



AEROCOINS

Aerogel-Based Composite/Hybrid Nanomaterials for Cost-Effective Building Super-Insulation Systems



PROJECT FINAL REPORT

Grant Agreement number: 260141

Project acronym: AEROCOINS

Project title: Aerogel-based Composite/Hybrid Nanomaterials for Cost-effective Building Superinsulation systems

Funding Scheme:

Period covered: from 16th June 2011 to 15th June 2015

Name of the scientific representative of the project's co-ordinator, Title and Organisation: Dr. Eunate Goiti, Senior Researcher, TECNALIA

Tel: +34 667 178 891

E-mail: eunate.goiti@tecnalia.com

Project website address: www.aerocoins.eu

VERSION RECORD

Version	Date	Author	Description of Changes
V ₁	15/04/2015	E. Goiti	First Version
V ₂	May	T. Budtova A. Rigacci	Inputs
V ₃	May	M.Koebel, S.Zhao	Inputs
V ₄	May	E. Zukowska, G- Reichenauer	Inputs
V ₅	May	M. Leivo, Z. Pakowski	Inputs
V ₆	18/06/2015	R. Garay,	Inputs
V ₇	20/06/2015	E. Zukowska	Inputs
V ₈	22/06/2015	G- Reichenauer	Inputs
V ₉	27/07/2015	E.Goiti	Final Version

Disclaimer

The information in this document is provided as is and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and liability.

The document reflects only the author's views and the Community is not liable for any use that may be made of the information contained therein.

TABLE OF CONTENTS

1	FINAL PUBLISHABLE SUMMARY	- 4 -
1.2	EXECUTIVE SUMMARY	- 4 -
1.3	PROJECT CONTEXT AND OBJECTIVES	- 5 -
1.4	DESCRIPTION OF THE MAIN S&T RESULTS/FOREGROUNDS	- 8 -
1.5	POTENTIAL IMPACT, MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION OF RESULTS	- 19 -
2	USE AND DISSEMINATION OF FOREGROUND	- 26 -

1 FINAL PUBLISHABLE SUMMARY

1.2 EXECUTIVE SUMMARY

In the context of global climate control policies, improving the energy efficiency of existing buildings represents a great challenge, worldwide as well as at the European level. Reducing the energy consumption of buildings is nowadays preferably achieved by increasing the thermal resistance of the insulation layer in the building envelope.

The AEROCOINs project, in order to contribute to the future reduction of energy consumption by decreasing heating and cooling demands of existing-buildings, has been working on the clever combination of sol-gel science and nanotechnology aiming to advance on the design and development of novel super-insulating aerogels.

The AEROCOINs project has developed new reinforcement strategies in order to produce mechanically strong super-insulating aerogel composite/hybrid materials. The main approaches developed are based on the employment of two polysaccharides materials: cellulose and pectin, respectively. These strategies open new possibilities for further development of superinsulating materials.

It was found in this project that the critical stress point when wet gels crack during Ambient Pressure Drying (APD) can be found by measuring the internal pressure evolution. This valuable information can be used to reduce the drying rate before the crack develops. In the current state-of-the art it is commonly assumed that this point roughly corresponds to transition from the constant to the falling rate period, which requires sample mass monitoring in situ.

For the thermal characterization of this type of highly insulating materials, an optimized hot-wire method has been developed within AEROCOINs, which permits the characterization of very small samples (down to diameters of about 27 mm). This method has been validated by comparing it to measurement with the same set-up on larger samples and comparing it to hot-plate results.

In addition, an efficient ambient pressure drying process and optimization on the supercritical drying process have allowed the up-scaling manufacture of aerogel boards. Designing and fabricating a novel building component prototype based on the developed aerogel-like material has yield a component compatible with conventional construction installations where the envelope is part of the buildings. This building component integrates low-conductive plastic-composite profiles and plasterboard renders within a multi-layer arrangement, and it has obtained the best fire classification for organic materials: B-s1,d0.

Demonstration of the structural, mechanical and thermal performance of the insulating component under real conditions have been performed in two demo buildings (in the DemoPark in Madrid and KUBIK in Bilbao) and compared with conventional insulating materials.

1.3 PROJECT CONTEXT AND OBJECTIVES

World energy demand is expected to increase by up to 71% between 2003 and 2030. As it is defined by the International Energy Agency (IEA) the energy future demand has to be a balance between the “three Es”: Environmental protection, Energy security and Economic growth. Different researches have indeed concluded that the only way to avoid a drastic increase of energy consumption is to achieve an order-of-magnitude improvement in Energy-Efficiency (EE), defined as the ratio between energy services provided and energy consumed.

According to the Buildings Performance Institute Europe (BPIE) the residential stock in Europe is the biggest segment with a floor space of 75% of the building stock and accounts for the 68% of the total final energy use in buildings¹. Space heating is the most energy intensive end-use in homes accounting for 70% of the total final energy use. This is due to the fact that more than 40% of the European residential buildings were constructed before the 1960s, when energy building regulations were very limited, and have not undergone renovations to improve energy performance, meaning that, these have low insulation levels and their systems are old and inefficient. One approach to improve energy efficiency of buildings is to enhance the thermal resistance of the envelope.

The development of advanced insulation technologies for energy efficient buildings is a very promising field. Indeed, the emerging field of superinsulating materials for new and retrofitting buildings, thanks to nanotechnology, has great promise to contribute to this unique domain of sustainable development.

Based on the “global” assessment that silica is the ideal raw material for large-scale commercial insulation application for buildings, the present project restricts its research area on a well-defined selection of improvement strategies for the silica-based aerogel composite/hybrid systems. The central goal is to capitalize on partners’ expertise and their deep knowledge of the state-of-the-art described in the literature by finding new and/or complimentary ways to manufacture superinsulating and strong very efficient aerogel-like materials.

The main goal of the AEROCOINs project was to develop a new composite/hybrid aerogel material to improve the insulating performance of existing buildings aiming at reducing their energy demands. Hence, the main objectives were:

OG1.- to synthesize and elaborate novel, mechanically strong and superinsulating aerogel-based materials via a subcritical ambient drying process.

OG2.- to design and fabricate a highly efficient and robust building component (based on the developed aerogel composite and/or hybrid material) for its implementation in the external part of the envelope of existing buildings.

¹ BPIE. Europe’s buildings under the microscope. Executive summary, 2011. ISBN: 9789491143014

OG3.- to demonstrate the significant cost reduction of the commercial production of superinsulating aerogel-like materials and hence also of the component.

These general objectives were expected to be achieved through the development and completion of complementary work packages. These, were based on the following specific **scientific and technical objectives**:

S&T O - Related to the elaboration and development of a composite/hybrid aerogel material.

1. To obtain a reinforced aerogel-based superinsulator material: improvement of mechanical properties (an improvement of up to 100 times *versus* plain silica aerogel) while maintaining thermal conductivity at a very low level ($\lambda < 0.018 \text{Wm}^{-1}\text{K}^{-1}$) by cross-linking and/or nanodispersion concepts.
2. To promote multifunctionality of the so-obtained superinsulating materials: for example, enhancement of flame retardancy with mineral nanodispersion in the sol.
3. To develop a subcritical ambient drying process: minimize evaporation-induced shrinkage thanks to an optimized fine-coupling between silylation chemistry of the silica network and strengthening techniques (cross-linking and nanodispersion).

S&T O – Related to the design and development of the insulation façade construction component.

4. To transfer the chemical process technology of best candidate lab-scale materials to the pilot scale (including both, the synthesis and ambient pressure drying processes for the elaboration of large monolithic superinsulating boards of 50 x 50 x 1 cm³ dimensions.
5. To design and fabricate a brand-new building component prototype based on the developed aerogel-like material, which will need to be compatible with conventional construction installations for implementation into the envelope part of buildings.
6. To design a cost-effective continuous industrial-level process for the production of the aerogel-like material board.

S&T O – Related to the validation of the efficiency of the insulation façade component and building integration.

7. To demonstrate the thermal performance of the highly insulating component under real conditions.
8. To demonstrate the structural and mechanical performance of the insulating component under real conditions.

To accomplish its objectives, the **AEROCOINs** project was structured into seven workpackages (WP), five of which address specific technical objectives (WP1-WP5), one of them is devoted to dissemination and exploitation issues (WP6) and the last one to management activities (WP7).

The seven WPs were the following:

The **WP1- Synthesis of reinforced superinsulating aerogels** was focused on the design and synthesis of brand new superinsulating silica-based aerogels. The main technical and scientific objective of WP1 has been to optimize the soft-chemistry processes for the preparation of such superinsulating silica-based aerogel-like materials *i*) to promote their mechanical reinforcement and *ii*) their multifunctionality, without degrading their very low thermal conductivity.

The **WP2 - Drying and thermal conductivity optimization** dealt with the development and optimization of a robust and efficient drying process to be transferred at pilot scale (in WP3) for elaboration of strong superinsulating aerogel-like boards. The main technical objective of WP2 was to develop an effective lab-scale subcritical ambient pressure drying (SAPD) process *i*) able to minimize shrinkage and cracking during evaporation, *ii*) permitting to obtain 10cm×10cm×1cm monolithic aerogel plates and *iii*) well-suited for further transfer to pilot scale. WP2 also aimed at adapting standard supercritical drying (SCD) process to the specificities of the brand new organic/inorganic gels synthesized within WP1. Because of its higher degree of maturity, the SCD route would provide the so-called “plates of reference”.

The **WP3- Pilot scale material fabrication** focused on the design and fabrication of new superinsulating aerogel board (of 50cm×50cm×1cm dimensions). The 3 main technical objectives of WP3 were *i*) up-scaling of optimized materials (at least one solution chosen from WP1-WP2), *ii*) to produce sufficient amounts of the selected best-case aerogel boards for the component manufacture in WP4 and *iii*) to perform an analysis of the potential for up-scaling and large-scale industrial fabrication of the aerogel boards. This included the design of a continuous fabrication scheme and a complete volume and parameter dependent cost estimation.

The **WP4- Aerogel-based component manufacturing** dealt with the design and fabrication of new superinsulating building components for retrofitting installations. The main technical objective of WP4 has been the customization of individual aerogel boards to yield a component which is compliant with current insulating systems and solutions and can be used directly in construction.

The **WP5- Building integration and validation** dealt with energy efficiency demonstration activities and its main objective was the integration of the component (obtained in WP4) in a demonstrator building to validate its thermal, mechanical and structural performance under real conditions.

The **WP6-Dissemination and exploitation** aimed at finely studying the global impact of the developed superinsulating silica-based aerogel-like materials for improving energy efficiency in buildings and to set up the academic/industrial dissemination and exploitation strategies of the outputs of the project.

Finally, the **WP7-Project Management** had as a main objective to ensure a sound coordination and management of the project covering administrative, legal and financial issues, and the relation with the EC.

1.4 DESCRIPTION OF THE MAIN S&T RESULTS/FOREGROUNDS

The main scientific and technical results of AEROCOINs project are described in this section. They can be divided in the following categories:

1. Developments on the sol-gel chemistry in order to prepare reinforced silica-based aerogel materials.
2. Characterization of Aerogel materials.
3. Development of the up-scaling process for the fabrication of aerogel material.
4. Life cycle analysis of aerogel materials.
5. Aerogel-based building component design and evaluation.

1. DEVELOPMENTS ON THE SOL-GEL CHEMISTRY IN ORDER TO PREPARE REINFORCED SILICA-BASED AEROGEL MATERIALS

Different chemical strategies have been pursued for the reinforcement of silica aerogels, based on crosslinking and nanodispersion approaches. Herein, the main achievements are described.

New strong polysaccharide and polysaccharide-silica aerogels have been developed within AEROCOINs. Two polysaccharides were used for this purpose: cellulose and pectin. Silica sol was polyethoxydisiloxane (PEDS), a product from PCAS.

Cellulose-based aerogels

a) New experimental set-up for accelerating the impregnation of silica sol into cellulose matrix, and strong cellulose-silica aerogels have been developed by ARMINES

Strong, light (bulk density around 0.2 g/cm^3) and monolithic crack-free cellulose-silica composite aerogels have been prepared by impregnation of wet coagulated cellulose with PEDS-based solution. The impregnation was performed either by molecular diffusion or by a forced flow process (due to a pressure gradient). The latter allowed an enormous decrease in the impregnation times, by almost three orders of magnitude. In both cases, nanostructured silica gel was in situ formed inside cellulose matrix porosity.

Nitrogen (N_2) adsorption analysis revealed an almost threefold increase in specific surface area, from cellulose aerogel alone to their organic-inorganic composite counterparts. Thermal conductivity of composite aerogels was lower than that of cellulose aerogel due to the formation of mesoporous silica inside cellulose pores. Composite aerogels were strongly reinforced as compared with the reference aerogels still keeping high ductility characteristic of Aerocellulose (i.e. pure cellulose aerogels): Young modulus increased by 3-4 times and fracture strain remained very high, about 60%.

b) Thermal super-insulating hydrophobic and monolithic cellulose-silica aerogels

Hydrophobic cellulose-based aerogels and their organic-inorganic counterparts were synthesized and characterized by ARMINES. Cellulose was chemically modified with triphenylmethyl chloride in homogeneous conditions; composite aerogels were prepared by impregnation of coagulated tritylcellulose by PEDS which was then in situ gelled in the porous cellulosic matrix (Figure 1). Silica phase was subsequently hydrophobised with HMDZ (hexamethydisilazane) and composite samples were dried with supercritical CO₂.

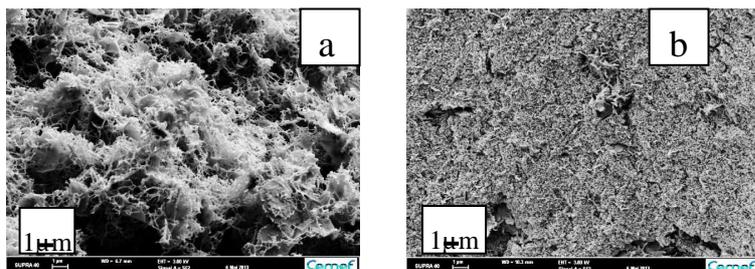


Figure 1. Morphology of tritylcellulose aerogel and associated organic-inorganic composite

The impregnation approach and hydrophobization of both phases resulted in new organic-inorganic monolithic thermal super-insulating aerogels with the thermal conductivity significantly below that of air at ambient conditions, 0.021-0.022 Wm⁻¹K⁻¹, and good resistance (in weight and volume) towards humidity in the conditions studied (at 30°C and 80%RH for 24 hours). The obtained organic-inorganic aerogels are finely nanostructured, with very high specific surface area (between 600 and 800 m²/g depending on synthesis parameters), and highly hydrophobic, with water contact angles 133-135°. Tritylcellulose aerogels are highly compressible, with zero Poisson's ratio. The mechanical properties of composite organic-inorganic aerogels are strongly improved as compared with pure silica aerogels.

c) Nanofibrillated cellulose dispersion route

Compounding of PEDS gels with unmodified, maleic anhydride esterified and TEMPO oxidized NFC works in principle, yielding monoliths via supercritical drying; mechanical reinforcement in compression is nonexistent but in tension there is a 50% improvement.



Figure 2. Cellulose-silica aerogels prepared from nanofibrillated cellulose (EMPA)

d) Cellulose foams route

Since a poor dispersion of the cellulosic fibers in silica sol was observed, an alternative route was developed by EMPA for compounding of PEDS gels with unmodified and silylated modified NFC foams. The approach

uses freeze drying of nanofibrillated cellulose in presence of MTMS. The E-modulus of the composites increased, but fracture toughness remained the same or was slightly lowered. Thermal conductivity values were around 0.016 W/(m K) at room condition for the composites reinforced with the MTMS modified foams, while values significantly higher (0.018-0.020 W/(m K)) were obtained for silica reinforced with the unmodified foams.



Figure 3. Cellulose-silica aerogels reinforced with silylated NFC foams (EMPA)

Pectin-based aerogels

Pectin based aerogels can be obtained applying crosslinking and nanodispersion approaches:

e-1) 100% pectin strong and monolithic thermal super-insulating aerogels via cross-linking

Pectin-based aerogels were synthesised via cross-linking of pectin with Ca^{2+} by ARMINES. Finely nanostructured Aeropectins with extremely low densities ($0.02 - 0.06 \text{ g/cm}^3$) were thus obtained, showing high specific surface areas ($200\text{-}300 \text{ m}^2\cdot\text{g}^{-1}$). Such Aeropectins are able to sustain up to 80-90% strain without breaking. The associated thermal conductivity is remarkably low, 0.015-0.023 W/(m.K) at room conditions (Figure 2). This fully biobased aerogel is thus completely falling in the range of true thermal super-insulating materials.

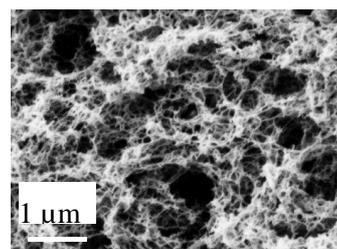
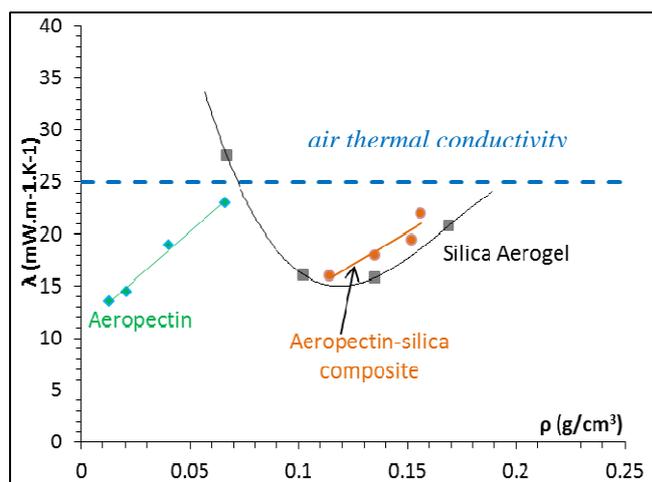


Figure 4. Aeropectin morphology (right) and thermal conductivity of Aeropectins and organic-inorganic composite as a function of bulk density (left). Data for silica aerogels (Bisson et al, J Non-Crystalline Solids, 350, 379–384 (2004)) are added for comparison.

e-2) Pectin route via nanodispersion

In the nanodispersion approach pectin biopolymer has also been employed. Using one-pot mixing of dissolved pectin with sodium silicate, monolithic pectin-silica aerogels with super-insulating properties could

be obtained via SCD; the thermal conductivity values of the resulting composites range from 0.016-0.022 W/(m K).

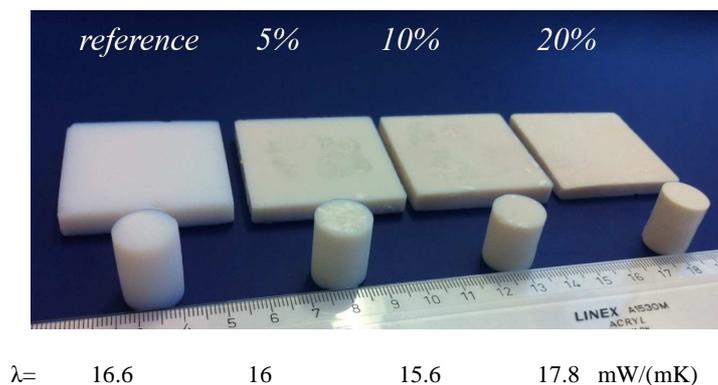


Figure 5. ‘One-pot’ pectin-silica aerogels designed by EMPA & ARMINES

f) Super-insulating pectin-silica aerogels.

Pectin-silica composite aerogels were prepared via impregnation of pectin matrix, using the same approach as developed for cellulose-silica composite aerogels. Hereby the silica phase was hydrophobized. Higher density as compared to the neat Aeropectin (0.10 – 0.15 g/cm³), and huge specific surface area (800-850 m².g⁻¹) were obtained. Pectin-silica aerogels were also super-insulating with the conductivity 0.015-0.023 W/(m.K) (Figure 5). The contact angle with water was around 135° and humidity uptake was strongly decreased as compared to neat Aeropectin at the same conditions.

2. CHARACTERIZATION of AEROGEL MATERIALS

Several characterization tools have been employed for the characterization of the developed aerogel materials and also for optimizing the synthesis strategies in reducing the thermal conductivity of silica aerogel based composites on one hand and improving their mechanical properties for handling and application on the other hand.

For the thermal characterization of this type of highly insulating materials, an optimized hot-wire method has been developed by ZAE within AEROCOINs, which permits the characterization of very small samples (down to diameters of about 27 mm). This method has been validated by comparing it to results derived with the same set-up on larger samples and comparing it to hot-plate results.

Structural and mechanical characterization was performed to provide first trends in terms of the two contributions, solid and gas phase thermal transport to the overall thermal conductivity (see Figure 6). After a cross validation of the methods with lab scale samples provided by the AEROCOINs partners, aerogel samples were analyzed with respect to their thermal properties at ambient conditions as well to their Young’s moduli.

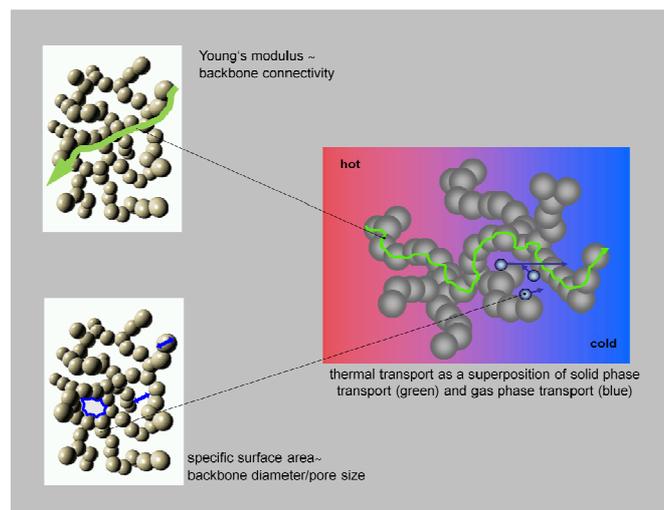


Figure 6: The measurement of the Young's modulus and the specific BET-surface area (pore size) provide quantities that allow for an identification of trends in terms of contributions to the total thermal conductivity to be expected. The later can also be measured at ambient conditions representing a superposition of the solid phase and the gas phase contribution. The two effects can be separated by measuring the gas pressure dependence of the thermal conductivity $\lambda(p)$, with $\lambda(p \rightarrow 0) = \lambda_{\text{solid}}$.

The evaluation of the thermal conductivity of some aerogels reinforced with **vinyl polymers** (prepared by TEC) reveals that the thermal conductivities as determined at ambient conditions decrease with density down to about a density of about 150 kg/m^3 and then saturate at 0.013 to 0.014 W/m K. In other cases, i.e. some aerocellulose-based aerogels, high thermal conductivities are obtained due to a combination of a high heat transport along the solid phase and a large fraction of macropores also present in the composites.

In general, for the **nanofibrillated cellulose** based aerogels the incorporation of individual NFC fibres into the aerogels yielded materials with poorer or equivalent mechanical properties; the elastic modulus was observed to decrease slightly, while no change was observed in the compressive strengths. However, the tensile properties were observed to increase by about 50 % with the addition of lower concentrations of NFC. The presence of the fibres does not affect the thermal conductivities of the aerogels or increased them slightly.

In the case of **Cellulose foams route** combined with supercritical drying, the presence of unmodified NFC foams within the silica aerogel caused a deterioration of the mechanical properties, as exemplified by the gradual decrease in elastic modulus (E), compressive strength and fracture strain with increasing NFC mass fraction. A significant improvement of mechanical properties is observed when the silica is interpenetrated with silylated NFC foams. In comparison with the reference silica aerogel, these composites display a maximum increase in E of 55 %. All composites displayed thermal conductivities of 0,020 W/m·K or less which makes them superinsulating materials.

For the supercritical dried **pectin based aerogels**, in general, the elastic modulus (E), compressive strength and fracture strain strongly depend on pectin loading and pH fabrication value. The most significant improvement of the optimized composite displayed an increase in E, final compressive strength and fracture

strain of 9.4 MPa/ 27.5 MPa/ >80%. All composites displayed thermal conductivity values below $0.017\text{Wm}^{-1}\text{K}^{-1}$, which shows that they are true superinsulating materials.

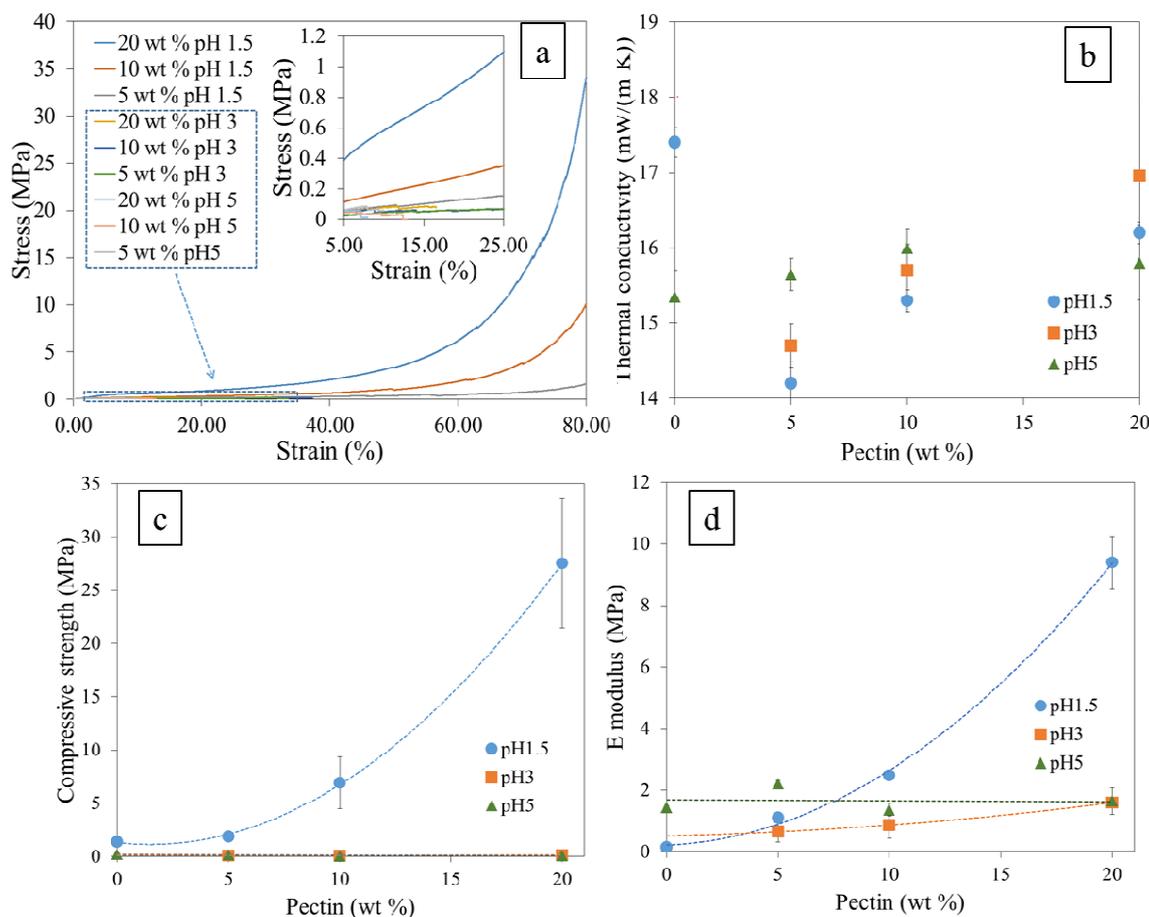


Figure 7. (a) Strain-stress curve (b) Thermal conductivity (c) Compressive strength and (d) E modulus of the supercritical dried NFC foam reinforced PEDS-P_{750E20} aerogels synthesized at different pH values.

3. DEVELOPMENT OF THE UP-SCALING PROCESS FOR THE FABRICATION OF AEROGEL MATERIAL

An ambient pressure drying process (EMPA) has been developed and applied in the manufacturing of aerogel boards in AEROCOINs. The reactors were constructed from corrosion resistant (HCl) grade stainless steel and are designed for 22 samples of $50 \times 50 \times 2 \text{ cm}^3$ per batch. The main steps for the fabrication of the boards are as follows:

Stage 1: Sol-gel process: In a first step, lab-scale recipes were adjusted to the large scale reactors and the gelation and aging processes optimized. In a typical batch, 190 liters of the sol with 30% of the PEDS-P_{750E20} precursor content (55.1L) was stirred with ammonia and then transferred into the gelation reactor.

Stage 2: Gelation and aging process of the aerogel composites: After keeping sols at 55°C for 2 hours, the gelation and aging proceeded simultaneously and the hydrogel blocks were lifted for checking the strength and removing the extra gels between plates.

Stage 3: Hydrophobization process of the aerogel composites. After aging, the hydrophobization of the gels is initiated by using HMDSO (the HMDSO can be recycled for next batches use) with catalytic amount HCl/Ethanol solution for 15 hours.

Stage 4: Ambient drying of the aerogel composites: After hydrophobization, the gels are dried employing the drying profile: 3 hours at 150°C.

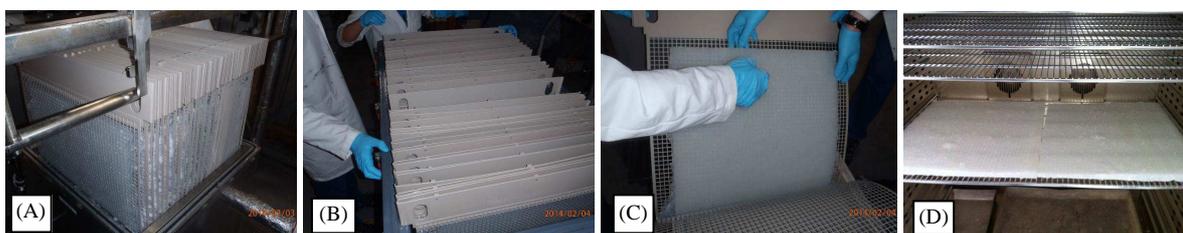


Figure 8. Fabrication of ambient pressure drying of the prototype board of aerogel: (A) the hydrogels moved out of the aging container (B) wet gels moved to modification reactor (C) silylated gels take out from modification (D) aerogels after drying.

4. LIFE CYCLE ANALYSIS (LCA) OF AEROGEL MATERIALS

An LCA assessment for the production of silica aerogel insulation has been developed and compared with conventional insulation materials made from oil or mineral bases.

Life cycle analysis has been performed for two silica aerogel production routes: for ambient drying and for supercritical drying processes, respectively. (Even if the scope of AEROCOINs was the development of ambient drying process, supercritical drying has also been employed).

The LCA assessment is made according to the basic principles of LCA methodology (ISO 14040/14044). The main goal was to use the data from European Life Cycle database (ELCD) but due to the limitation of this database, the LCA has taken also existing literature data.

The assessment covers also some variation in raw-material routes and electricity production method. Normally the life cycle of a product assessment covers all the phases of the product life but as this is a novel product and thus its environmental impact size is not known, only production phase (A1 – A3) and global warming potential (GWP) is taken into consideration. Thus the assessment covers life cycle stages from “cradle to factory gate” including information from raw material supply, transportations, manufacturing of products and all upstream processes.

Total GWP for aerogel life cycle stages A1 - A3: GWP impacts for the aerogel life cycle stages A1 – A3 (raw material acquisition, transportation and production) calculated per 0.11 m³ aerogel board for ambient drying- and 0.06 m³ for the supercritical product. The result is shown in Table 1, 2 and in **¡Error! No se encuentra el origen de la referencia..**

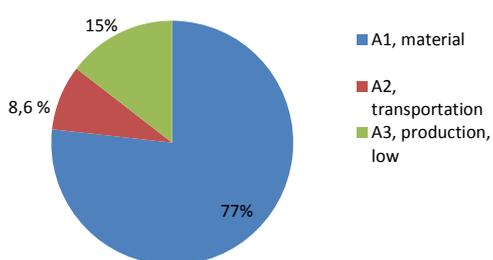
Table 1. GWP results for the aerogel production (0.11 m³). Electricity, which used in production process, has low GWP (140 g/kWh). Production life cycles are: raw-materials (A1), raw material transportation (A2) and aerogel production (A3). A1 considers that virgin HDMSO is used by 7 % and virgin ethanol is used by 2%.

	A1 kg CO ₂ e	A2 kg CO ₂ e	A3, low kg CO ₂ e	Total, A1-A3, low kg CO ₂ e	Relative impact, %
Sol gel preparation	50	9.5	0.74	60	52 %
Gelation and aging	5	0.0063	0.71	5.2	5 %
Hydrophobization	33	0.33	2.0	35	31 %
Ambient drying			13	13	12 %
Total, kg/0.11 m³ aerogel	88	9.9	17	114	100 %
Total, kg/kg aerogel	7.3	0.82	1.4	9.5	100 %

Table 2. GWP results for the supercritical aerogel production (batch size 0.06 m³). Electricity, which used in production process, has low GWP (140 g/kWh). Life cycles are: raw-materials (A1), raw material transportation (A2) and aerogel production (A3). A1 considers that ethanol and isopropanol is recycled and only 1% of virgin substance is used.

	A1 kg CO ₂ e	A2 kg CO ₂ e	A3, low kg CO ₂ e	Total, A1-A3, low kg CO ₂ e	Relative impact, %
Sol gel preparation	22	4.2		26.2	31%
Gelation and aging	3.1	0.93		3.2	5%
Hydrophobization	2.8	0.001 8		2.8	3%
Total for production			50.6	50.6	61%
Total, kg/0.06 m³ supercritical aerogel	28	5.1	51	83.3	100%
Total, kg/kg supercritical aerogel	4.2	0.78	7.7	12.6	100%

**GWP share for Aerogel life cycle
A1 - A3**



**GWP share for supercritical aerogel
life cycle A1 - A3**

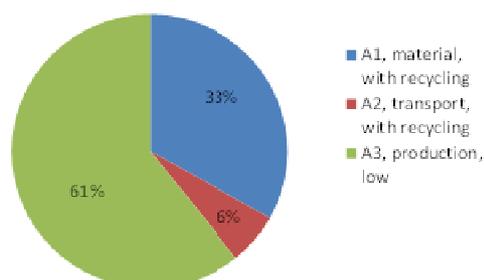


Figure 9. GWP share for Aerogel life cycle A1-A3.respectively for ambient drying and supercritical drying product. Electricity used in production produced with low GWP.

The assessment is also made for the aerogel use. The GWP result is compared on the level of building components with alternative insulation solutions (building components with traditional insulation materials with the same performance and for the case of renovation with 100 mm additional aerogel in Northern or Southern Europe use). Figure 8 shows the example of energy saving, which is presented for one analysed case.

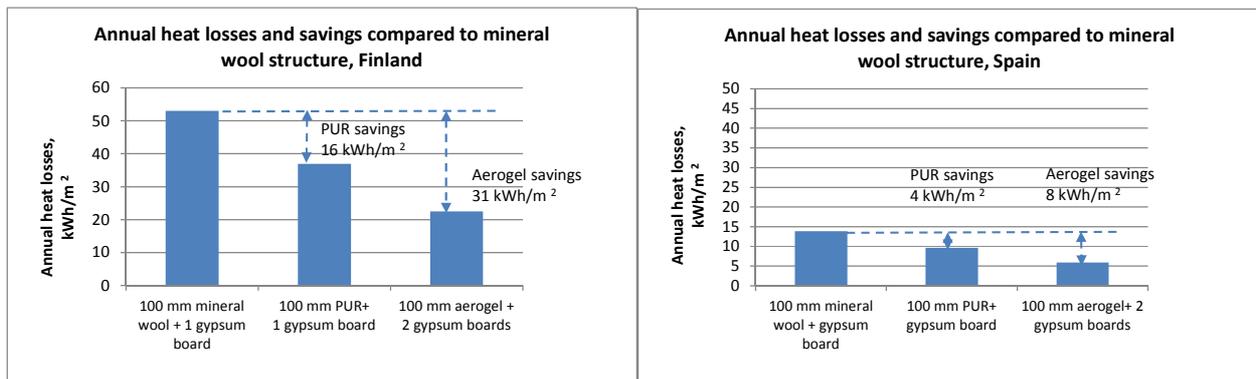


Figure 10. Annual heat losses and savings compared to the 100 mm mineral wool insulation, cases Finland and Spain.

5. AEROGEL BASED BUILDING COMPONENT DESIGN AND EVALUATION

A building integration framework has been generated, as it is directly linked with the format in which the material/building component is available. The defined integration framework targeted at internal insulation systems for building retrofitting, as this application provided the most suitable environment for the competitive advantage of superinsulation: reduced use of space in locations with space constraints.

Several alternatives were discussed, and integration of laminated aerogel boards in plasterboard based solutions was approached. However, when manufacture tests were conducted with up-scaled aerogel processes, this solution was evaluated inadequate for full-scale deployment, and an alternative building component was proposed. This finally developed building component integrates all the elements needed for the building integration of aerogel boards, as it incorporates all the elements previously defined as part of the construction system for building integration. The final version of the prototype consists of: 2 aerogel boards closed between two polymeric profiles and covered on one side by the reflexive cover and on the other side by the plaster board (Figure 11).



Figure 11. Prototype selected for the further studies

In AEROCOINs, a novel approach has been provided to the use of structural reinforcement profiles for internal insulation systems. State of the art dry internal insulation systems rely on metal or wooden profiles/studs to mechanically bear the system and render. Along the project, it was realized that these solutions tend to produce relevant thermal bridge effects (above 30% reduction of insulation capacity) when used in highly insulated façades, and traditional solutions are not applicable when highly insulating materials such as aerogels are used. Therefore, TEC has applied plastic composite based solutions which provide a high performing solution to this problem.

The moisture performance was also evaluated as relevant. This issue was approached through the evaluation under typical construction environments by VTT, where assessments in typical building applications under cold and warm climate conditions were performed. The moisture performance principles, required protection means against moisture loads and the moisture risks in the aerogel applications were studied. Only the performance of AEROCOINs aerogel materials were studied, other materials were assumed to have safe moisture performance in the presented assembly.

Example of simulation performance is presented in Figure 12. In this simulation performance in Malaga (south Spain) was examined in undamaged composite. Also effects of different structure and small damages were investigated both in Finland and Spanish climatic conditions.

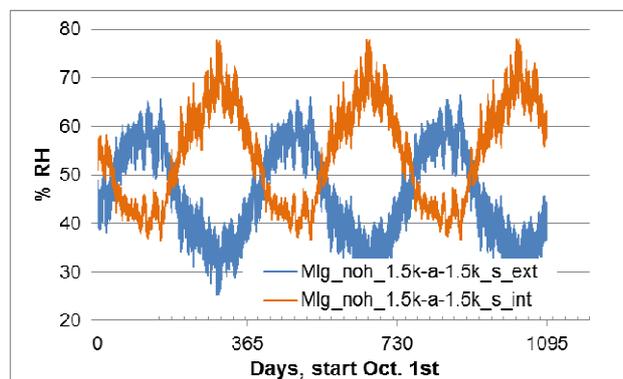


Figure 12. Simulation of relative humidity values for the exterior (ext) and interior (int) surfaces of aerogel thermal insulation under Malaga climate (south Spain).

To verify used parameters in simulations also experimental investigation was performed. In these test the aerogel component was subjected to different moisture loadings and moisture behaviour was followed. Example of these tests is presented in Figure 13. In the test, component is subjected to 95%RH moisture. In the test, a moisture barrier prevents moisture accumulation. Even small nail or drill hole did not cause dramatic weakening in moisture behaviour.

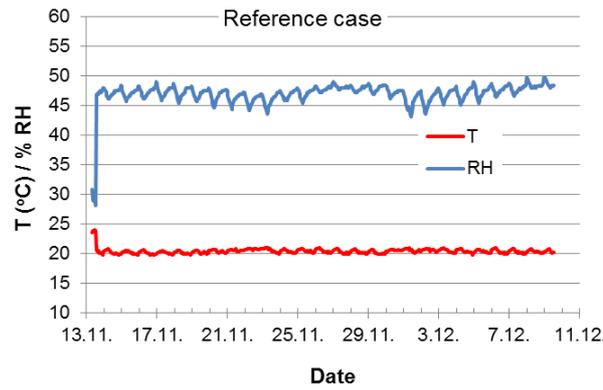


Figure 13. Panel interior humidity when subjected to high relative humidity in moisture barrier side.

According to simulations and measurements the moisture damage risks were higher in cold northern climate than in warm climate conditions. This is due to the higher temperature and partial vapour pressure gradients in structures and the also the lower drying capacity of the structures under cold conditions. These differences set also different requirements for the protection of aerogel insulation layer under different climate loads, something to be considered for further designs of aerogel-based materials.

On the other hand, concerning the fire retardant properties of this type of materials, indicative Single Burning Item (SBI) test and inflammability test were performed by TEC. Organic modified silica-based aerogels developed in AEROCOINs ignited very quickly as soon as the burner was on. Hence, the peak of the heat release was very high. Once the organic part burns, the inorganic part starts to fall down. This phenomenon should be considered the final of the test (according to EN13823 standard and an E classification would be declared). The sample did not ignite neither propagate after the application of the flame. However, the building component based on the aerogel materials has obtained the best fire classification for organic materials: B-s1,d0.

AEROCOINs has evaluated the performance of aerogel materials in two demo buildings, KUBIK in Bilbao by TEC and DemoPark in Madrid by ACC, respectively. Test set-ups were constructed and monitorization campaigns performed over roughly 6 months where the overall thermal and mechanical performance of building components was evaluated. Results from demonstration reached the performance obtained at laboratory scale, and that in all cases superinsulated assemblies were obtained.



Figure 14. Left: External view of the test set-up for Aerocoins at the Kubik test facility in Bilbao (Spain). Right: DemoPark in Madrid, Spain.

1.5 POTENTIAL IMPACT, MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION OF RESULTS

The **DISSEMINATION EFFORTS** undertaken within the AEROCOINs project were aimed at communicating and disseminating the relevance and importance of super-insulating materials aerogels, mainly for the building application. Over last years, the European Commission has boosted innovative measures to improve Europe's energy efficiency and to contribute to the objectives 40-27-27 by 2030². Specific Directives³, energy labels and standards for products save money which can partially result in new job creation. Under this context, AEROCOINs has aimed at communicating the developments of high insulation performance aerogel based materials developed within the project.

Dissemination activities were deployed at two levels: consortium/project level as well as by individual project partners using their own dissemination channels and networking relationships. Below the main dissemination channels and respective activities developed within AEROCOINs are presented.

Project website and mailings

AEROCOINs project web site (www.aerocoins.eu) was created as a primary source of information about the project activities and its key outputs. Some visual materials that have been presented there include public deliverables, information on relevant events, list of dissemination activities, and list of publications.

Mailings as a dissemination channel were also used. Since the creation of AEROCOINs website it has received a total of 8.023 visitors, with a 72.2% of new visitors and a 27.8% of returning visitors.

Restricted access zone of the web site

To ensure proper dissemination of project outcomes amongst project partners, a restricted access zone was created within AEROCOINs web site. All key documents, restricted deliverables, working presentations, minutes of the meetings have been uploaded for internal consortium use.

Workshops and Conferences

Two AEROCOINs workshops and a final conference have been organized.

i) 1st AEROCOINs workshop “Superinsulation Aerogel Materials for Energy Efficiency” was organized by ARMINES and TECNALIA on the 19th of June 2012 in Sophia Antipolis (France).

The goal of the workshop was to engage external academic and industrial experts together with Aerocoins partners in scientific and technical discussions and exchanges concerning the opportunities arising from the current demand in Europe for Energy Efficient Materials particularly focused on superinsulating aerogel materials for strategic sectors (building, space, ...).

² Change our Energy System - Decarbonisation Energy Supply System - A policy framework for climate and energy in the period from 2020 to 2030 – COM(2014) 15 http://ec.europa.eu/clima/policies/2030/documentation_en.htm

³ Directive 2012/27/EU of the European parliament and of the Council of 25 October 2012 on energy efficiency

More than 30 persons from Finland, France, Germany, Poland, Portugal, Spain and Switzerland participated to the work-shop. There were about 10 representatives from companies, and also from agencies related to building industry. About 20 participants were from public research laboratories and universities.

The work-shop showed a lot of interest from all players, both at industry and academy levels, involved in the development of efficient insulation materials for building envelopes applications. The presentations were followed by questions and discussions; the exchanges on hot topics continued during lunch and poster presentations.

ii) 2nd AEROCOINs Workshop “**High Performance Thermal Insulation (HPI) 2013 - Towards Near Zero Energy Buildings**” organized by ZAE and TECNALIA at the Energy Efficiency Center (EEC), ZAE Bayern (Würzburg, Germany) on the 27/28th of November 2013.

The focus of the workshop was specifically more on competitive insulation systems and integration rather than materials synthesis.

In particular, the workshop aimed at bringing together the people in the field of thermal insulation, building physics and architecture to:

- Present recent developments in terms of insulation materials and components suited for building applications;
- Address problems to be solved upon integration and combination of new components towards zero energy buildings;
- Give an overview over current demo-activities;
- Discuss degradation and recycling issues related to next generation buildings.

90 participants from all over Europe attended the workshop. The attendees were from industries (30 companies), universities and research institutes (20). In particular, all AEROCOINs partners as well as partners from the Nano-E2B Cluster attended the workshop. The attendees came from 16 different European countries (e.g. D, F, NL, DK, GR, N, E, B, SVN, FL, SE, CH) as well as Hong-Kong.

The workshop attracted a lot of interest in particular from industries and partners in Nano E2B projects. The vivid podium discussions at the end of each day as well as during coffee breaks and the dinner reflected the current importance of the workshop’s topics.

During the workshop the following key points for high performance thermal insulations (HPI) were addressed; hereby high performance insulation was defined by thermal conductivities $< 0.02 \text{ W/(mK)}$:

- 1) performance & handling
 - a) thermal conductivity
 - b) costs (added values, e.g. comfort for example with respect to moisture)

- c) handling (easy to handle on construction site)
 - d) installation (time needed for installation, components required for installation that reduce the overall performance of the thermal insulation material, specific training of architects and craftsmen)
- 2) characterization of HPI components (homogeneity, on-site measurements)
 - 3) building regulations, standards (extensions required?)
 - 4) long term stability of thermal and mechanical properties of nanomaterials based HPI such as VIP cores, fumed or precipitated silica boards, aerogels (high surface energies, stability of hydrophobization)
 - 5) recycling
 - 6) health risks, public acceptance

In the current phase, costs and handling issues are key characteristics that represent thresholds that must be overcome to allow introduction of HPI into the market. In the second phase, installation related topics, standards and long term stability as well as public acceptance have to be addressed.

iii) The **Final Conference** was held in the frame of the VII International Congress on Architectural Envelopes organized by TECNALIA on the 27-29th May 2015 ([www. http://icae.hei-tecnalia.com](http://icae.hei-tecnalia.com)). The conference was organized together with AMANAC Cluster (www.amanac.eu) in which AEROCOINs is taking part very actively.

On the 27th an AMANAC entitled session was organized in which AEROCOINs project presented some of its developments. On the 28th a Fire Workshop took place. The full agenda for the conference can be found on the following webpage: <http://www.icae2015.com>.

The main objective of AMANAC session was to disseminate, promote, raise awareness on the latest results and the technologies developed within the cluster projects with the main focus put on the envelope application. Several participant projects gave talks around the following topics:

- High performance insulation systems based on aerogel-based materials.
- Nano-based HVAC systems
- Buildings with low embodied energy materials
- Lightweight materials and components for construction
- New materials/composites/paints for a Healthier indoor environment
- New materials for Smart windows

AEROCOINs project presented the next three presentations:

<p>Mechanically robust pectin-silica nanocomposite aerogels: potential materials for thermal superinsulation</p> <p>S.Zhao¹, A. Demilecamps², A.Rigacci³, L.Huber¹, T. Budtova^{2,*}, M.M. Koebel^{1,*}</p> <p>¹Lab. for Building Energy Materials and Components, EMPA, CH; ²MINES ParisTech, Centre de Mise en Forme des Matériaux, France ³MINES ParisTech, Centre procédés, énergies renouvelables et systems énergétiques, France</p>
<p>Full scale performance evaluation of Aerogel products and systems for building insulation</p> <p>Ignacio del Val¹ Roberto Garay², Ewa A. Zukowska¹, Eunat Goiti²</p> <p>¹ Acciona Infraestructuras, Spain. ² Tecnalía Research & Innovation, Spain</p>
<p>Bio-aerogels: new promising materials for thermal superinsulation</p> <p>Cyrielle Rudaz¹, Arnaud Demilecamps¹, Georg Pour¹, Margot Alves¹, Arnaud Rigacci², Christian Beauger², Claudia Hildenbrand², Gudrun Reichenauer³, Tatiana Budtova¹</p> <p>¹Centre for Materials Forming (CEMEF), MINES ParisTech, France; ²Centre procédés, énergies renouvelables et systèmes énergétiques (PERSEE), MINES ParisTech, France; Bavarian Center for Applied Energy Research, Germany</p>

The main objective of Fire Workshop was to make an overview on the fire aspects related to the buildings components and systems, and for doing so, the following topics were addressed:

- New trends in fire-retardant materials
- Reaction to Fire and Resistance to Fire Testing and related European Regulations: Challenges for advanced Materials
- Façade and Structural fire Testing: State of the Art and future needs
- Computational tools for Fire Research: Potentials and link to Performance based Codes.

The vivid podium discussions at the end of each day as well as during coffee breaks reflected the current importance of the conference topics.

This type of events represents a good opportunity to disseminate and also increase the impact of the projects such as AEROCOINs as the promising applications, uses and advantages of materials such as aerogels in the building envelope were presented in front of a wide audience composed of companies related to architectural envelopes and their components; Architectural and Engineering studies; Facade manufacturers; Developers and builders.

Participation at conferences, seminars, workshops outside the project framework

AEROCOINs consortium members took part in up to 70 events organized in different part of Europe. List of these events are included in Table A2.

Peer-reviewed publications

Six scientific papers have been published so far in indexed journals. A seventh paper has been recently submitted and additional ones are expected to be submitted in the following months. The list of papers is presented in Table A1.

Awards

ARMINES received an award from ADEME (French Agency for Energy and Environment) in innovation for materials for energy for 2014, based on the work performed on BIOAEROGELS within AEROCOINs. (see <http://www.pollutec.com/prix-techniques-innovantes.htm>).

Within AEROCOINs project a number of **EXPLOITABLE RESULTS** have been identified:

ER1 Trityl cellulose aerogels and their silica-based composites
ER2 Pectin-silica one-pot
ER3 Hot-wire characterization method suitable for small samples
ER4 Profile-based facade insulation system for highly insulating materials
ER5 Method of identification of critical stress point in ambient pressure drying
ER6 Knowledge for analysis, simulation procedures and sheltering principles

New reinforcement strategies for silica aerogels (ER1 and ER2)

AEROCOINs have developed new reinforcement strategies for the silica based aerogels. These approaches are aiming at improving the mechanical properties of silica aerogels to obtain aerogels via ambient drying process.

An innovative cellulosic route to elaborate some reinforced silica-based superinsulating materials at lab-scale has been developed by ARM. The processing is based on impregnation of nanostructured hydrophobic cellulose matrix with a silica sol and gelation in the porosity of the superinsulating silica gel. The corresponding product does not present yet the targeted thermal conductivity and is still dried in supercritical conditions but the achieved level of conductivity is really promising (20 mW/m.K) and the basic mechanical properties are significantly increased.

As alternative and innovative ‘one pot’ route of reinforcement, cross-linked silica network with pectin biopolymer has also been explored for the elaboration of strong super-insulating aerogel composite materials by ARM and EMPA. The main innovation is ‘one-pot’ synthesis route, based on inexpensive sodium silicate.

SEP and PCAS industrial partners could be interesting in exploiting these results, however, there is an issue of importance, that is a common baseline in the area of aerogels, the high cost of the precursors/starting materials. This aspect could retrieve/delay the exploitation of these two results mainly for the application of the resultant aerogels, at least in the building sector. Therefore it is an important aspect to consider in future developments.

Hot-wire characterization method suitable for small samples

A modified hot-wire set-up was developed by ZAE that allows analysis of thermal conductivity for small samples down to about 3 cm in diameter at height of about 1 cm. The method was validated within the AEROCOINs project.

Profile-based facade insulation system for highly insulating materials

State of the art dry internal insulation systems rely on metal or wooden profiles/studs to mechanically bear the system and render. These solutions tend to produce relevant thermal bridge effects (above 30% reduction of insulation capacity) when used in highly insulated façades, and traditional solutions are not applicable when highly insulating materials such as aerogels are used. The profile system employed by TEC is independent of the aerogel material developed in AEROCOINs. Its target technical niche covers the integration of any superinsulation material (AEROGEL/VIP), or insulation materials below a threshold of $\lambda \leq 0.020 \text{ W/m}^2\text{K}$.

Method of identification of critical stress point in ambient pressure drying

TUL has developed a method that identifies the critical stress point when wet gels crack during Ambient Pressure Drying (APD). The method is based on the experimental analysis performed in a tunnel that can measure drying kinetics of solvent saturated gels under variable conditions and measure internal pressure in gel as a representative of stress formation inside.

Knowledge for analysis, simulation procedures and sheltering principles

New materials have properties that differ from traditional materials, therefore, the building physics behaviours are also different. Reliable and verified simulation is one result of this research work within AEROCOINs. This can be used in all new superinsulation material concepts and also in different applications with different superinsulation materials. So it is not dependent of the material development in the project. Major risk in this result is if the used parameters in simulation are not practical, but this could be dealt by doing sensitivity analysis.

CONTACTS AEROCOINs

Visit AEROCOINs webpage www.aerocoins.eu

No.	BENEFICIARY NAME	CONTACT
1	FUNDACION TECNALIA RESEARCH & INNOVATION Spain	Dr. Eunate Goiti eunate.goiti@tecnalia.com
2	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS - ARMINES France	Dr. Arnaud Rigacci arnaud.rigacci@mines-paristech.fr
3	EIDGENOESSISCHE MATERIALPRUEFUNGS- UND FORSCHUNGSANSTALT EMPA Switzerland	Dr. Matthias Koebel matthias.koebel@empa.ch
4	TEKNOLOGIAN TUTKIMUSKESKUS VTT Finland	Dr. Markku Leivo Markku.Leivo@vtt.fi
5	POLITECHNIKA LODZKA TUL Poland	Dr. Zdzisław Pakowski zdzislaw.pakowski@p.lodz.pl
6	BAYERISCHES ZENTRUM FUR ANGEWANDTEENERGIEFORSCHUNG ZAE EV Germany	Dr. Gudrun Reichenauer Gudrun.Reichenauer@zae-bayern.de
7	PRODUITS CHIMIQUES AUXILIAIRES ET DE SYNTHESE SA France	Dr. Pierre-Andre Marchal pierre-andre.marchal@pcas.com
8	SEPAREX SA France	Dr. Eric Francais efrancais@separex.fr
9	ACCIONA INFRAESTRUCTURAS S.A. Spain	Ms. Ewa Zukowska ewaalicja.zukowska@acciona.com

2 USE AND DISSEMINATION OF FOREGROUND

SECTION A (PUBLIC): DISSEMINATION

This section describes the dissemination measure, including scientific publications relating to foreground.

PART A1: SCIENTIFIC PUBLICATIONS

In table A1 the peer reviewed publications from AEROCOINs are included.

Table A1. Scientific (peer reviewed) publications

N°	Title	Authors	Title of the periodical or the series	Number	Publisher	Year of publication	Relevant pages
1	Mechanical properties of monolithic silica aerogels made from polyethoxydisiloxanes	J.C.H. Wong H. Kaymak S. Brunner M. M. Koebel	Microporous and Mesoporous Materials	183	Elsevier	2014	23-29
2	Cellulose-silica composite aerogels from “one-pot” synthesis	A. Demilecamps G. Reichenauer A. Rigacci T. Budtova	Cellulose	21	Springer	2014	2625–2636
3	The Mechanism of Moisture Transport in a Gel Cylinder	R.Adamski, Z.Pakowski, A.Kamińska	Drying Technology	32 (11)	Taylor & Francis	2014	1266-1268
4	Cellulose-silica aerogels	A. Demilecamps C. Beauger C. Hildenbrand A. Rigacci T. Budtova	Carbohydrate Polymers	122	Elsevier	2015	293-300
5	Multiscale assembly of superinsulating silica aerogels	S. Zhao Z.Zhang G. Sèbe	Advanced Functional Materials	25	Wiley	2015	2326-2334

	within silylated nanocellulosic scaffolds: improved mechanical properties promoted by nanoscale chemical compatibilization	R. Wu RV.Rivera Virtudazo P. Tingaut MM. Koebel					
6	Xerocellulose: lightweight, porous and hydrophobic cellulose prepared via ambient-drying	G. Pour, C. Beauger, A. Rigacci, T. Budtova	J Materials Science	50(13)	Springer	2015	4526-4535
7	Mechanical and Thermal Properties of Nanobrillated Cellulose Fibre Reinforced Silica Aerogel Composites	J. C. H. Wong H. Kaymak P. Tingaut S. Brunner M. M. Koebel‡	Microporous and Mesoporous Materials	Submitted Feb 2015		Elsevier	
8	Strong, Thermally Superinsulating, Biopolymer-Silica Aerogel Hybrids by Cogelation of Silicic Acid with Pectin	S. Zhao, W. J. Malfait, T. Budtova , A. Rigacci, A. Demilecamps, Y. Zhang, S. Brunner, L. Huber, P. Tingaut M. M. Koebel		It will be submitted in June 2015			

PART A2: DISSEMINATION ACTIVITIES

List of all dissemination activities: conferences, workshops, flyers, presentations, posters, etc.

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
N°	Type of activities ⁴	Main leader	Title	Date	Place	Type of audience ⁵	Size of audience	Countries addressed
1	Workshop Short oral presentation Dr. María Moragues	TEC	<i>1st Workshop on Impact of the EeB PPP</i>	26 November 2010	Brussels (Belgium)	Scientific Community Industry Policy Makers	100	European Union
2	Conference Short oral presentation Mr. Jose Cubillo Capuz	ACC	<i>Sustainable Energy Week. Energy Efficient Buildings PPP: long term roadmap, synergies and potential in addressing societal challenges</i>	13 June 2011	Brussels (Belgium)	Scientific Community Industry Policy Makers	100	European Union
3	Publication	TEC	<i>E2B Project Review 2011</i>	July 2011	-	Scientific Community Industry	-	European Union

⁴ A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

⁵ A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible).

						Policy Makers		
4	Press Release	TEC		September 2011	-	Scientific Community Industry Policy Makers Media	-	International
5	Aerocoins Flyer	TEC		October 2011	-	Scientific Community Industry Policy Makers Media	-	International
6	Publication Announcement	ARM	<i>EPNOE – European Polysaccharide Network of Excellence – Newsletter</i>	October 2011	-	Scientific Community Industry	-	International
7	Web site	TEC	www.aerocoins.eu	November 2011	-	Scientific Community Industry Policy Makers Media	-	International
8	Aerocoins KoM Video	TEC		November 2011	-	Scientific Community Industry Policy Makers Media	-	International

9	Publication Announcement	TEC	<i>The Parliament Magazine, Issue 338</i> <i>THE RESEARCH REVIEW - FOCUS on NANOTECHNOLOGIES</i> http://www.theparliament.com/digimag/issue338	21 November 2011	-	Scientific Community Industry Policy Makers Media	80.000	European Union
10	Flyers Distribution	TUL	<i>Faculty of Civil Engineering and Architecture of TUL</i>	January 2012		Scientific Community	-	Poland
11	Aerocoins short announcement on TUL's Webpage	SEP	<i>TUL WEB-Page</i> http://www.p.lodz.pl/bmpn.podmenu.menu367,tul_in_fp_7_index.htm	January 2012	-	Scientific Community Industry Policy Makers Media	-	International European Union France
12	Meeting Short oral presentation Dr. Arnaud Rigacci	ARM	<i>AerSus Kick-Off Meeting</i>	7-8 February 2012	Coimbra (Portugal)	Scientific Community Industry	~20	European Union
13	Workshop Flyers distribution	ZAE	<i>Membrankonstruktionen zur energetischen Sanierung von Gebäuden</i>	16 February 2012	München, (Germany)	Scientific Community Industry	About 60-100	Germany
14	Meeting Short oral presentation Dr. Tatiana Budtova	ARM	<i>EPNOE – European Polysaccharide Network of Excellence – Meeting</i>	6-7 March 2012	Sophia Antipolis (France)	Scientific Community Industry	~20	European Union

15	Workshop Oral presentation Dr. María Moragues Cánovas	TEC	2 nd Workshop on Impact of the Energy-efficient Buildings PPP	14-15 March 2012	Brussels (Belgium)	Scientific Community Industry Policy Makers	~20	European Union
16	Link of Aerocoins web page on SEPAREX Webpage	SEP	SEPAREX WEB-Page http://www.separex.fr/index.php/news	March 2012	-	Scientific Community Industry Policy Makers Media	-	International European Union France
17	Project Description and Link of Aerocoins web page on ZAE BAYERN Webpage	ZAE	ZAE BAYERN WEB-Page http://www.zae-bayern.de/querschnittsthemennanomaterialien/projekte/aerocoins.html	March 2012	-	Scientific Community Industry Policy Makers Media	-	German Speakers Countries
18	Publication Announcement	TEC	The Parliament Magazine, issue 346 Sustainable Building & Construction http://www.theparliament.com/digimag/issue346	16 April 2012	-	Scientific Community Industry Policy Makers Media	~80.000	European Union
19	International Conference Oral presentation Written publication	TEC	International symposium on "Superinsulating Materials"	26 April 2012	Brussels (Belgium)	Scientific Community Industry	>250	International

	Dr. María Moragues Cánovas							
20	International Conference Flyers distribution Dr. Michel Perrut	SEP	<i>10th International Symposium on Supercritical Fluids</i>	13-16 May 2012	San Francisco (USA)	Scientific Community Industry	>250	International
21	International Conference Flyers distribution Oral presentation Written publication Dr. María Moragues-Cánovas	TEC	<i>NICOM 4 - 4th International Symposium on Nanotechnology in Construction,</i>	20-22 May 2012	Crete (Greece)	Scientific Community	>120	International
22	International Conference Oral presentation Dr. Mathias Koebel	EMPA	<i>NICOM 4 - 4th International Symposium on Nanotechnology in Construction.</i>	20-22 May 2012	Crete (Greece)	Scientific Community	>120	International
23	Project Description and Link of Aerocoins web page on the BUILDING UP PORTAL	TEC	<i>BUILDING UP PORTAL SUPERINSULATION MATERIASL COMMUNITY</i> http://www.buildup.eu/links/community/26315	June 2012	-	Scientific Community Industry Policy Makers Media	>120	International
24	Aerocoins General Poster	TEC		June 2012	-	Scientific Community	-	

						Industry Policy Makers Media		
25	Aerocoins General Presentation	TEC		June 2012	-	Scientific Community Industry Policy Makers Media	-	
26	International Conference Aerocoins Poster Flyer Distribution	TEC	<i>INDUSTRIAL TECHNOLOGIES 2012</i> http://industrialtechnologies2012.eu/	19-21 June 2012	Aarhus (Denmark)	Scientific Community Industry Policy Makers Media	>100	International
27	International Workshops Aerocoins Oral Presentation Aerocoins Poster	ALL	<i>1st Workshop AEROCOINs</i>	19 June 2012	Shopia –Antipolis (France)	Scientific Community Industry	>30	International
28	Publication	TEC	<i>E2B Project Review 2012</i>	July 2012	-	Scientific Community Industry Policy Makers	-	European Union
29	Oral presentation Dr. Tatiana Budtova	ARM	<i>Conference « Centenary of education in chemical engineering »</i>	28-30 November 2012	Iasi, (Romania)	Scientific Community Industry	50	European Union

30	Seminar Poster communication	TEC	<i>Seminar on AEROGELS (ISASF-2012) Properties-Manufacture-Applications</i>	6-7 December 2012	Nancy (France)	SC, I	100	European Union
31	Poster presentation G. Pour	ARM	<i>Seminar on AEROGELS (ISASF-2012) Properties-Manufacture-Applications</i>	6-7 December 2012	Nancy (France)	Scientific Community Industry	100	Internation al
32	Oral presentation A. Rigacci, C. Beauger	ARM	<i>Seminar on AEROGELS (ISASF 2012)</i>	6-7 December 2012	Nancy (France)	Scientific Community Industry	100	Internation al
33	Flyers distribution	ACC	<i>Fair GENERA 2013</i>	28 February 2013	Madrid (Spain)	All sectors related to Construction	>100	Spain
34	Workshop Oral presentation Dr. María Moragues Cánovas	TEC	<i>3rd Workshop on Impact of the Energy- efficient Buildings PPP</i>	12-13 March 2013	Brussels (Belgium)	Scientific Community Industry Policy Makers	30	European Union
35	Oral presentation Dr. Tatiana Budtova	ARM	<i>American Chemical Society conference, Cellulose division</i>	7-11 April 2013	New Orleans (USA)	Scientific Community Industry		Internation al
36	Nano-E2B-Cluster - Video	TEC		May 2013		Scientific Community Industry Policy Makers Media	>100	Internation al

37	Oral presentation A. Demilecamps	ARM	<i>European Polymer Federation conference</i>	16-21 June 2013	Pisa (Italy)	Scientific Community Industry	1200	International
38	Oral presentation Flyers Distribution Dr. Eunate Goiti, Dr. María Moragues Cánovas	TEC ACC	<i>EuronanoForum 2013</i>	18-20 June 2013	Dublin (Ireland)	Scientific Community Industry Policy Makers	>100	European Union
39	Oral presentation A. Rigacci, C. Beauger	ARM	<i>1st France-Japan Symposium on Green- Materials and Advanced Characterization (GMAC2013)</i>	26-27 June 2013	Nancy (France)	Scientific Community Industry		International
40	Oral presentation E. Goiti	TEC	<i>Euronanoforum 2013</i>	18-20 June 2013	Dublin, Ireland	Scientific Community Industry	50	International
41	Publication	TEC	<i>E2B Project Review 2013</i>	September 2013	-	Scientific Community Industry Policy Makers	-	European Union
42	Oral presentation A. Demilecamps	ARM ZAE	<i>3rd EPNOE International Polysaccharide Conference "POLYSACCHARIDES AND POLYSACCHARIDE-DERIVED PRODUCTS FROM BASIC SCIENCE TO APPLICATIONS"</i>	21-24 October 2013	Nice (France)	Scientific Community Industry	450	International
43	Oral presentation T. Budtova	ARM	<i>3rd EPNOE International Polysaccharide Conference "polysaccharides and polysaccharide-derived products from</i>	21-24 October	Nice (France)	Scientific Community Industry	450	International

			<i>basic science to applications”</i>	2013				
44	Publication (Communication)	ACC	Real scale thermal assessment of advanced insulation materials. Collaborative research success story.	Autumn 2013	European Energy Innovation	Scientific Community Industry Medias	+1000	EU
45	Oral Presentation E. Goiti	TEC	<i>Superinsulating Materials: state of the art Webinar</i>	5 November 2013	Web Seminar	Scientific Community Industry	210	International
46	International Workshop preparation	ZAE	<i>High Performance Thermal Insulation (HPI) 2013 - Towards Near Zero Energy Buildings (2nd Workshop AEROCOINs)</i>	27-28 November 2013	Würzburg (Germany)	Scientific Community Industry	>80	International
47	Poster presentation A. Demilecamps	ARM	<i>High Performance Thermal Insulation (HPI) 2013 - Towards Near Zero Energy Buildings (2nd Workshop AEROCOINs)</i>	27-28 November 2013	Würzburg (Germany)	Scientific Community Industry	>80	International
48	Oral Presentation (invited)	TEC	<i>World Sustainable Energy Days</i>	26-28 February 2014	Wels (Austria)	Oral Presentation	>100	International
49	Oral presentation T.Budotva	ARM ZAE	<i>247th American Chemical Society national meeting, cellulose division</i>	16-20 March 2014	Dallas, USA	Oral Presentation		International
50	Oral Presentation	SEP	<i>14th European Meeting on Supercritical Fluids</i>	18-21 May 2014	Marseille (France)	Oral Presentation	>100	International
51	Invited Lecture at CIMTEC	ARMIN	<i>Aerogel materials for energy</i>	10-13 June	Montecatini, Italy	Invited Lecture at	50-100	International

	2014	ES		2014		CIMTEC 2014		al
52	Oral presentation at XII International Conference of nanostructured materials	ARM	<i>New thermal superinsulating materials from pectin based bio-aerogels</i>	13-18 July 2014	Moscow, Russia	Oral presentation at XII International Conference of nanostructured materials		International
53	IDS'2014 International Drying Symposium	TUL	<i>Identification of solvent transport coefficient in silica gel during convective ambient pressure drying - R.Adamski, Z.Pakowski, A.Kamińska</i>	24-27 August 2014	Lyon, France	Scientific Community, Industry	300	International
54	IDS'2014 International Drying Symposium	TUL	<i>Experimental investigation of sorption isotherm and surface of silica hydrogel – R.Adamski, Z.Pakowski, A.Kamińska</i>	24-27 August 2014	Lyon, France	Scientific Community, Industry	300	International
55	<u>Oral presentation</u> at French-Romanian Conference on Polymers	ARMIN ES (with ZAE)	<i>Nanostructured organic-inorganic cellulose-based aerogels for thermal superinsulation</i>	27-29 august 2014	Pitesti, Romania	Academy	100	French and romanian
56	Oral presentation at “NIMS Technical Seminar”	EMPA	<i>From efficiency to renewables and storage - Sol-gel materials for integrated building solutions</i>	28 August, 2014	Tsukuba Ibaraki, JAPAN	Oral Presentation, Academy	>100	International
57	Oral presentation at International Seminar on AEROGELS - 2014 Properties-Manufacture-Applications	ARMIN ES	<i>Pectin and pectin-silica aerogels: new promising thermal super-insulating materials</i>	6-7 october 2014	Hamburg, Germany	Academy and industry	200	All
58	Oral presentation at International Seminar on	EMPA	<i>Aerogels as high-performance insulation materials: preparation techniques and mechanical reinforcement strategies</i>	6-7 October 2014	Hamburg, Germany	Academy and industry	200	All

	AEROGELS - 2014 Properties-Manufacture-Applications							
59	<u>Invited talk</u> at European-Japanese conference on cellulose and functional polysaccharides	ARMIN ES (with ZAE)	<i>Bio-based aerogels: a new generation of thermal super-insulating materials</i>	14-16 october 2014	Berlin, Germany	Academy	100	Europe and Japan
60	Oral presentation	PCAS	<i>NEDO (New Energy and Industrial Technology Development Organization)</i>	22 October 2014	Tokyo	Industrial	100	Japan
61	Oral presentation at International Seminar on Sol-Gel 2014	EMPA	<i>From efficiency to renewables and storage - Sol-gel materials for integrated building solutions</i>	22 October 2014	Würzburg, Germany	Academy and industry	>100	All
62	<u>Oral presentation</u> at French National Conference MATERIAUX 2014	ARM (with ZAE)	<i>Bio-aerogels pour la superisolation thermique</i>	24-28 november 2014	Montpellier, France	Academy and industry	1000+	France
63	<u>Invited Conference</u> at French National Conference MATERIAUX 2014	ARM	<i>Superisolants thermiques à pression atmosphérique</i>	24-28 november 2014	Montpellier, France	Academy and industry	1000+	France
64	<u>Invited lecture</u> at “Polymer Energy, Materials, Nanotechnology”	ARMIN ES (with ZAE)	<i>Bio-based aerogels: a new generation of thermal super-insulating materials</i>	7-10 january 2015	Orlando, USA	Academy and industry	100	International
65	<u>Invited lecture</u> at French workshop « Bio-based materials for high-performing thermal insulators and super-	ARMIN ES	<i>Overview on bio-based thermal super-insulators</i>	18 march 2015	Lyon, France	Academy and industry	50	France

	insulators”							
66	<u>Invited lecture</u> at French workshop « Bio-based materials for high-performing thermal insulators and super-insulators”	ARM	<i>Overview on conventional thermal super-insulators</i>	18 march 2015	Lyon, France	Academy and industry	50	France
67	<u>Invited lecture</u> at “Biopolymer Materials and Engineering”	ARM (with ZAE)	<i>Bio-aerogels</i>	15-17 april 2015	Slovenij Gradec, Slovenia	Academy and Industry	100	International
68	<u>Oral Presentation</u> on VII International Congress on Architectural Envelopes ICAE 2015	ARM, ZAE	<i>Bio-aerogels: new promising materials for thermal superinsulation</i>	27-29 May 2015	Donostia, Spain	Industry, Academy		International
69	<u>Short Oral presentation</u> on ICAE 2015	EMPA ARM	Mechanically robust pectin-silica nanocomposite aerogels: potential materials for thermal superinsulation	27-29 May 2015	Donostia, Spain	Industry, Academy		International
70	<u>Short Oral presentation</u> on ICAE 2015	ACC, TEC	Full scale performance evaluation of aerogel products and systems for building insulation	27-29 May 2015	Donostia, Spain	Industry, Academy		International
71	<u>Oral presentation</u> on ICAE 2015 <i>P. Elguezabal</i>	TEC	Experiences and challenges for the development of architectural systems when increasing insulation levels and incorporating energy harvesting & heat delivery systems	27-29 May 2015	Donostia, Spain	Industry, Academy		International
72	<u>Oral presentation</u> on “6th International Building Physics Conference” Roberto Gary	TEC	Application of superinsulation materials into real world façade retrofitting actuations	14-17 June 2015	Turin, Italy	Academy and Industry		International
73	<u>Oral presentation</u> on “Conference on Advanced Building Skins” Roberto Gary	TEC	Full scale performance assessment of advanced materials in architectural envelopes	3-4 November 2015	Bern, Switzerland			International

SECTION B: USE OF FOREGROUND

This section specifies the exploitable foreground and provide the plans for exploitation. **All these data can be public or confidential; the report must clearly mark non-publishable (confidential)** parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

PART B1: APPLICATION FOR PATENTS

There are not applications for patents, trademarks, registered designs, etc (thus table B1 is empty).

TABLE B1: LIST OF APPLICATION FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC

Type of IP Rights: Patents, Trademarks,	Application reference(s)	Subject or title of application	Applicant (s) (as on the application)

PART B2 (CONFIDENTIAL): EXPLOITATION OF FOREGROUND

In the following table AEROCOINs exploitable results are recorded.

Type of Exploitable Foreground ⁶	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application ⁷	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Technology	Trityl cellulose aerogels and their silica-based composites				F.41.1 Development of building projects			ARM as owner + PCAS & SEP as beneficiaries
Technology	Aerogels based on cross-linked pectin and pectin-silica aerogels				F.41.1 Development of building projects			ARM
Technology	Pectin-silica one-pot	No		Product	F.41.1 Development of building projects	The products are quite promising, but further R&D activity is needed		EMPA & ARM as owner SEPREX, ZAE as beneficiaries
Service	Hot-wire characterization method				M74.9 - Other professional, scientific and technical activities			ZAE

² A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

⁷ A drop down list allows choosing the type sector (NACE nomenclature) :

http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Technology/ Service	Profile-based facade insulation system for highly insulating materials				F.41.1 Development of building projects M71. Architectural and Engineering activities: technical testing and analysis	2 years of time to market due to certification requirements according to the Construction Products Regulations (CPR)		TEC
Technology	Method of identification of critical stress point in ambient pressure drying	No			M74.9 - Other professional, scientific and technical activities			TUL
Technology	Knowledge for analysis, simulation procedures and sheltering principles				M71. Architectural and Engineering activities			VTT

In addition to the table, in the following pages further information about the exploitable foreground is provided, including the purpose, how the foreground might be exploited, IPR exploitable measures, potential/expected impact.

Exploitable Result 1: Trityl cellulose aerogels and their silica-based composites

Description: Development of soft strengthening processes, based on impregnation of hydrophobic wet cellulose network, permitting to synthesize strong super insulating organic-inorganic composite aerogel. The main innovation is in use of hydrophobized biobased matrix for the impregnation with silica-based sol.

- Linking strengthening strategies with biobased (hydrophobized) solutions and fast impregnation processing.
- Significant mechanical reinforcement of silica aerogels by soft chemistry.
- Thermal conductivity can reach 0.020 W/m.K

Market: The new aerogels developed is associated with ensuring that buildings become increasingly energy efficient. This clearly represents a next generation aerogel product including some biobased fraction potentially permitting to improve environmental impact. The market volume should be >10M EUR in the building insulation markets for 2020.

Impact on the construction and related industries is first targeted but other niche “insulation” market where greener products are necessary could also be addressed.

Time to market: 5 to 10 years after the end of the project if thermal conductivity level is improved further and if processing route is simplified.

Prospects/Customers: Mainly, cement/lime based product manufacturers – insulation industry plasterboard

IPR & Exploitation claims:

Table 3. IPR and Exploitation Claims: Trityl cellulose aerogels and their silica-based composites

IPR		Exploitation Claims			
B	F	M	U	L	O
ARM	ARM	PCAS	ARM		
ZAE	SEP	SEP	SEP		
SEP					

Exploitation routes: ARM: Publications and/or further scientific research at lab scale and/or industrial transfer and/or patent. Industrial partners SEP and PCA could be interested in using it.

Risks: New patent from a competitor. There is another risk which is associated with the high cost of the precursors/starting materials. This aspect could retrieve the exploitation of this result mainly for the application of the resultant aerogel in the building sector.

Exploitable Result 2: Pectin-silica one-pot

Description: As alternative and innovative ‘one pot’ route of reinforcement, cross-linked silica network with pectin bio-polymer was used to elaborate strong super-insulating aerogel composite materials. The main innovation is ‘one-pot’ synthesis route, based on inexpensive sodium silicate. The composite displays an improved mechanical property: E modulus shows 5 times higher than the reference, final compressive strength presents marvelous increase ~ 20 times higher than reference, and the composite can be compressed up to 80% strain. Thermal conductivity presents no obvious increase (15.6-22 mW/m.K with varying ratios of pectin) as compared to the typical silica aerogels. Such cross-linked aerogel composite shows less dust release, which may ease the concerning of “nano” safety. The new material is associated with ensuring that buildings become increasingly energy efficient. This clearly represents a next generation aerogel product.

Market: The products are quite promising, but further R&D activity is needed. The market volume should be >10M EUR in the building insulation markets for 2020.

Applications: Acoustic & Thermal insulating materials for building & pipeline insulation but niche markets in drug delivery, shock absorption, filtration, spill cleanup should also be considered.

IPR & Exploitation claims:

Table 4.IPR and Exploitation Claims: Pectin-silica one-pot

IPR		Exploitation Claims			
B	F	M	U	L	O
ARM	ARM	PCAS	ARM	EMPA	
EMPA	EMPA	SEP	EMPA		
ZAE	SEP		SEP		
SEP					

Exploitation Routes: EMPA and ARM: Publications and/or further scientific research at lab scale and/or industrial transfer and/or patent. PCAS and SEP: Patent, Direct industrial use, technology licensing

Risks: Some technical risks are identified: as the gelation period is quite long at low pH, so far, these gels only can be dried under supercritical condition. Potential intervention: Working at slightly higher pH or try to accelerate gelation by adding crosslinking agents As for ER1, there also exists the risk which is associated with the high cost of the precursors/starting materials. This aspect could retrieve the exploitation of this result mainly for the application of the resultant aerogel in the building sector.

Exploitable Result number 3: Hot-wire characterization method suitable for small samples

Description: For thermal characterization of highly insulating materials, ZAE optimized the hot-wire method so that very small samples (down to diameters of about 27 mm) could be analyzed. The method was validated by comparing it to measurement with the same set-up on larger samples and comparing it to hot-plate results.

Market: Market requested by R&D departments of companies and science during materials development irrespective of their field of final application, in particular in a screening phase where only small samples are available. The set-up could be provided via a thermal analysis company transferring the ZAE know-how.

IPR & Exploitation claims:

Table 5. IPR and Exploitation Claims: Hot-wire characterization method suitable for small samples

IPR		Exploitation Claims			
B	F	M	U	L	O
ARM	EMPA	--	--	--	ZAE
EMPA	ZAE				
ZAE					
ACC					

Exploitation Routes: ZAE: Publications; improvement of thermal analysis techniques. Service for thermal analysis.
 EMPA: Publications and/or further scientific research at lab scale.

Exploitable Result number 4: Profile-based façade insulation system for highly insulating materials

Description: State of the art dry internal insulation systems rely on metal or wooden profiles/studs to mechanically bear the system and render. These solutions tend to produce relevant thermal bridge effects (above 30% reduction of insulation capacity) when used in highly insulated façades, and traditional solutions are not applicable when highly insulating materials such as aerogels are used. Plastic composite based solutions provide a high performing solution to this problem.

Applications: Cement/Lime based product manufacturers – plaster, plasterboard, blocks, bricks, roof tiles, finishing composite tiles

Market: There is a clear trend towards energy efficient solutions in the construction sector. Highly insulated façades are one of its main vectors. Insulation materials manufacturers as Isover, Rockwool, Ursa, Basf,...could be end-users.

IPR & Exploitation Claims:

Table 6.IPR and Exploitation Claims: Profile-based façade insulation system for highly insulating materials

IPR		Exploitation Claims			
B	F	M	U	L	O
TEC	TEC		TEC		TEC
VTT	ZAE		VTT		VTT
ZAE	ACC				
ACC					

Exploitation Routes: TEC: Consultancy in the development of architectural systems and to architects in pilot projects/solutions. VTT: Using and modification of the developed results in further research and developed work in the future.

Risks:

Market factors: 1) Market price cost is too high. Contingency plan: Selection of different profile supplier. Reduce the amount of different profile geometries to increase production levels. 2) Delay obtaining a certification. Contingency plan: Direct link to national testing and assessment bodies

Technical factor: Performance failure in one or several of the basic requirements in the Construction Products Regulation. Contingency plan: modification of design.

Exploitable Result number 5: Method of identification of critical stress point in ambient pressure drying

Description: It was found in this project that the critical stress point when wet gels crack during Ambient Pressure Drying (APD) can be found by measuring the internal pressure evolution. This information can be used to reduce the drying rate before the crack develops. In the current state-of-the art it is commonly assumed that this point roughly corresponds to transition from the constant to the falling rate period, which requires sample mass monitoring in situ.

Market: Growing interest in aerogel-like materials production by APD method. Determination of drying conditions of monolithic gels in APD

Time to market: Ca. 3-5 years after project completion.

IPR & Exploitation Claims:

Table 7. IPR and Exploitation Claims: Method of identification of critical stress point in ambient pressure drying

IPR		Exploitation Claims			
B	F	M	U	L	O
TUL	TUL	TUL	TUL PCAS	TUL	TUL

Exploitation routes: Services and test facility provided by TUL and PCAS: further scientific research at lab scale.

Risks: Market factor: Offer of similar service by competing labs. Scope and type of potential intervention: Improvement of the method resulting from ongoing research

Exploitable Result number 6: Knowledge for analysis, simulation procedures and sheltering principles

Description: New materials have properties that differ from traditional materials. So the building physics behaviours are also different. Reliable and verified simulation results are one result of this research work. This can be used in all new superinsulation material concepts. Numerical simulation and analyse is widely accepted method of verifying performance in building physics. New knowledge can be used to help new materials to market.

Market: It could be utilised in addition of traditional building industry also in industrial, energy and arctic applications. Cold temperature applications are for instance cold storages, LNG and Arctic applications. High temperature applications are in energy productions and industrial processes. Material industry, component industry, structure owners, designers.

Time to market: Ca. 1 year after project completion.

IPR & Exploitation Claims:

Table 8.IPR and Exploitation Claims: Knowledge for analysis, simulation procedures and sheltering principles

IPR		Exploitation Claims			
B	F	M	U	L	O
VTT ACC	VTT ACC	--	VTT	--	VTT

Exploitation routes: VTT: Direct use of result in research and development work. It will also be published for reference.

Risk: Technical factor: Major risk in this result is if the used parameters in simulation are not practical. Contingency plan: Doing sensitivity analysis and validating used parameter values from literature and previous analysis