tailings yield specimens with compressive strength above 20MPa. The first extrusion trials showed that geopolymer pastes based on perlite tailings can be successfully extruded by extruders similar to the ones used in the clay industry, specially equipped. The rheological properties of the geopolymer pastes are crucial for the successful extrusion, and were further studied.

- 3I foamed boards

The research has been performed on three stages: synthesis of geopolymeric paste, foaming of the paste and curing of foamed paste. For each stage, the key parameters were defined, and the process was optimised. Optimum formulations yield foamed products with density as low as 350 kg/m^3 and thermal conductivity of 0.065 W/mK .

WP2 was successfully completed on month 24, providing selected formulations for the lab and pilot scale development of the various LEEMA products in WPs 3, 4 and 5. Nevertheless, the knowledge obtained within WP2 was used to properly adapt the formulations when requested, especially during the up-scale of the products development and production.

1.3.1.2 WP3: Development of 3I loose-filling materials

A lab scale expansion furnace was developed and used for the expansion of small scale 3I loose-fill material precursors for the evaluation of the various formulations developed in WP2. The IR lamps temperature was set at 600 °C, while the actual expansion temperature was estimated to be ~300-350 °C, significantly lower than the expansion temperature for natural perlite.

The pilot scale production of the 3I LFM was designed based on the lab scale process. The pilot production consists of a mixing unit (typical cement mixer), a crushing/ sieving system and an Infrared expansion furnace with higher capacity compared to the lab scale furnace.

A hydrophobation process was developed by S&B, based on solid siloxane vapours. A lab scale method has been used for the hydrophobation of small scale samples. Moreover, a pilot scale vertical cylinder-like reactor was installed in Ritsona. However, as the new 3I Loose Filling materials have good water repellency and in most cases further improvement was not necessary, it was decided to skip the hydrophobation step so as to reduce the production cost.

Initially, small scale samples of 3I Loose filling materials were produced by NTUA at lab scale, hydrophobised by S&B when necessary, and delivered to the industrial partners, for the different applications. After the selection of the most suitable materials, pilot scale samples were produced by SandB and NTUA and delivered to the industrial partners, to be used in the pilot scale production of the LEEMA products. The final 3I Loose Filling materials are presented below:

1. Loose fill insulation for cavity walls.

1.2 m³ of 3I Loose Filling material for cavity walls (Figure 1.1) was delivered to WP6 partners for field tests and the final evaluation. The sample has 35% lower LBD and 17% lower thermal conductivity, compared to the commercial hydrophobic expanded perlite for cavity walls. The water absorption is similar even without hydrophobation and it was decided to eliminate this step to reduce the production cost. The crushing resistance is lower, due to the lower LBD, but is considered adequate.



Figure 1.1. 3I Loose Filling materials for cavity walls

2. Loose fill material for 3I EPBs (WP4 - TCERAM).

Project partner TCERAM has been inactive during the 2nd reporting period. The consortium put a lot of effort in finding a new partner. A new partner has been found and will join the consortium in order to undertake the role of TCERAM in the project. The work under WP3 continued in order to identify the most suitable 3I Loose Filling material for 3I EPBs, that has 41% lower LBD and 20% lower thermal conductivity compared to the expanded perlite TCERAM uses in its production. The crushing resistance is lower, as expected, but still considered adequate in order for the material to be used for the production of 3I EPBs.

3. Loose fill material for fibre and non-fibre boards (WP4 - ETEX).

Several small and large scale samples were prepared and delivered to ETEX for lab and pilot scale experiments. The first large scale sample (1m³) was produced and delivered in June 2013 for the first pilot scale production trials of fibre cement boards. The final – optimized sample (1 m³ delivered to ETEX in October 2014)) had similar LBD and lower thermal conductivity compared to the expanded perlite currently used by ETEX. The crushing resistance was significantly improved so as the material withstands the production process of the fibre boards. Moreover, the water repellency was significantly higher compared to expanded perlite, even without hydrophobation.

4. Loose fill material for 3I bricks and facades (WP5-SCHLAG).

Several small scale samples were prepared and delivered to ETEX for lab scale experiments. The final – optimized sample (delivered December 2014) had similar LBD and 13% lower thermal conductivity compared to the expanded perlite currently used by SCHLAG.

1.3.1.3 WP4: Development of 3I formed products

Task 4.1 Development of 3I foam boards

Initially, the aim of WP 4 was the development of new 3I formed products with similar thermal performance to XPS and EPS, but also with good mechanical and acoustical properties and chemically inert. From the study that was performed under WP2 and WP4 concerning the foamed boards, the optimum products from perlite waste were lightweight (density 450-650 Kg/m³) with medium thermal properties (thermal conductivity 0.06-0.10 w/mk) and higher mechanical strength than EPS and XPS (0.8-2.7 mpa). Taking into consideration that a. the market of lightweight porous materials is exclusively occupied by the autoclaved aerated concrete (AAC) b. the AAC production suffers from some disadvantages such as increased plant precautions due to the explosive nature of hydrogen gas difficulties in the production control and high energy consumption, the study of WP4 will focus on the development of 3I blocks with similar performance to AAC blocks. These changes will be implemented in the next amendment.

An optimized foaming process was developed at lab scale, using inorganic or organic foaming agents. It was decided that efforts on up-scaling would focus on the organic foaming agents.

The lab scale 3I foamed boards had densities below 400 kg/m^3 and λ 0.06 W/mK . The optimization on pilot scale took a lot of effort, as both the inorganic polymerization as well as the foaming process are strongly dependent on the volume as well as the geometry of the samples.

Pilot scale samples have been produced with densities $\sim 600 \text{ kg/m}^3$ and λ below 0.11 W/mK . The samples can be successfully cut, retaining their shape and mechanical properties (Figure 1.2)



Figure 1.2. Photos of 3I foamed boards during cutting

Task 4.2 Development of 3I EPBs

Different samples of 3I LFM have been delivered to TCERAM for lab scale production of 3I EPBs. Lab scale products were successfully produced, replacing partially or fully the expanded perlite by the 3I LFM. The 3I EPBs exhibit similar performance to the lab scale reference samples.

Task 4.3 Development of 3I fibre and non-fibre boards

The development of 3I fibre and non-fibre boards by ETEX can follow two different routes.

- A. Fibre cement (FC) boards, where the standard lightweight filler is substituted by 3I LFM;
- B. Fibre cement (FC) boards, where a 3I based (geopolymeric) binder is used.

Different lab scale samples of 3I LFM have been delivered to ETEX for evaluation as replacement of expanded perlite in the Hatschek production of FC boards.

Several pilot scale trials were performed by ETEX for the production of different FC boards on mini-Hatschek (MiH) line. The LFM material was evaluated as substitution for the standardly used expanded perlite in Promatect H and Eterspan boards, and the standardly used exfoliated vermiculite in the Supalux boards (Figure 1.3). After the first trials, the efforts focused on the Promatect-H product, replacing expanded perlite with the 3I Loose Filling material.



Figure 1.3. First Pilot 3I Fibre boards samples

No major production problems were experienced when using the 3I LFM. Some accumulation issues were resolved by proper pre-handling of the 3I LFM. The 3I boards seem to have similar (or slightly higher density) but significantly higher flexural strength. The final sheet samples will be characterised and evaluated under WP6.

The development of 3I Fibre – non fibre boards with inorganic polymer binder is an extremely ambitious goal as, except for the development of a suitable binder formulation, a suitable board shaping-production process needs to be developed, as confirmed also by the first extrusion experiments. Lab scale experiments on inorganic polymer binders, based on the formulations developed under WP2, were performed. Extruded sheet samples, produced during the final extrusion trials at Morando will be evaluated.

1.3.1.4 WP5: Development of 3I polymer bricks

One of the objectives of LEEMA project is the substitution of expanded natural perlite with the new geopolymeric based LFM as insulating material for insulant-filled bricks. The most important property of an insulant lay in the thermal conductivity of the bound granules, forming a rectangular thermal insulation board with dimensions 20 cm to 20 cm, as this bound sample board represents the insulant conditions in the construction material, the brick, and can be measured using the standard procedure for thermal conductivity.

The first prototype bricks (Figure 1.4) and façade panels (Figure 1.5) were produced by SCHLAG in July 2013 thus proving in principle the substitution of natural perlite with 3ILFM.



Figure 1.4. 3I Infill brick for new buildings: POROTON T7”



Figure 1.5. 3I Façade panel for refurbishment: “WDF”

Several 3I LFM samples were delivered to SCHLAG. The final 3I LFM sample (non hydrophobised as well as hydrophobised) was successfully bound to form the insulant boards. The board of the non-hydrophobised sample showed a very good thermal conductivity of 35.5mW/m.K with apparent density of 64 g/L in dry conditions at mean temperature of 10 °C. The hydrophobised plate showed higher values (40.2 mW/m.K for thermal conductivity and 115 g/L for the apparent density), due to agglomeration issues. The hydrophobation will be further optimized and 3I brick samples will be sent to WP6 for evaluation.

For the ambitious goal of substitution of the heavy clay based brick body with geopolymeric material, several extrusion trials took place by Morando and NTUA. Efforts were made by NTUA to adapt the formulations so as to enhance the extrudability of the pastes. Morando designed and constructed a dedicated pilot scale extruder for “soft-clay” extrusion. During the final trials, the

extrusion process was optimized and several samples were produced (Figure 1.6), in order to be evaluated for use in 3I boards (ETEX) or 3I Bricks (SCHLAG).



Figure 1.6. Extruded column of 3I binder

SCHLAG is developing new generations of bricks for single or multi-family buildings. The geometry of the new brick is mostly given by a former brick generation of perlite filled brick. The performance of thermal conductivity was simulated by MFPA. Different hole patterns of the brick body have been modelled by finite element method (FEM) in order to determine the equivalent thermal conductivity of the brick. The equivalent thermal conductivity - as a measure of the thermal resistance of the whole brick for a given thickness - is a function of the thermal conductivity of the components. These components are the brick material (burnt clay or 3I-material) and the holes in the structural material with or without insulating filling. These results can be used both for the burnt brick products and for the 3I-polymer bricks.

1.3.1.5 WP6: Field tests of new components – Certification

WP6 partners provided input in order to create a detailed inventory of the potential applications of the 3I products in buildings, and the relevant characteristics to be tested.

The test programs for all the 3I products (intermediate as well as final) have been agreed among the relevant partners and are reported in WP6 deliverables. The main results obtained during the 2nd reporting period are presented below.

The main properties of the Loose Fill material samples are summarized in Table 1.1. Samples 1 and 2 are intermediate samples delivered in small scale amounts (<50L). Sample 3 is the final product, delivered in large scale (1.2 m³) in October 2014.

Table 1.1. LFM Samples for cavity walls

Property	Standard Method	Reference (CellFill)	3I LFM for cavity walls		
			Sample 1	Sample 2	Sample 3
Delivered		06/2013	06/2013	05/2014	10/2014
LBD [kg/m ³]	EN 1097-3: 1998	113.4	64.6	43.7	pending
Water repellency [%]	EN 14316-1	89.6	90	88.8	pending
Density (std) [g/cm ³]	N ₂ pycnometer	1.245 (0.016)	0.616 (0.003)	1.400 (0.016)	1.224 (0.007)
Thermal conductivity [W/mK] (sample density in Kg/m ³)	EN 12667:2001	0.0499(121.5)	0.0379(75.5)	0.0338 (52.5)	pending
Water solubility (% weight)	-	3.2	3.0	6.17	0.48
Alkali Dissolution at 24h (% weight)	Si	1.33	3.50	3.45	1.82
	Al	0.18	0.24	0.31	0.16
pH	ISO 787-4: 1981 and ISO 787-3: 2000	10.27	11.85	12.05	11.94

3I Foamed boards

The properties of selected 3I foamed block pilot scale samples, evaluated by NTUA, are given in Table 1.2. The optimum batch gave a range of properties, depending on the sample dimensions (cured in different moulds). The required samples will be sent to WP6 for the final evaluation.

Table 1.2. Properties of pilot and lab scale foamed blocks

	FA 22 content	d _(wet) kg/m ³	d _(dry) kg/m ³	λ (W/mK)
Batch 1	Low	918	790	0.121
Batch 2		1150	852	0.124
Batch 3		1100	780	0.120
Batch 4	Medium	1018	760	0.110
Batch 5	High	677	500	0.085
Optimum Batch ¹	High (increased S/L)	800-940	600-770	0.095-0.115
Lab Scale		800	600	0.098

3I EPBs

The composition and main properties of the samples, characterized by TCERAM and BBRI, are given in Table 1.3.

¹ Depending on the mould/sample dimensions

Table 1.3. Properties of lab scale 3I EPBs

Composition (% on dry weight)		A EPB (reference)	B	C	D	E
Expanded Perlite (Ref.)		Reference sample (Perlite only)	Samples with decreasing perlite and increasing 3I LFM content		-	
3I LFM Sample 3		-			Sample with same amount of 3I LFM	
3I LFM Sample 4-5		-	-	-	-	Sample with same amount of 3I LFM
Properties						
Thickness	Mm	29.8	30.3	29.9	29.5	29.6
Density	Kg/m ³	151	150	152	154	154
Flexural Strength	MPa	0.35	0.34	0.34	0.36	0.35
Compressive Strength at 10% deformation	MPa	0.22	0.20	0.21	0.19	0.22
Thermal conductivity λ_{10}	W/mK	0.0486	0.0482	0.0484	0.0482	0.0490
Mercury pycnometry	g/cm ³				0.481	0.956
Total pore area	ml/g	327			89.3	10.5
Median Pore Diameter (Volume)	μm	30.4			14.7	1.1
Median Pore Diameter (Area)	μm	0.0973			0	1.134
Bulk density at 0.0034MPa	g/cm ³	0.091			0.112	0.089
Porosity	%	96.4			91.8	94.1
N ₂ pycnometry	g/cm ³	0.952	0.981	0.909	0.795	0.803

3I Fibre non-fibre boards

The density and flexural strength of the FC Boards with Perlite (Reference) and 3I Loose Filling material are presented in Table 1.4.

Table 1.4. Properties of pilot scale Reference and 3I FC Boards

Trials		20/6/2013				6/3/2014		27/11/2014		
Property		Perlite		3I LFM		Perlite	3I LFM	Perlite	3I LFM	Prom Fake
		Prom-R1a	Prom-R2a	Prom-T1a	Prom-T2a	Prom-R3	Prom-T3	Prom-R4	Prom-T4	
SMOR (MPa)	AD	9.74	9.96	12.92	12.72	9.27	11.60	9.69	11.74	10.66
	WS	5.40	5.49	8.21	7.80	4.95	7.51	5.05	7.80	6.85
Density (g/cm ³)	AD	0.88	0.88	0.94	0.93	0.95	0.95	0.93	0.92	0.93
	WS	0.87	0.87	0.93	0.92	0.94	0.95	0.93	0.92	0.92

The results of the hydric movement tests of 4 samples (November 2014 trials) are presented in Figure 1.7. The water content upon saturation is presented in and Figure 1.8.

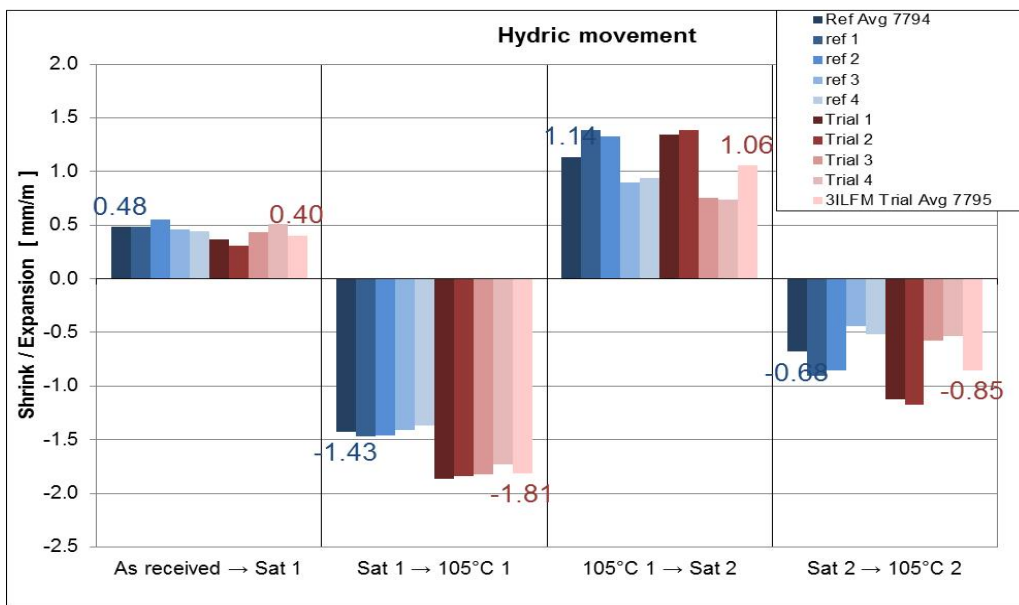


Figure 1.7. Hydric Movement test results

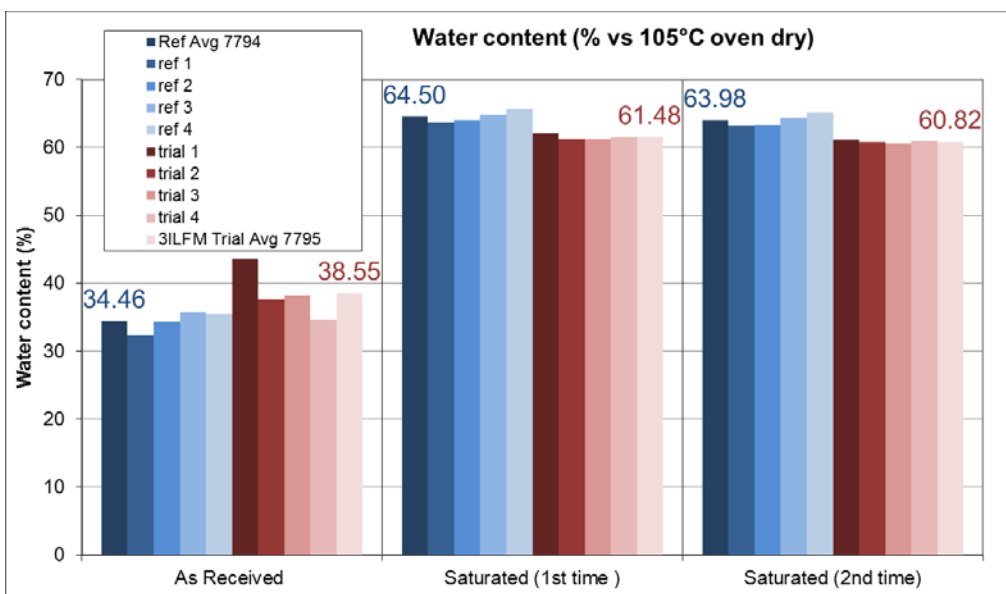


Figure 1.8. Water content upon saturation – Hydric Movement tests

1.3.1.6 WP7: LCA

The preparatory activities performed in first period, have been used in period M18-M36, as starting point for performing preliminary LCA studies for the different products, developed during LEEMA project. The questionnaires filled by industrial partners have been collected by DAPPO in order to proceed with specific LCAs for:

- Intermediate lab scale products: Loose Fill Materials for several applications, Foam Blocks and Binders (NTUA)
- Loose Fill Materials for cavity Walls (S&B)
- Fibre Cement Boards (ETEX)
- Foam Boards (FIBRAN)
- EPBs (TCERAM)
- Insulating bricks/facades (SCHLAG)

A first version of LCA study has been finalized and issued in June 2014, including preliminary results for standard products in terms of environmental impacts, which constituted Deliverable D7.1.

Some information was still missing and therefore in some products only a qualitative description of the process has been done. The objective is to have this first iteration as a solid reference, which will be used for implementing and updating information in the second iteration (D7.2 - June 2015).

The process of implementation is already on-going. Each partner has received the 1st Iteration LCA study related to its own products and DAPPO is collecting feedbacks in order to proceed with 2nd Iteration LCA study, which will include:

- Update of Block Flow diagrams related to Innovative products due to latest R&D work performed in WPs 2, 3, 4 and 5,
- Update of industrial up scaled processes,
- Comparison between Standard Products versus Innovative LEEMA products, based on the same Functional Units.

1.3.1.7 WP8: Technical evaluation of the new products

The technical evaluation of the new processes and products is currently on-going, and will be finalized during the last year of the project.

A preliminary evaluation of the **3I Loose Filling materials** has been performed and the following observations have been made:

The energy consumed during expansion of the 3I LFM for cavity walls is lower compared to that of expanded perlite (up to-43%).

The 3I LFM for cavity walls has superior properties in terms of density and thermal performance, compared to expanded perlite. The crushing resistance is lower, as expected, but considered acceptable for the specified application.

The cost of raw materials per Kg of product is below 0.15€ for any of the different 3I LFM products.

The **embodied energy per Kg** of the 3I LFM for cavity walls, based on preliminary calculations **using pilot scale data, is 14% lower than that of expanded perlite**. Considering the **embodied energy per Functional unit-FU** (FU=1m² of insulation, with variable thickness so as to achieve an R value of 1 m²K/W), taking into account the density and performance of the materials, the effect is more pronounced and **the reduction is higher than 50%**.

1.3.1.8 WP9: Business plan

A new updated web- survey was conducted in November 2013 to collect data on the requirements of architects for insulation materials. The results will provide valuable input for the Preliminary Business Plan.

The Project's web site has been created, successfully launched and is continuously updated by NTUA (D9.1: Web-site, submitted on M9). The Project website address is: www.leema.eu. Additionally, accounts in the most popular Social media were created (Facebook, Twitter, LinkedIn, Google+ and Youtube) and are constantly updated, to increase the project's visibility.

The project partners have been engaged in several dissemination activities such as; organization/participation in workshops, fairs and exhibitions, presentations and papers in conferences and scientific journals by SandB, SCHLAG, NTUA and ACE, participation in clustering activities with other projects, preparation of dissemination material (brochures, posters etc, and dissemination videos.

1.3.1.9 WP10: Project Management

The Consortium submitted internal financial statements to the coordinator on M27 and all foreseen Deliverables to the EC. A project partner, TCERAM, has expressed the will to withdraw from the project. The Consortium will request for a new amendment

1.3.1.10 WP11: Project Scientific Coordination

The Consortium has submitted internal activity reports on M27 and has met in October 2013 (18M Review meeting), February 2014 (24M Technical Meeting) and June 2014 (30M Technical Meeting), in order to discuss on the research progress and future planning.

1.3.2 Activities per Beneficiary

The main activities performed by each beneficiary during the 2nd reporting period are summarised in the following tables:

1 SandB		
WP	Description	Status
2	Development of inorganic precursor polymeric materials	<ul style="list-style-type: none"> - Provision of waste raw materials to NTUA - Definition of properties for 3I LFM - Assist NTUA in defining the optimum types and blends of industrial mineral wastes for the synthesis of inorganic polymer formulation appropriate for the manufacture of 3I loose-filling materials - Provision of waste raw materials to Morando for extrusion trials (relevant also for WP4-WP5)
3	Development of 3I loose-filling materials	<p>WP leader</p> <ul style="list-style-type: none"> - Provision of raw materials to NTUA - Hydrophobation of 3I LFM samples - Design of a new pilot scale production scheme for the production of 3I LFM samples in cooperation with NTUA - Pilot scale production of large scale 3I LFM samples in cooperation with NTUA.
4	Development of 3I formed products	<ul style="list-style-type: none"> - Provision of 3I Loose Filling material samples for FC boards (ETEX) and 3I EPBs (TCERAM)
5	Development of 3I polymer bricks	<ul style="list-style-type: none"> - Assist NTUA and SCHLAG in defining the specifications of the 3I LFM to be used as filling of the 3I bricks. - Provision of 3I Loose Filling material samples for 3I Bricks - Provision of waste raw materials to SCHLAG and Morando for extrusion trials of geopolymer binders for 3I Bricks.
6	Field tests of new components - Certification	<ul style="list-style-type: none"> - Provision of 3I LFM for cavity walls samples.
7	LCA	<ul style="list-style-type: none"> - Provision of LCA related data deriving from the pilot scale production of 3I LFM, in cooperation with NTUA and DAPPO.
8	Technical evaluation of new products	<p>WP leader</p> <ul style="list-style-type: none"> - Technical evaluation of lab and pilot scale 3I Loose Filling materials production process and products
9	Business Plan	<ul style="list-style-type: none"> - Completion of the ESS forms and preparation of a preliminary list of exploitable results (with the contribution of all partners) - Review of the template sent by ACE, used for the second version of the market analysis questionnaire that will provide valuable input for the Preliminary Business Plan. - Various dissemination activities

2 Etex		
WP	Description	Status
1	Materials specifications and characterisation	- Study of literature on potential secondary raw materials for geopolymer formulations were followed up.
3	Development of 3I loose-filling materials	- Characterization and evaluation of lab and pilot scale 3I LFM samples
2-4	Development of inorganic precursor polymeric materials Development of 3I formed products	- Study of literature on geopolymer formulations. - Workshop was organised at RedCo in November 2013. - Experiments with geopolymer alike formulations (at lab scale) WP4 leader - Pilot scale production of reference and 3I FC-board samples using 3I LFM - Evaluation of geopolymer binders, in cooperation with NTUA, as cement replacement
6	Field tests of new components - Certification	- Provision of reference and 3I FC board samples using 3I LFM.
7	LCA	- Provision of relevant data for LCA analysis
9	Business Plan	- Review of the template sent by ACE, used for the second version of the market analysis questionnaire that will provide valuable input for the Preliminary Business Plan.

3 SCHLAG		
WP	Description	Status
3	Development of 3I loose-filling materials	- Provision of the requirements and specifications of the 3I LFM to be used in as filling of 3I bricks. - Characterization and evaluation of lab scale 3I LFM samples
2-5	Development of inorganic precursor polymeric materials Development of 3I polymer bricks	WP5 leader - Characterization and evaluation of lab and pilot scale 3I LFM samples - Lab scale experiments and characterization of "insulant" boards with 3I LFM - Pilot scale extrusion trials of geopolymer binders in cooperation with Morando and NTUA
7	LCA	- Provision of relevant data for LCA analysis
9	Business Plan	- Review of the template sent by ACE, used for the second version of the market analysis questionnaire that will provide valuable input for the Preliminary Business Plan. - Dissemination activities (presentation in conference)

4 TCeram		
WP	Description	Status
2-3-4	Development of inorganic precursor polymeric materials Development of 3I loose-filling materials Development of 3I formed products	-
7	LCA	-
9	Business Plan	-

5 NTUA		
WP	Description	Status
2, 4, 5	Development of inorganic precursor polymeric materials Development of 3I formed products Development of 3I polymer bricks	<p>WP leader</p> <ul style="list-style-type: none"> - Development of inorganic polymeric formulations/materials with the proper composition and properties to be used, upon further processing, for the development of various new insulation products of improved insulation performance and reduced embodied energy and cost. - Extrusion trials on the optimum formulations for 3I foam boards and binders for 3I boards and 3I bricks, in cooperation with Morando (also for WPs 4 and 5). - Study of the compatibility between the silicate/alumino-silicate wastes available across EU and the market expectations – technical requirements.
3	Development of 3I loose-filling materials	<ul style="list-style-type: none"> - Design of a lab scale IR furnace for the expansion of inorganic polymer precursors for 3I LFM. - Lab scale production and characterization of 3I LFM samples. - Provision of 3I LFM samples to WP3, 4 and 5 partners - Characterization of expanded perlite samples currently used by the industrial partners. - Assist SandB on the production of inorganic polymer precursors for 3I LFM at pilot scale - Expansion of first large scale sample of 3I LFM for ETEX
6	Field tests of new components - Certification	<ul style="list-style-type: none"> - Provision of 3I LFM for cavity walls to SandB for hydrophobation
7	LCA	<ul style="list-style-type: none"> - Provision of data and information related to the processing and composition of inorganic polymer and formulation of the input-output streams of materials involved in WP2
8	Technical evaluation of new products	<ul style="list-style-type: none"> - Evaluation of raw materials cost of the inorganic polymer precursor formulations for the various 3I products
9	Business Plan	<ul style="list-style-type: none"> - Completion of the ESS forms and Preparation of a preliminary list of exploitable results (with the contribution of all partners) - Various dissemination activities (creation-maintenance-update of the website, presentation in international conference)

6 DAPPO		
WP	Description	Status
7	LCA	<p>WP leader</p> <ul style="list-style-type: none"> - Coordination of LCA activities, through the questionnaires collection, data analysis and delivery of 1st Iteration LCA study. Actually contacts are active with S&B, NTUA, ETEX, SCHLAG, FIBRAN, MORANDO for updating LCA models and finalize 2nd Iteration LCA study.
9	Business Plan	<ul style="list-style-type: none"> - Completion of the ESS forms and Preparation of a preliminary list of exploitable results (with the contribution of all partners)

7 Morando		
WP	Description	Status
2, 4, 5	<p>Development of inorganic precursor polymeric materials</p> <p>Development of 3I formed products</p> <p>Development of 3I polymer bricks</p>	<ul style="list-style-type: none"> - Extrusion trials on the new binders for 3I boards and bricks, in cooperation with NTUA, SCHLAG and FIBRAN - Provision of details on the extrusion process of clay materials
3	Development of 3I loose-filling materials	<ul style="list-style-type: none"> - Design of a pilot scale IR furnace
6	Field tests of new components - Certification	<ul style="list-style-type: none"> - Optimisation of the Morando lab-scale system for the manufacturing of the 3I products. - Pilot- scale testing for the production of foamed and fesco-like boards, as well as geopolymeric brick
7	LCA	<ul style="list-style-type: none"> - Installation of appropriate instruments for measuring the energy consumption during the production process to all the machines involved, needed for data collection for the LCA
9	Business Plan	<ul style="list-style-type: none"> - Completion of the ESS forms and preparation of a preliminary list of exploitable results (with the contribution of all partners) - Various dissemination activities in Morando's intra-network

8 MFPA		
WP	Description	Status
5	Development of 3I polymer bricks	<ul style="list-style-type: none"> - theoretical calculations of heat transport in the brick (changing shape and materials properties) in order to optimise thermal conductivity - Simulations of performance of thermal conductivity - Microscopic investigations on thin sections of existing material structures with thin sections.
6	Field tests of new components - Certification	<ul style="list-style-type: none"> - Determination of moisture uptake in 3I samples - Determination of hygrothermal behaviour of retrofitted walls - Visualisation of results

9		USTUTT	
WP	Description	Status	
6	Field tests of new components - Certification	<ul style="list-style-type: none"> WP leader - Detailed inventory of the potential applications of the 3I products in buildings, and the relevant characteristics to be tested, in cooperation with BBRI. Definition of a specific test program for each application. - Comparative analysis between internal testing methods (of Etex and Thermal Ceramics) and standardised methods for building applications in cooperation with BBRI - Characterization of 3I LFM and reference samples 	

10		ACE	
WP	Description	Status	
3,4,5,8	<ul style="list-style-type: none"> Development of 3I loose-filling materials Development of 3I formed products Development of 3I polymer bricks Technical evaluation of new products 	<ul style="list-style-type: none"> - Design and conduct a survey amongst architects regarding market implementation criteria of LEEMA products (analysis and reporting of the results) 	
7	LCA	<ul style="list-style-type: none"> - Preparation in order to provide the necessary data for the LCA study of the 3I products, in relation to the end-users requirements. 	
9	Business Plan	<ul style="list-style-type: none"> WP leader - Report on the first market analysis questionnaire, as part also of WP3, 4, 5, 7 and 8. Creation and distribution of the second version of the market analysis questionnaire that will provide valuable input for the Preliminary Business Plan. - Various dissemination activities (publications, presentations, participations in workshop) 	

11		BBRI	
WP	Description	Status	
4,5	RTD Work package title Development of 3I formed products Development of 3I polymer bricks	- support of other partners (producers) by testing intermediate materials composition	
6	Field tests of new components - Certification	<ul style="list-style-type: none"> - Detailed inventory of the potential applications of the 3I products in buildings, and the relevant characteristics to be tested, in cooperation with USTUTT. Definition of a specific test program for each application. - Comparative analysis between internal testing methods (of Etex and Thermal Ceramics) and standardised methods for building applications in cooperation with USTUTT - Characterization of 3I LFM and reference samples 	

13		FENIX	
WP	Description	Status	
3-5	Development of 3I loose-filling materials Development of 3I formed products Development of 3I polymer bricks	<ul style="list-style-type: none"> - Preliminary evaluation of the new developed 3I loose-filling material, 3I formed products and 3I polymer bricks in relation to the end-users requirements. - Video filming of the products/processes/interviews for future dissemination video. 	
9	Business Plan	<ul style="list-style-type: none"> - Completion of the ESS forms and preparation of a preliminary list of exploitable results (with the contribution of all partners). - Preliminary Market analysis of the Czech and Slovak building industry for the currently used insulating materials and the new 3I products to be developed. Technical, safety, health and environmental performance standards applied in the European Union and in the Czech Republic for insulation products were considered. - Various dissemination activities (creation of a draft advertising video – design of preliminary storyboard) 	

14 FIBRAN		
WP	Description	Status
2-4	Development of inorganic precursor polymeric materials Development of 3I formed products	<ul style="list-style-type: none"> - Assist NTUA in the lab scale development of 3I foam boards. - Provision of organic foaming agent - Participation in the first extrusion trials on the 3I foam boards at Morando - Design of the necessary modifications on a pilot scale extruder to be used in pilot production of 3I foam boards
7	LCA	<ul style="list-style-type: none"> - Collection of all the required data and completion of the LCA questionnaire. Provision of comments and feedback on the LCA Goal and Scope document for the foam boards.
9	Business Plan	<ul style="list-style-type: none"> - Completion of the ESS forms and Preparation of a preliminary list of exploitable results (with the contribution of all partners) - Completion of the template sent by ACE, concerning the new 3I foam boards, to be used for the preparation of a market analysis questionnaire that will provide valuable input for the Preliminary Business Plan.

15 AMS		
WP	Description	Status
9	Business Plan	<ul style="list-style-type: none"> - Commercial materials are under evaluation and the current legislation (Greek and European) is thoroughly investigated. Further, a questionnaire about the performance of commercial materials is applied in both construction personnel and end users. Market analysis inputs are prone to controversy due to economic crisis in Greece (started in 2008) and the issue of new legislation about these materials (issued 2009 when construction was in decline).

1.4 Contact information

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