Wood-based Thermal Insulation Materials (WOTIM)

FINAL REPORT

Title of the research project	**Wood-based Thermal Insulation Materials**
Coordinator of the project	Petri Jetsu

BASIC PROJECT DATA

Project period	1.2.2014-31.12.2016
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URL of the project	http://wotim.eu/

FUNDING

Total budget in EUR	1 449 867 EUR
Public funding from WoodWisdom-Net Research Programme:	Total funding granted in EUR by source:
Finland Tekes – the Finnish Funding Agency for Innovation	348 000 EUR
France Ministry of Agriculture, Fisheries and Forestry Resources (MAAF)	291 741 EUR
Sweden Swedish Governmental Agency for Innovation Systems (VINNOVA)	145 840 EUR
Other public funding:	

Other funding:

VTT Technical Research Centre of Finland Ltd, Finland	147 000 EUR
Institut Technologique FCBA, France	149 352 EUR
Holmen AB, Sweden	69 352 EUR
Soprema SAS, France	213 582 EUR
Stora Enso Oyj, Finland	45 000 EUR
Ekovilla Oy, Finland	25 000 EUR
Neovo Solutions Oy, Finland	6 000 EUR
Oy Interenergy Ltd.	9 000 EUR

PROJECT TEAM (main participants)

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PROJECT SUMMARY REPORT

In the WOTIM project, high-performance cellulose-based insulation materials were developed. The target was that the overall performance of the novel cellulosic insulation material is at a comparable level with the materials made of foamed plastic. The insulation properties of a new type of material made from paper-making pulps will be enhanced by creating a tortuous and highly porous fibre matrix. Foam-forming technology adapted from other industries was used for the manufacturing of high performance cellulosic thermal insulation panels. We also aimed to develop cellulose based spray foam material, which is easy to be sprayed in-situ at construction site.

The foam formed materials based on papermaking pulps showed potential for positioning as the best current cellulose-based insulation material and thus could compete with mineral wools and EPS/XPS open cell polymer foam materials. The benefit of using papermaking pulps as a raw material is that the price of the raw material is lower compared for example to glass and polymer fibres. The project results indicated that foam formed highly porous materials made from papermaking fibres suited well for thermal insulation material in wall cavities or ceilings.

Developed solutions related to spray-on foams were very promising and the proof of concept in laboratory scale was demonstrated successfully. However further development is needed before the technology is ready for upscaling.

1.1 Introduction

1.1.1 Background

Fibreglass is the most widely used insulation material worldwide and growing. A steady growth is expected as well in the foamed plastic insulation segment because of their high insulation values. From environmental and sustainability point of view this trend is very worrying, because of fibreglass materials have high embodied energy amount and foamed plastic insulation materials are oil-based. In addition, fiberglass fibres can be harmful when they are inhaled and the used spraying chemicals for foamed polyisocyanurate and polyurethane are hazardous for health before curing has occurred.

Cellulose is the oldest building insulation material. In the history of buildings many types of cellulosic materials have been used, including newspaper, cardboard, cotton, straw, sawdust, hemp and corncob. Recently cellulose insulation has increased again in use. Part of the reason for this growth is because of the increased interest in green building. Cellulose has lower environmental impact and higher recycled content compared to mineral and synthetic polymer based materials.

1.1.2 Objectives

In this project high performance cellulose based insulation materials were developed. The insulation properties were enhanced by creating air pockets to the cellulose fibre material matrix by foam or foam-like structures. Foam forming technology adapted from other industries was used for manufacturing high performance cellulosic thermal insulation panels. We also aimed to develop cellulose based spray foam material, which is as easy to be sprayed in-situ at construction site as polyurethane spray foam. The target was that the performance of the novel cellulosic insulation materials is at comparable level with the materials made of foamed plastic.

Project objectives were

1. Develop a high performance wood-based cellulosic thermal insulation panel material manufactured by foam forming to replace the oil-based insulation materials
2. Develop a new bio-based in-situ spray-on thermal insulation foam based on (nano)cellulose to replace traditional spray-on synthetic insulation foams

1.2 Results and discussion

Thermal insulation panels

Figure 1 shows the measured thermal conductivity of the foam formed materials based on northern bleached softwood kraft cellulose (SW), northern bleached softwood kraft cellulose and 5 - 20 % cellulose microfibrils (SW+CMF), northern bleached hardwood kraft cellulose (HW) and lignocellulosic, mechanically defibrated wood pulp from Scandinavian spruce (TMP) as a function of bulk density. Thermal conductivity decreased when bulk density increased from 25 to 45 kg/m^3 with all materials. Thermal conductivity did not decrease much after the density of 45 kg/m^3 was exceeded. SW pulp around 80 kg/m^3 bulk density level showed again increasing λ-value. This behaviour was not seen with TMP pulp. It was concluded that the various pulps induced fairly small differences to thermal conductivity.

The best foam formed material (TMP at bulk density 45 kg/m^3) had thermal conductivity at similar level with the commercial glass wool products, however at significantly higher bulk density level. However, the foam formed materials had clearly lower λ-values compared to the commercial cellulose wadding product (Univercell Panneaux), the largest gap being over 4 mW/m·K units.

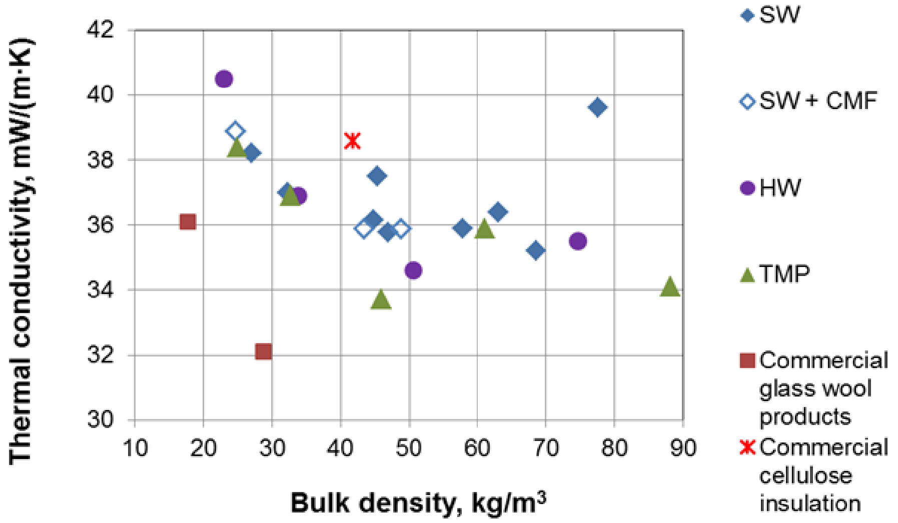

Figure 1. Thermal conductivity of foam formed and commercial thermal insulation materials as a function of bulk density.

Compared to thermal conductivity, the pulp type had clearer effect on the air flow resistivity of the materials (Figure 2). Foam formed material made of TMP pulp resisted the air flow the most. The air flow resistivity of materials based on HW was higher than materials based on SW. Fibre dimensions of HW are smaller than SW, incereasing the tortuosity of the material. However, the addition of CMF to SW pulp did not increase the air flow resistance compared to pure SW.

At similar bulk density the air flow resistance of foam formed materials was 4-11 times higher than that of the commercial cellulose wadding and at the same level as glass wool products. Foam formed materials with the air flow resistivity value above 100 kPas/m^2 are already considered as a wind shielding material according to the Finnish building norms.

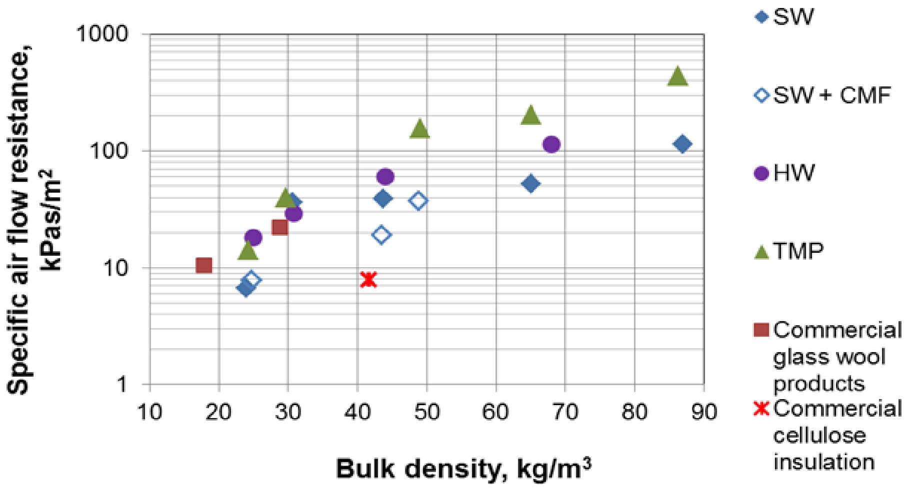

Figure 2. Specific air flow resistance of foam formed and commercial thermal insulation materials as a function of bulk density.

Compression strength perpendicular to faces at 10% of deformation was the highest in materials based on TMP pulp (Figure 3). Addition of CMF to SW pulp increased the compression strength of SW materials to the same level than commercial cellulose wadding, because of the MFC increased the bonding capability of fibres. HW and SW panels without CMF addition had the lowest compression strength from the foam formed materials, but the compression strength was still higher compared to the commercial glass wool products. The compression strength levels of the foam formed panels suit well for thermal insulation material in wall cavities or ceilings, where high loads are not applied.

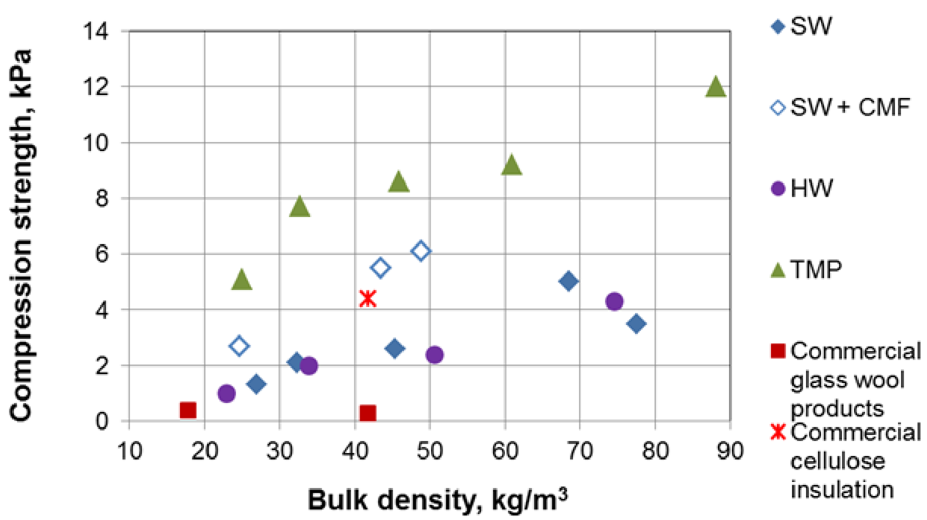

Figure 3. Compression strength (at 10% deformation) of foam formed thermal insulation materials as a function of bulk density.

<u>Spray-on thermal insulation foam</u>

The main research activities were related to the development of foam stabilizers, improving foam adhesion to surfaces, prevention of shrinkage of foams, decreasing the initial water content of foams and screening the suitable foaming and spraying equipments. The main outcome of this part was that the proof of concept in laboratory scale was demonstrated successfully. Example of in-situ sprayed fibre foam in the window slit can be seen in Figure 4. The microscopic structure of the developed dry foam is shown in Figure 5.

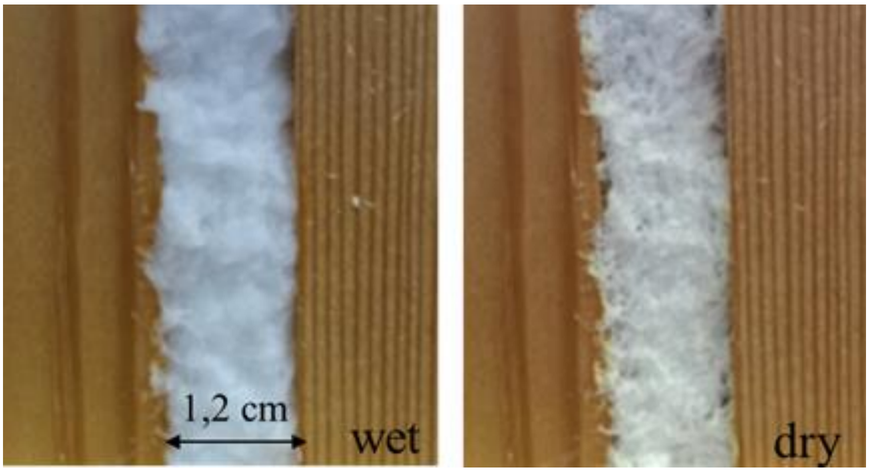

Figure 4. In-situ sparyed fibre foam in the window slit before and after drying. Foam is retaining its volume in drying and has excellent adhesion to frame.

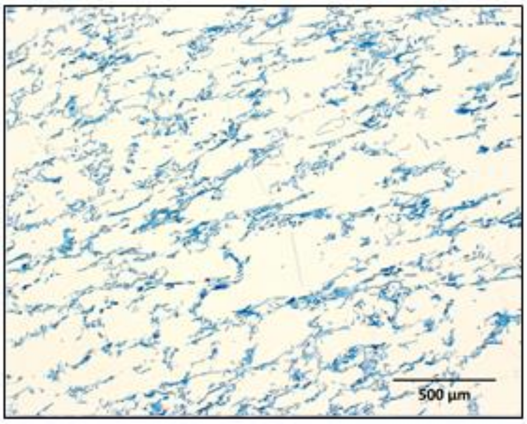

Figure 5. Microscope image of the cross section of the dry foam, produced with the developed proof of concept. In the image, cellulosic material is seen as blue and white space is air.

1.3 Conclusions

The project results indicated that foam formed highly porous materials made from papermaking fibres suited well for thermal insulation purposes. TMP as fibre raw material showed the lowest thermal conductivity values, although the effect of bulk density level on the thermal conductivity was larger than the effect of the used fibre raw material. The air flow resistance and the mechanical properties of the wood fibre based insulation materials can be adjusted by pulp selection.

The foam formed materials based on papermaking pulps showed potential for positioning as the best current cellulose-based insulation material and thus could compete with mineral wools and EPS/XPS open cell polymer foam materials. Additional competitive advantages are the enhanced recycling possibilities of thermal insulation materials, and the reduced dependence on oil, when using wood-based solutions. The benefit of using papermaking pulps as a raw material is that the price of the raw material is lower compared for example to glass and polymer fibres. The cost efficiency of the solution can be further improved by the optimization of fibre processing phase. Quality of virgin pulps is also more uniform compared to currently used recycled pulp or recycled paper shreds.

Developed solutions related to spray-on foams were very promising and the proof of concept in laboratory scale was demonstrated successfully. However further development is needed before the technology is ready for upscaling.

1.4a Capabilities generated by the project

New knowledge related to the processing of wood fibres for thermal insulation applications and the effects of fibre type and additives on the properties of cellulosic based thermal insulation materials was generated. New cellulosic based thermal insulation material demonstrators were made as well as a proof of the concept in laboratory scale. The business potential of new cellulosic based thermal insulation materials was shown.

1.4b Utilisation of results

Outcomes of the project have presented in several public events like conferences and training modules for disseminating the results. Many discussions related to commercialization of the developed materials have been kept with participating companies and/or companies outside the project. The next steps for the exploitation of the results are to find funding for the up-scaling of the production of foam formed thermal insulation materials into pilot-scale and to find funding for the further development of spray-on materials.

1.5 Publications and communication

a) Scientific publications

1. Articles in international scientific journals with peer review

- *Lecourt M, Pöhler T, Hornatowska J, Salmén L, Jetsu P. On the structure of novel wood-fibre based foam formed thermal insulation materials, Holzforschung. will be submitted*
- *Pöhler T, Jetsu P, Fougerón A, Barraud V. Use of papermaking pulps in foam-formed thermal insulation materials, Nordic Pulp and Paper Journal. will be submitted*

2. Articles in international scientific compilation works and international scientific conference proceedings with peer review

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3. Articles in national scientific journals with peer review

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4. Articles in national scientific compilation works and national scientific conference proceedings with peer review

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5. Scientific monographs

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6. Other scientific publications, such as articles in scientific non-refereed journals and publications in university and institute series

a) Conference presentations

- Jetsu P, Pöhler T, Pääkkönen E. Foam formed wood-based thermal insulation materials, 9th Global Insulation Conference & Exhibition, Copenhagen, Denmark, 30 - 31 October 2014.
- Pöhler T, Jetsu P, Salmén L, Hornatowska J, Barraud V, Fougeron A, Lecourt M, Seppänen R, Larsson E. Comparison and development of wood-based thermal insulation materials, 10th Global Insulation Conference & Exhibition, Istanbul, Turkey, 29-30 September 2015.
- Jetsu P, Pöhler T. Wood-based Thermal Insulation Materials - WOTIM, 10th Johan Gullichsen Colloquium, Helsinki, Finland, 19th November 2015.
- Pöhler T, Pääkkönen E, Jetsu P. Wood fibre based thermal insulation and sound absorption materials made by foam forming, IX Iberoamerican Conference on Pulp and Paper Research, Espoo, Finland, September 25-28, 2016.
- Keynote speech in Materiaux2014 conference “Les matériaux isolants: Développement d’un produit expansé à base de cellulose”
- Poster in 14th European Workshop on Lignocellulosics and Pulp conference

b) Other dissemination

- Innventia customer magazine Beyond #1/2014, "WoodWisdom-Net focus on new forestbased products"
- Presentation in WW-Net Seminar, "WOTIM"
- Innventia web page, project examples, "WOTIM"
- Innventia customer magazine Beyond #2/2014, "Announcement of WoTIM project"
- Project web page
- WoTim Newsletter 1
- VTT News, "Replacing plastic and mineral wool insulation with wood fibre"
- Tekniikka&Talous magazine, "Ei paluuta sahanpuruaikaan, mutta... puukuitu voi pian korvata muovin ja lasivillan eristemateriaalina"
- Kauppalehti magazine, "Selluloosasta uusi supereriste"
- Kauppalehti web link "Replacing plastic and mineral wool insulation with wood fibre"
- Bio-fibre magazine "Replacing plastic and mineral wool insulation with wood fibre"
- Rakennuslehti magazine " Puukuitu korvaa tulevaisuudessa osan muovi- ja mineraalivillaeristeistä"
- Paperi ja Puu magazine "Eristemateriaaleja puukuidusta"
- WoTim Newsletter 2
- WoTim Training module 1
- WoTim Newsletter 3
- WoTim Newsletter 4
- WoTim Training module 2
- WoTim Newsletter 5
- WoTim Training module 3 and final workshop
- WoTim samples to material library, Innovatheque, Paris
- WoTim Newsletter 6

1.6 National and international cooperation

The project team consisted of experts from research organizations, large companies and SMEs representing three EU countries; Finland, Sweden and France. General assembly meetings and national steering group meetings (in Finland) was held regularly at six months intervals. In addition, technical project and WP meetings were kept frequently. Three open training modules (one in every representative country) were organized during the project for disseminating the project results. The team spirit was well developed during the project and our team worked in very motivated, inspired and international atmosphere.

During the project several raw material supplier and end user companies contacted us and informed that they were interested in testing their raw materials in foam forming process to generate some functionalities to end product or they were interested in testing the developed insulation material in their applications. After positive feedback from companies, two EU project applications were done, where the up-scaling of the production of foam formed thermal insulation material was included.

The project enhanced the national and international cooperation between the research institutes and companies and the whole value chain related to the commercialization of the new cellulose based thermal insulation material was represented.