Title	Wood-based Thermal Insulation Materials - WOTIM
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Citation	10th Biennial Johan Gullichsen Colloquium 2015, 19 November 2015, Helsinki, Finland (2015)
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Wood-based Thermal Insulation Materials - WOTIM

10th Johan Gullichsen Colloquium

19th November 2015

Petri Jetsu and Tiina Pöhler VTT

Outline

- WOTIM project
- Insulation markets
- Basics of foam forming
- Properties of foam formed cellulose based insulation materials
- Summary

WOTIM-project

Targets:

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

Programme: WoodWisdom-Net

Budget: 1,46 milj. eur

Schedule: 1.2.2014 – 31.12.2016

More info http://wotim.eu/

WOTIM-project – Partners

Partners:

- **VTT** (RTD-Finland): Coordinator, development of thermal insulation panel and spray-on foam
- **Innventia** (RTD-Sweden): Fibre processing, characterization
- **FCBA** (RTD-France): Economic, ecological and health evaluations
- **Holmen** (Large-Sweden): Fibre supplier, fibre processing
- **Soprema** (Large-France): Insulation material manufacturer, performance evaluations

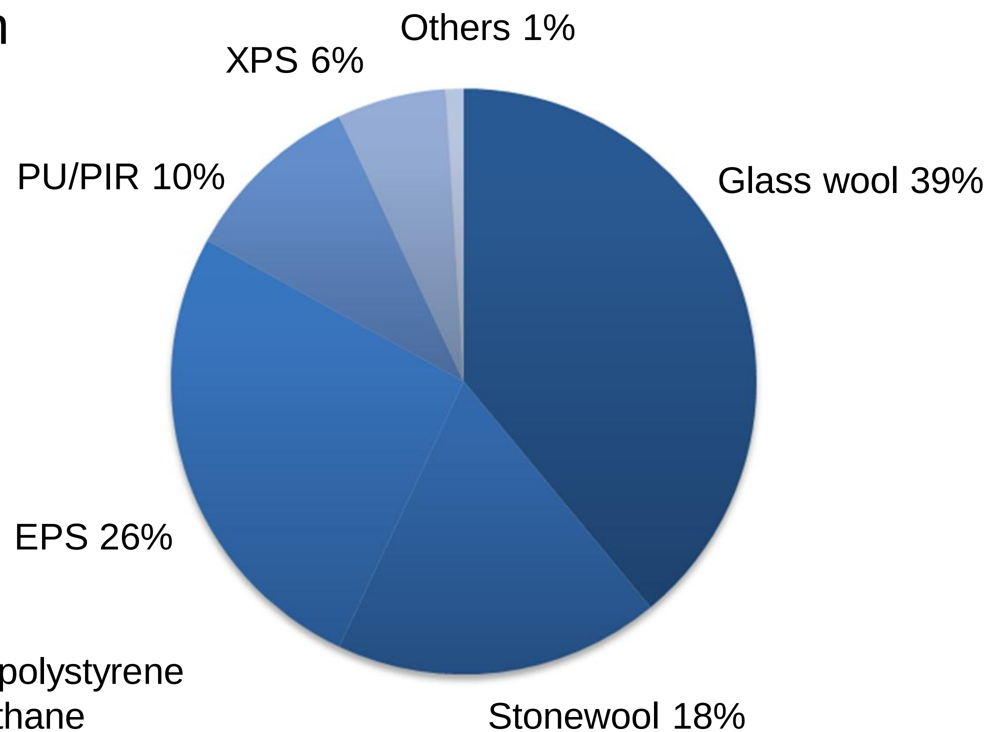
Co-funding companies:

- **Stora Enso** (Large-Finland): Fibre supplier, fibre processing
- **Ekovilla** (SME-Finland): Insulation material manufacturer
- **Neovo Solutions** (SME-Finland): Insulation material manufacturer
- **Interenergy** (SME-Finland): Fire retardant chemicals supplier

European Market for Insulation 2012

- The total market was approximately 5,6 million tonnes
- Estimated value was €9,600 million
- Annual growth rate 2,2%

The EU Directive of energy efficiency is a market driver!



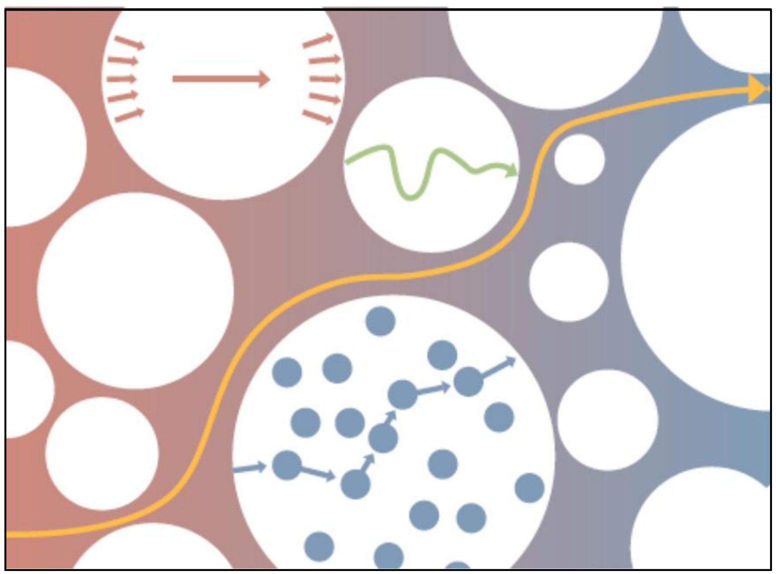
EPS: Expanded polystyrene
PU/PIR: Polyurethane
XPS: Extruded polystrene

Source: IAL Consultants, The European market for thermal insulation products

Definition of Thermal Conductivity

Thermal conductivity is the result of several components

$$\lambda_T = \lambda_M + \lambda_G + \lambda_C + \lambda_R$$



λ_M Thermal conductivity in the matrix
λ_G Thermal conductivity through cell gas
λ_C Convection in the cell gas
λ_R Radiation

Thermal Conductivity of Some Insulation Materials

Insulation product	Composition	λ (W/m K)
Mineral wool	Inorganic oxides	0.034–0.045
Glass wool	Silicon dioxide	0.031–0.043
Foam glass	Silicon dioxide	0.038–0.050
Expanded polystyrene (EPS)	Oil-based polymer foam	0.029–0.055
Extruded polystyrene (XPS)	Oil-based polymer foam	0.029–0.048
Phenolic resin foam	Oil-based polymer foam	0.021–0.025
Polyurethane foam	Oil-based polymer foam	0.020–0.029
Silica aerogels	SiO2 based aerogel	0.012–0.020
Organic aerogels	Aerogels derived from organic compounds, e.g. cellulose	0.012–0.020
Vacuum insulation panels (VIP)	Silica core sealed and evacuated in laminate foil	0.003–0.011
Vacuum glazing (VG)	Double glazing unit with evacuated space and pillars	0.003–0.008

Source: Aegerter M A, Leventis N, Koebel M M, Aerogels handbook, USA: Springer; 2011.

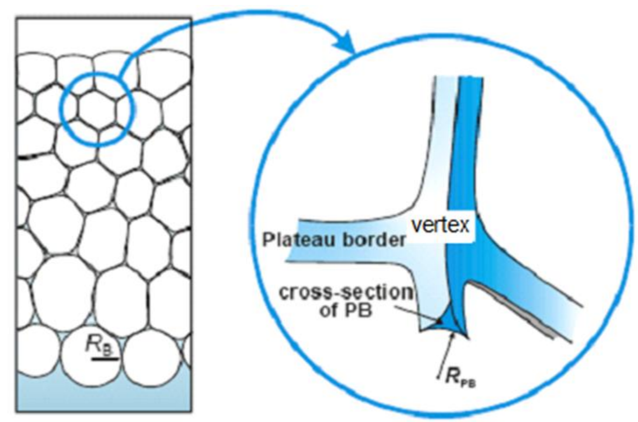
Other Important Properties for Insulation Materials

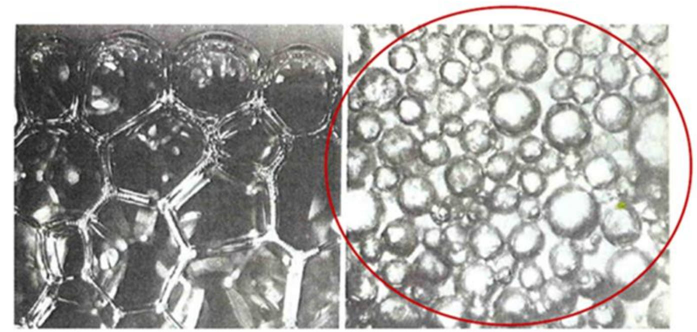
- Fire resistance
- Water absorption
- Mould growth resistance
- Resistance against pests
- Compression strength / reversibility
- Bending strength

The importance of these and performance level needed depends heavily on application and structural solution!

Basics of Foam Forming

- Fibres and other raw materials are mixed with aqueous foam instead of water
- Foam consists of water, foaming agent and air
- Typical air content 50 – 70 %
- Material is located in “bubble pockets”
- Fibres are ”frozen” in their dispersed state leading to uniform material distribution



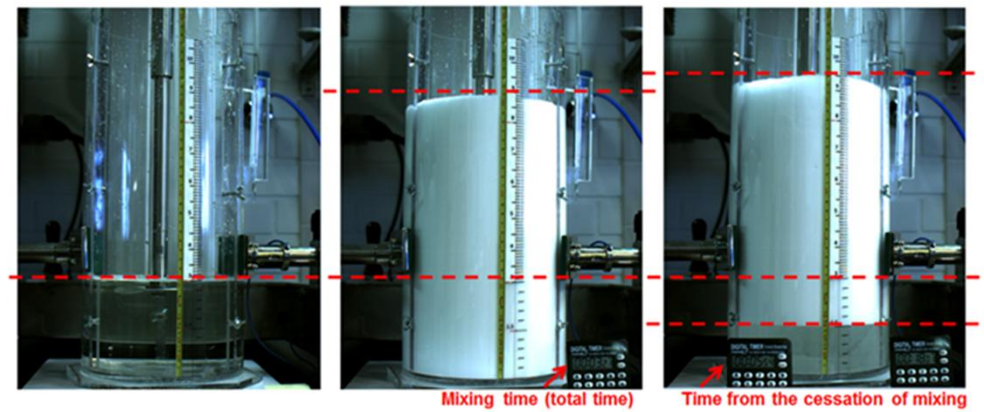


Froth, 2-4 mm bubbles
’Fairy foam, dish washing’

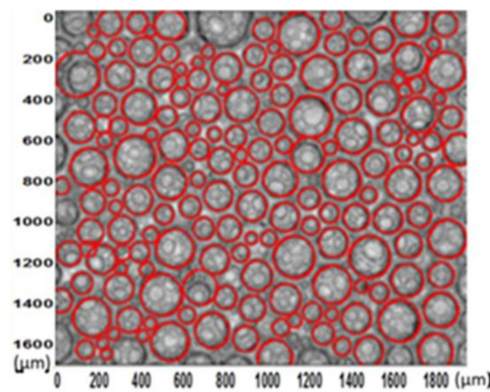
Foam, 20-100 μm round bubbles
Dense foam

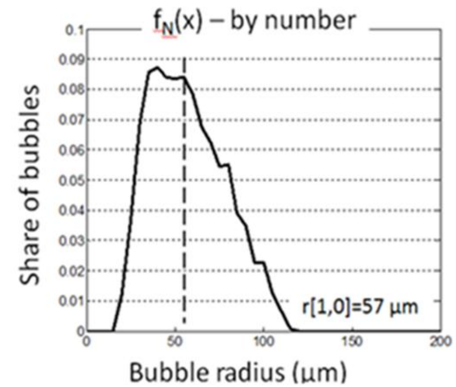
Important Foam Characteristics

- … which effect on the product properties and controlling of processes



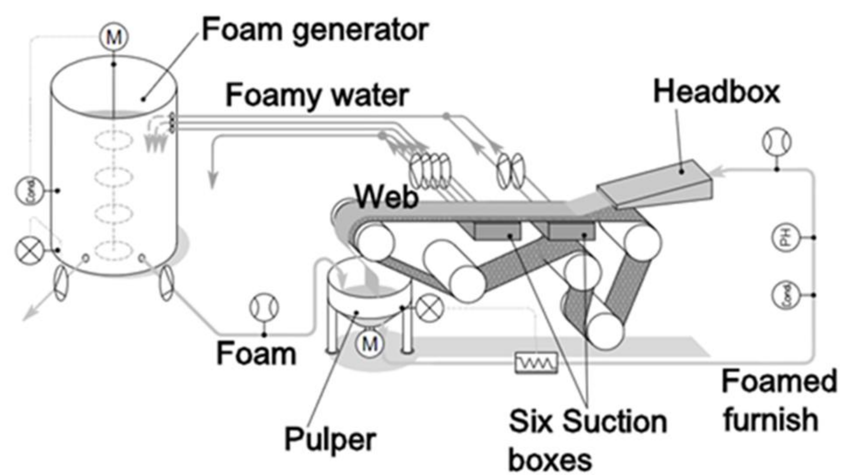
- Foam density
  - air content
- Foam stability
  - Half life time (liquid volume reaches half of its initial height)
- Bubble size





Main Process Phases and Features

- Generation of foam and mixing of raw materials in the foam: In tank or on-line in tube
- Web forming: Foam removal with vacuums
- Wet pressing: Not used if aiming to highly porous structures
- Drying: With contact or non-contact techniques
- Process can be batch or continuous process



Potential of Foam Forming

- Possible to produce highly porous structures
- Possibility to get very uniform structures even with several centimetres long fibres
- Foam allows utilization of raw materials from long fibers to nanoscale particles as well as particles lighter than water
- Possibility to produce layered products with excellent layer purity
- Technology can be resource efficient and cost competitive compared to many other manufacturing methods

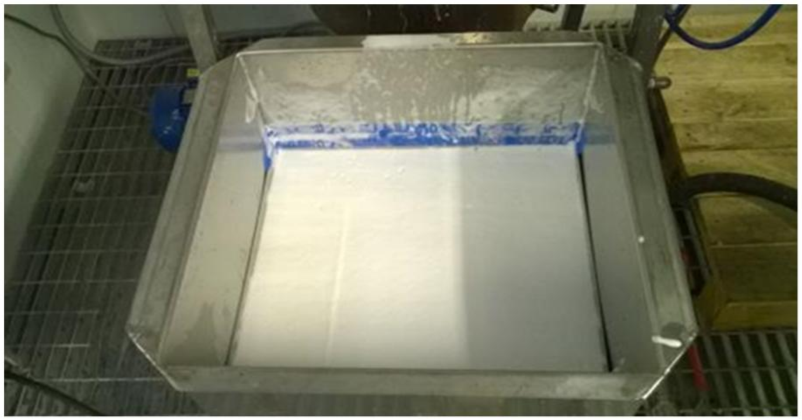
Properties of Foam Formed Cellulose Based Insulation Materials

Preparation of Foam Formed Materials

Phases:

- Fibre foam generation: Mixing of pulp suspension and foaming agent
- Sheet forming: Fibre foam is poured into a mould and drained by gravity
- Drying in the oven
- Rewetting to dsc. 50% and pressing to targeted thicknesses
- Drying in the oven

Foaming



Sheet forming

Pressing

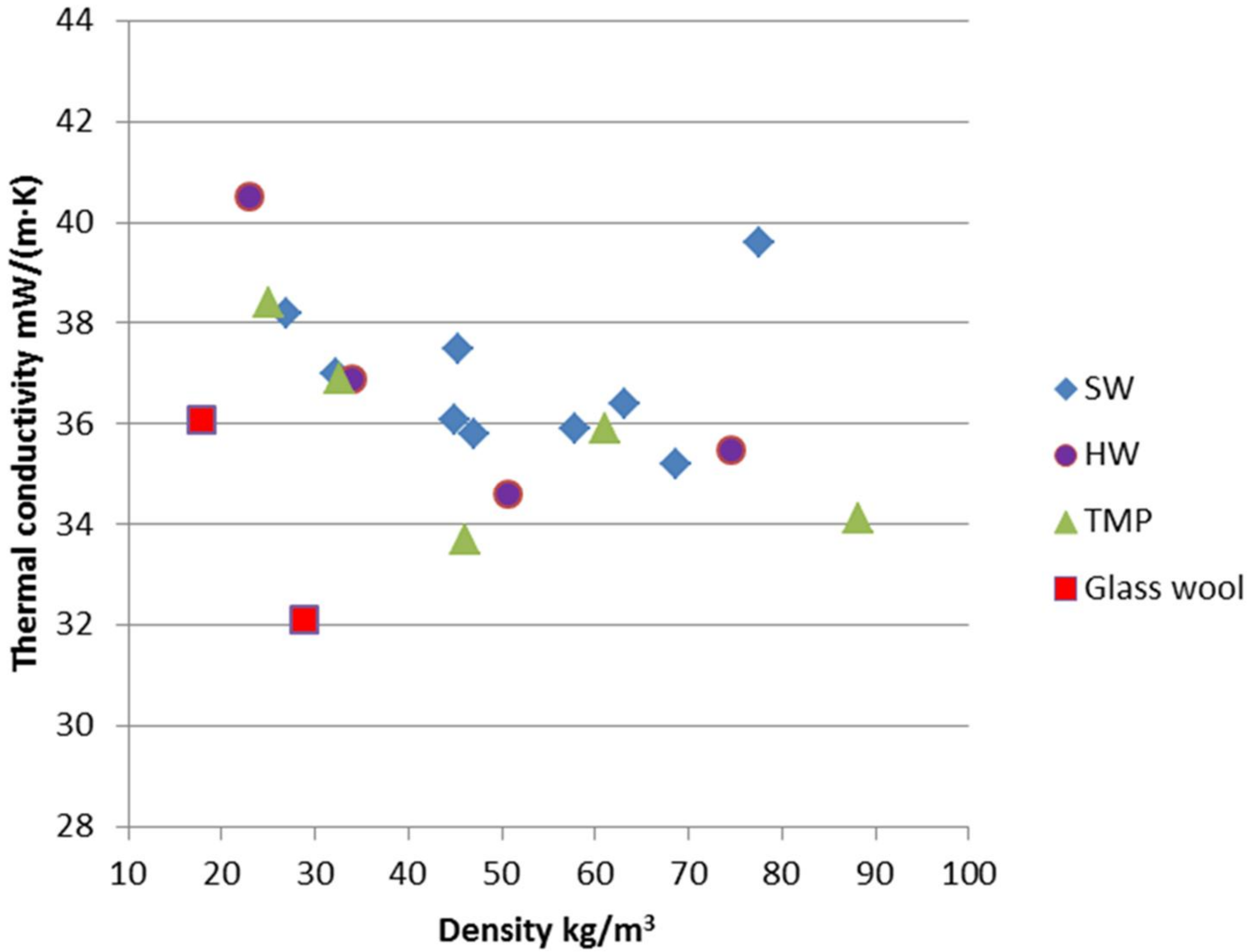
Samples and Testing Methods

Pulp	Abb.	Fibre length mm	Freeness ml	Thickness mm	Density kg/m^3
Unrefined softwood chemical pulp	SW	2.0	700	10…38	27…78
Unrefined hardwood chemical pulp	HW	0.8	650	17…39	23…75
Thermomechanical pulp	TMP	1.4	540	10…39	25…88

Glass wool	Thickness mm	Density kg/m^3
Wall insulation	100	29
Ceiling insulation	60	18

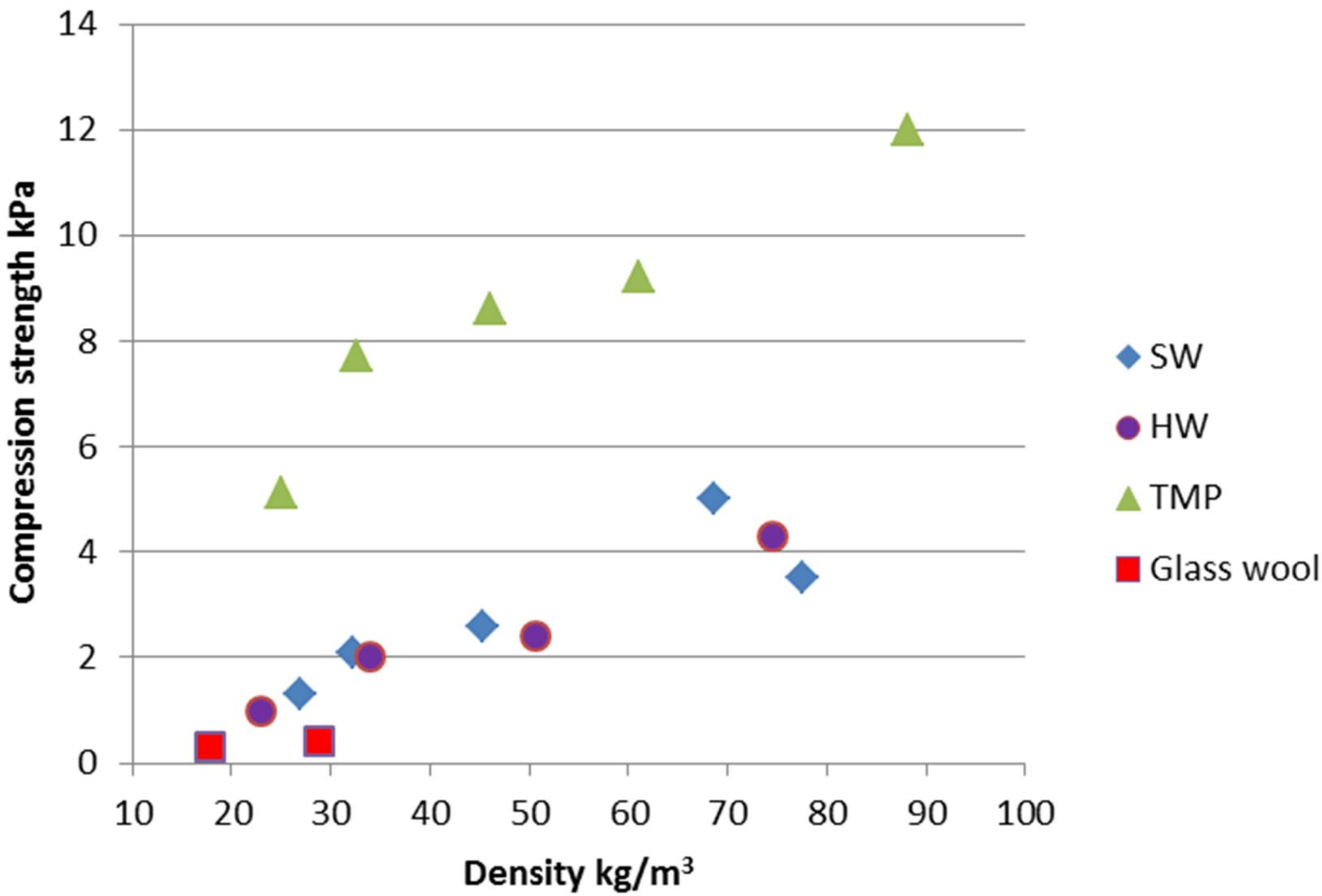
- Thermal conductivity: EN12667
- Compression strength: EN826
- Bending strength: ISOLE classification
- Water retention capacity: ISO17190-6
- Fire resistance: EN11925-2

Thermal Conductivity



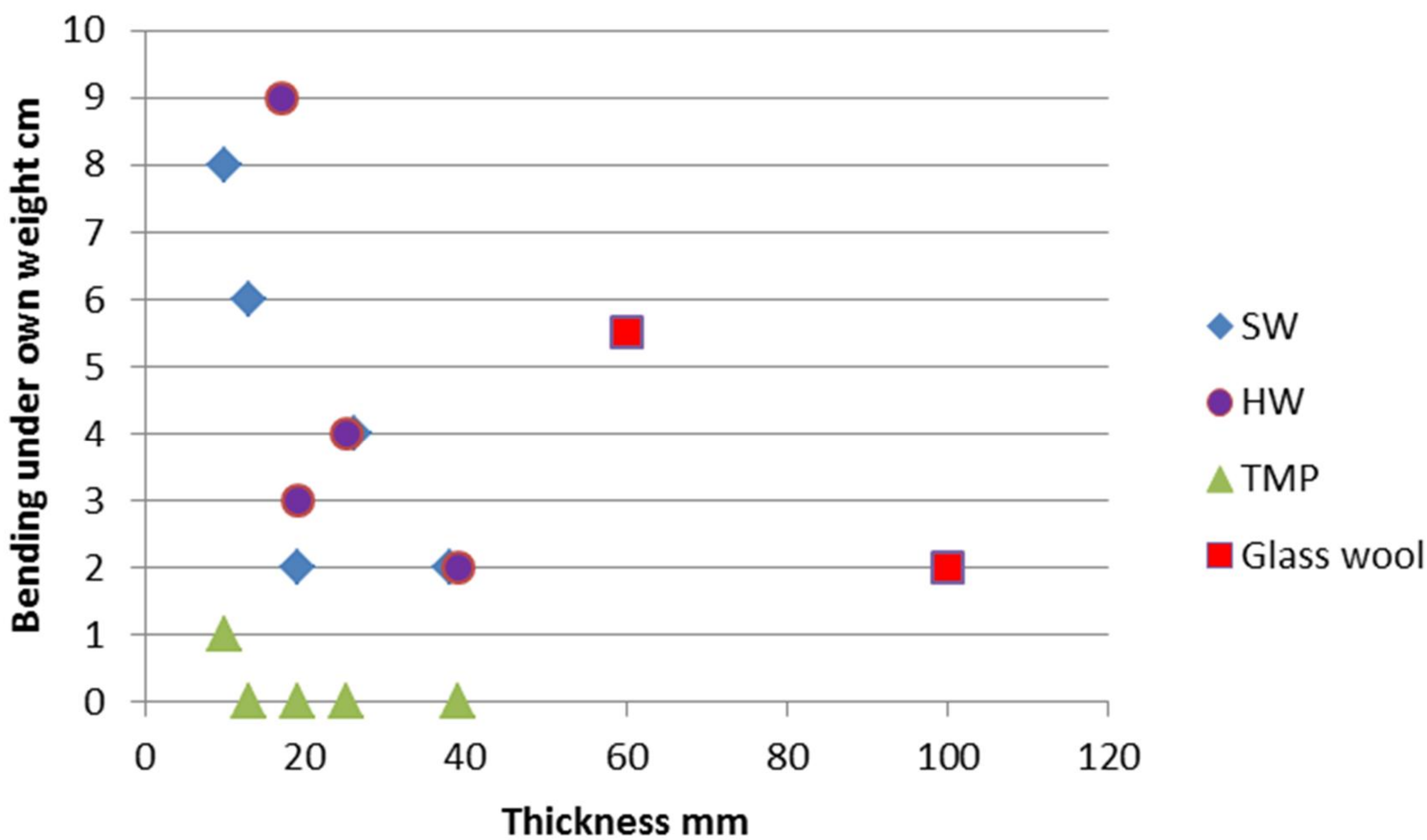
EN12667

Compression Strength



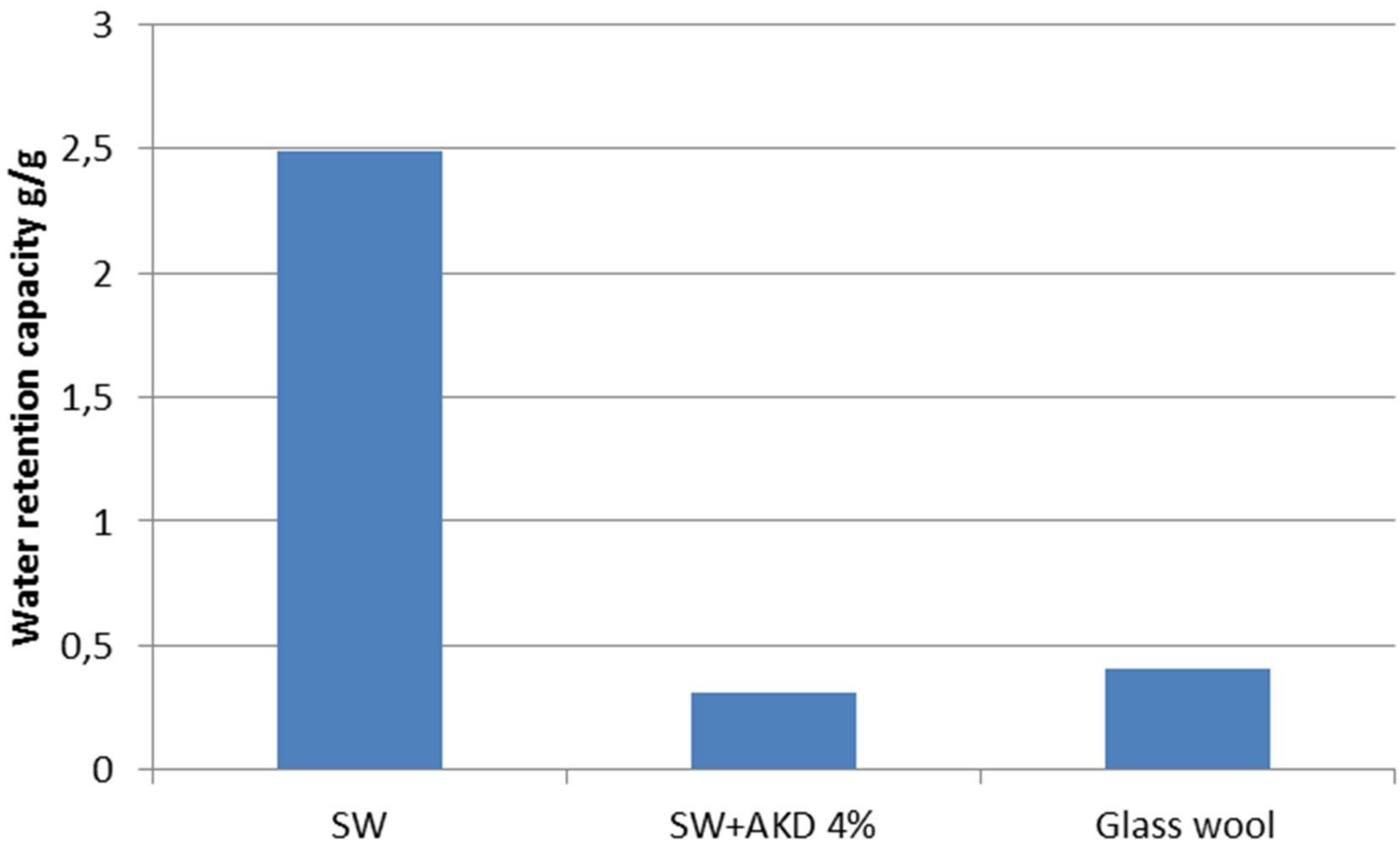
EN826 (at 10% deformation)

Bending Under Own Weight



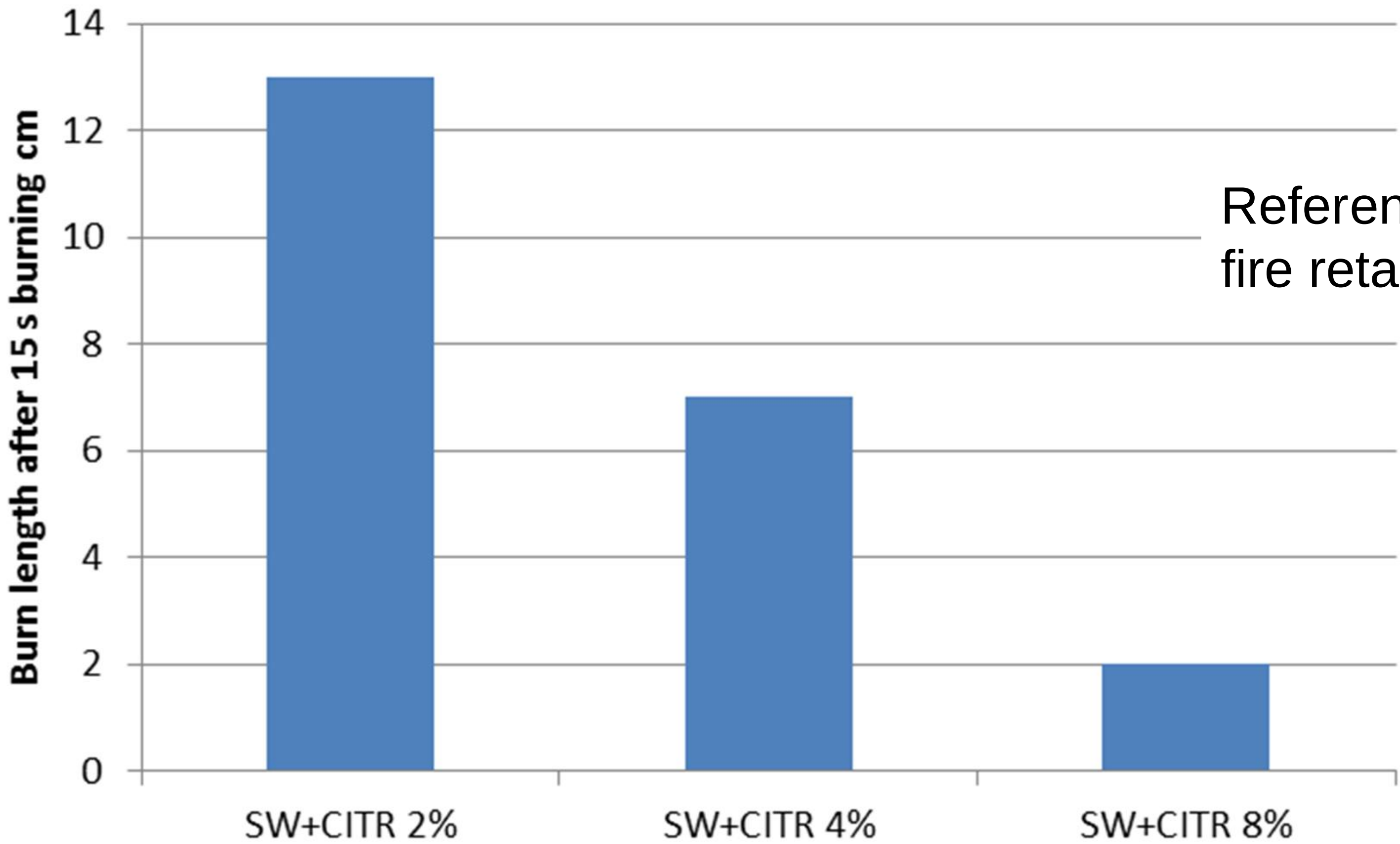
ISOLE classification (Sliding sample over the table)

Water Retention Capacity



ISO17190-6 (Weighing sample before and after water immersion and centrifuge)

Ignitability Resistance



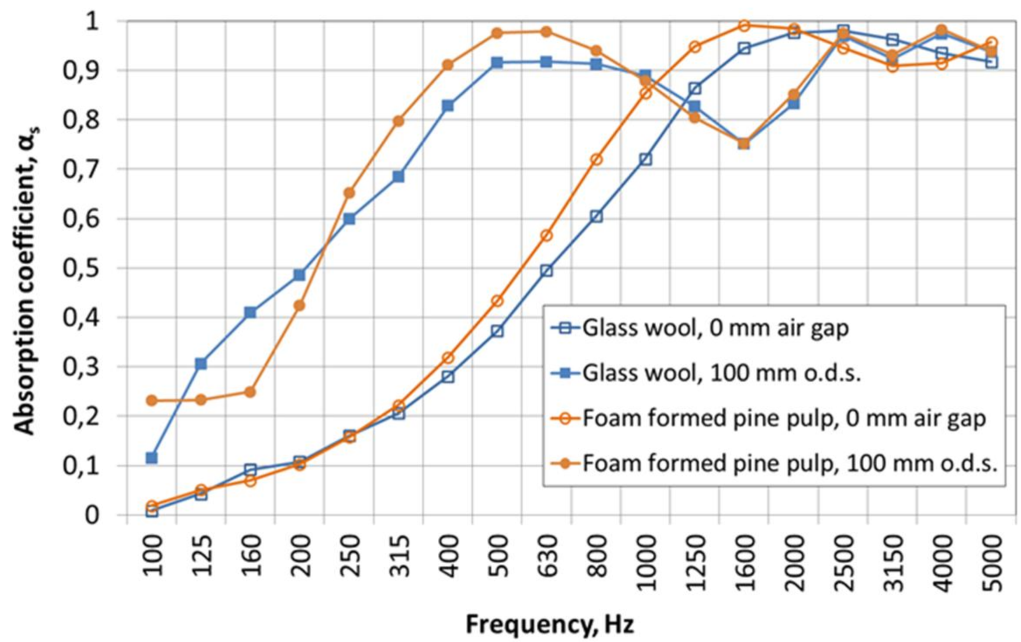
Reference without fire retardant > 22 cm

EN11925-2 (Ignitability of materials subjected to direct impingement of flame - Single Flame source test)

Sound Absorption

Glass wool product

Material	Thickness	Density	Grammage	Flow resistivity
	mm	kg/m^3	g/m^2	Ns/m^4
Commercial glass wool	30	53	1585	27300
Foam formed pine pulp	30	42	1260	23600



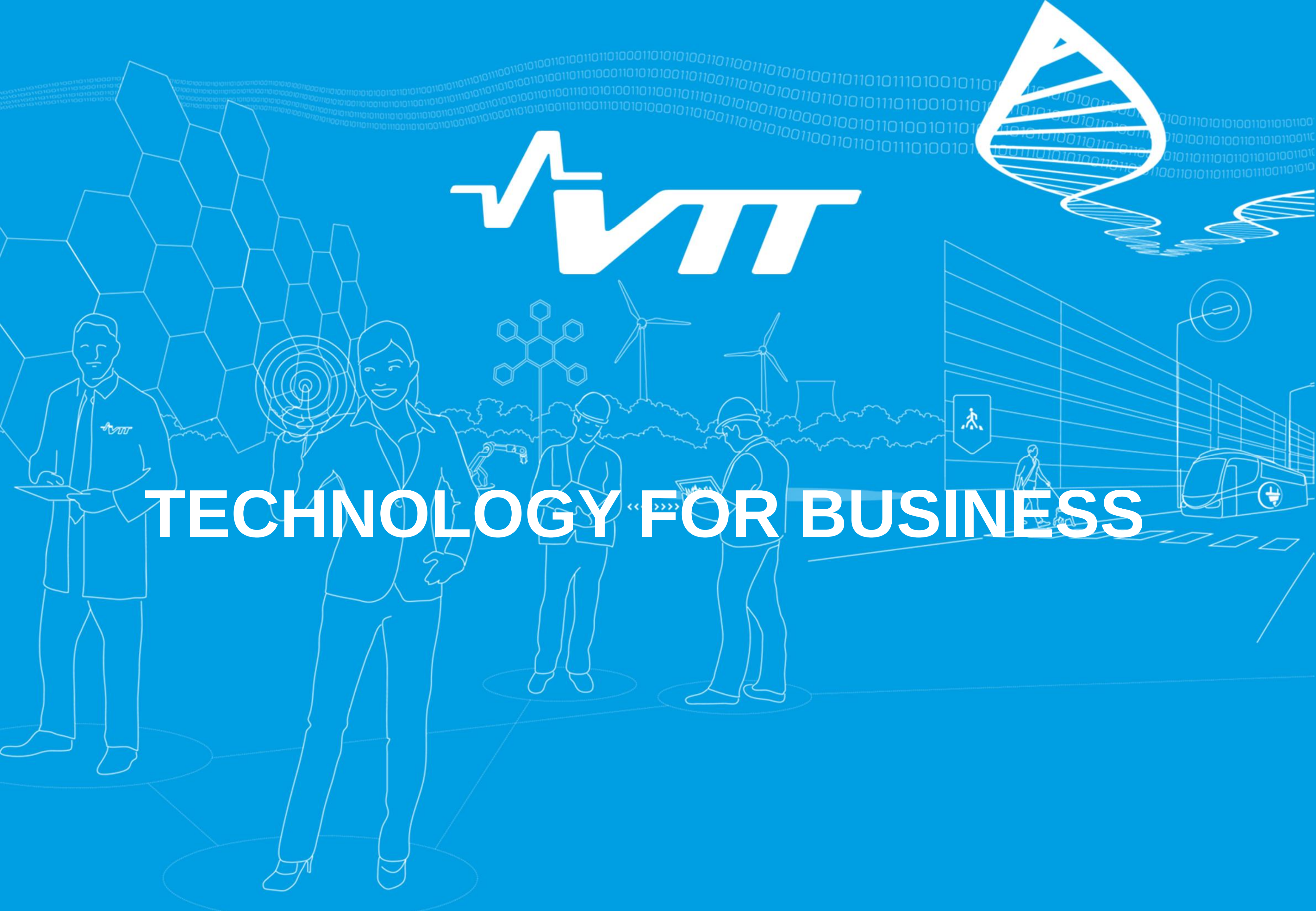
ISO 10534-2 (Impedance tube)

Conclusions

- Thermal conductivity of the foam-formed insulation panels based on paper-making pulps were at a minimum at density levels of 40-70 kg/m^3.
- The different pulp types induced fairly small differences in thermal conductivity values.
- In general, thermal conductivity of foam-formed materials was more or less comparable to commercial glass wool materials.
- The pulp properties and fibre dimensions significantly affected the mechanical properties of the panels.
- In general, foam-formed materials made from paper-making pulps can be categorised as semi-rigid thermal insulation materials.
- Mechanical properties, water absorption and fire resistance can be controlled with additives.
- Based on the results, these materials could be used as thermal insulation materials between rafters or in walls of wood construction or in internal partition walls.

Acknowledgements

- WoodWisdom-Net programme
- Tekes – the Finnish Funding Agency for Technology and Innovation
- Project partners and co-funding companies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