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nZEBIO

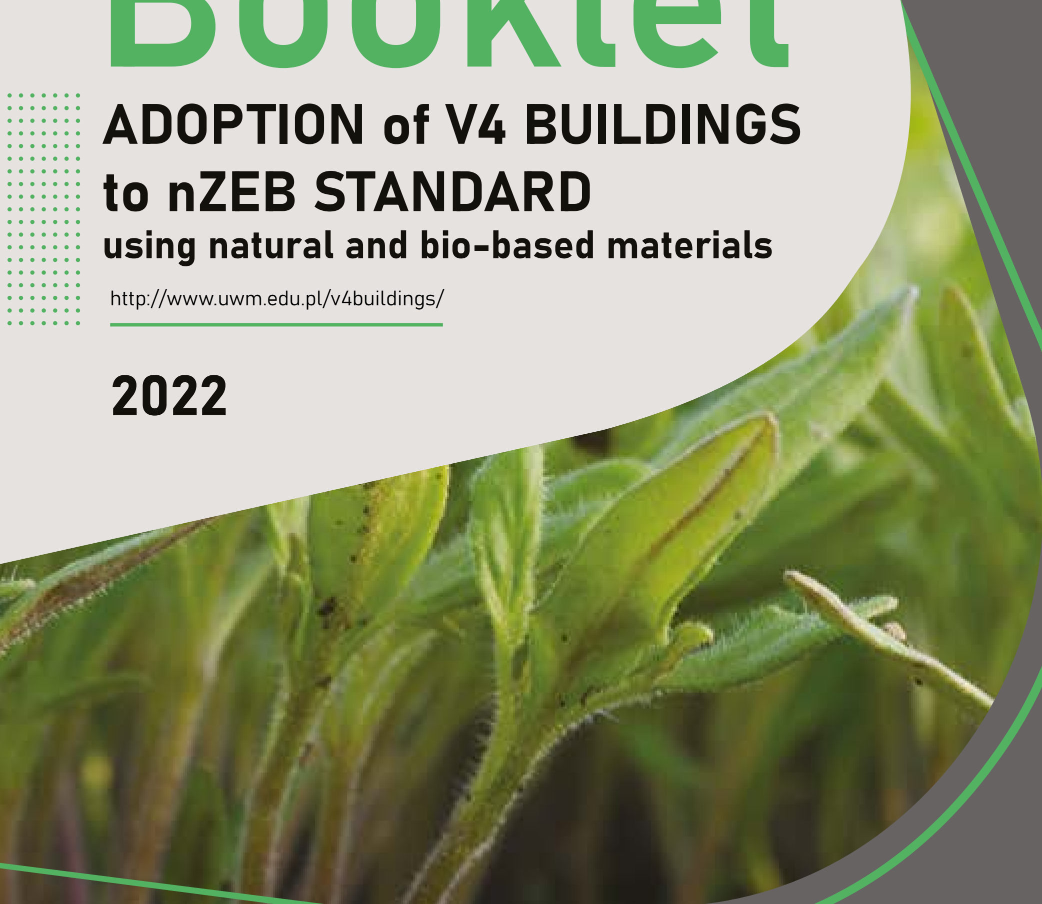
Booklet

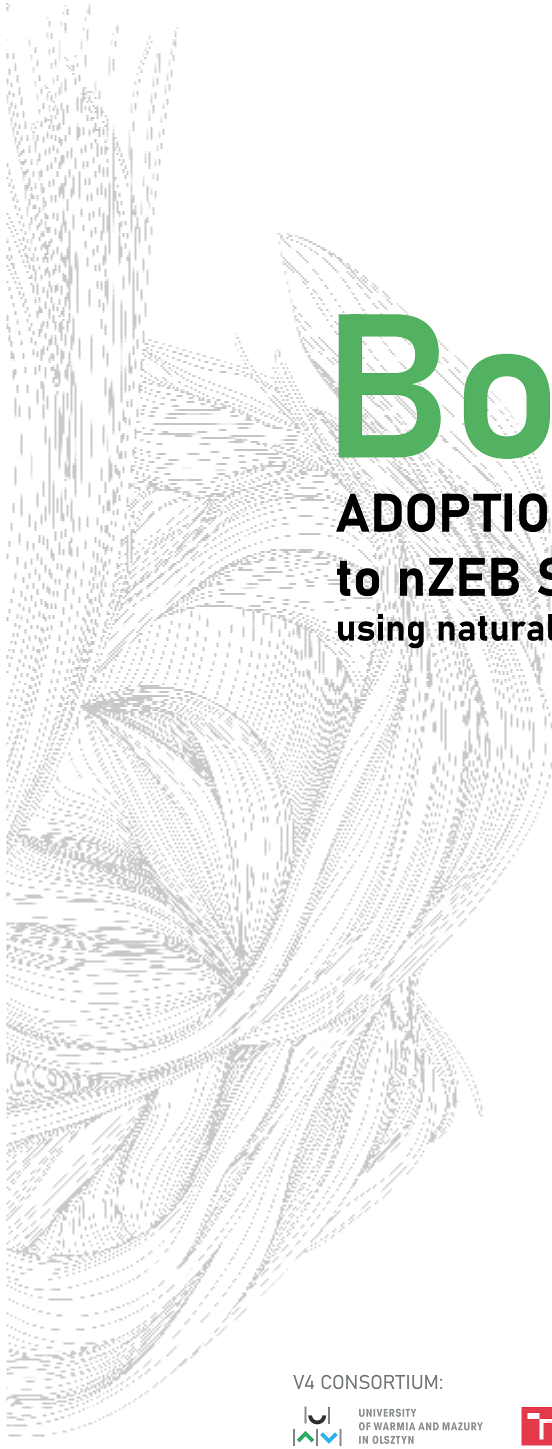
ADOPTION of V4 BUILDINGS to nZEB STANDARD

using natural and bio-based materials

http://www.uwm.edu.pl/v4buildings/

2022





Booklet

ADOPTION of V4 BUILDINGS to nZEB STANDARD

using natural and bio-based materials

V4 CONSORTIUM:

UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN

STU SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

MŰEGYETEM 1782

nZEBIO
BOOKLET

Adoption of V4 buildings to nZEB standard using natural and bio-based materials

ABOUT THE PROJECT

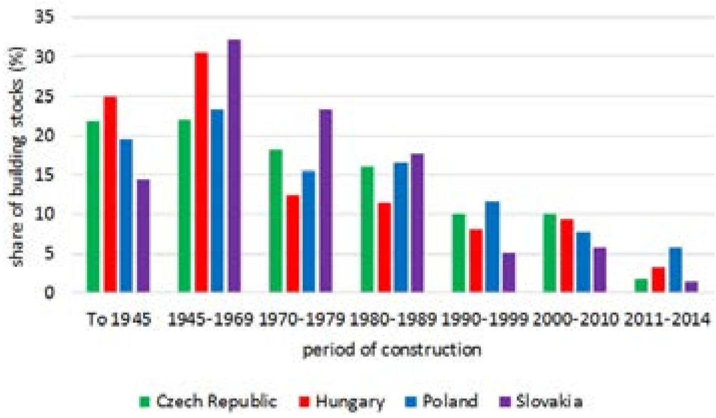
The aim of the project 'Adoption of V4 buildings to nZEB standard using natural and bio-based materials' is to familiarize experts, engineers, as well as local authorities that deep renovation of building stocks does not have to mean an investment in expensive systems and materials.
The idea of efficient building refurbishment (e.g. to nZEB standard) is nowadays often connected with installation of significant amounts of conventional thermal insulations, such as polystyrene, polyurethane or mineral wool. Sadly, these popular thermal insulations have rather high embodied environmental impacts. Moreover their waste is long lasting and their recycling is currently uneconomical. Therefore these materials are commonly incinerated or landfilled at the end of their life cycle. Besides that, using incompatible thermal insulation on the building envelope could change hygrothermal behaviour of whole building. This could lead to deterioration of the original structures, which contradicts the aim of the refurbishment.

Existing works and guides on refurbishing buildings to nZEB standard are mostly focusing on conventional materials. They are also using simplified thermal calculations, which cannot address deterioration of the hygrothermal properties due to built-in conditions and ageing. This is related to another often underestimated issue: Lack of reliable data on the materials of the building stock containing the effect of ageing and deterioration of the hygrothermal properties.

Therefore proposed project focuses on bio- and natural-based materials. It will analyse, develop and propose concepts for application of these environmentally friendly materials as thermal insulation in conventional buildings (improving them to nZEBs) in V4 countries using advanced conjugated dynamic hygrothermal and environmental simulation and measuring methods.

INTRODUCTION
The need to improve energy efficiency of buildings

Our world faces a number of challenges. Climate change, pollution and increasing population result in overexploitation of resources, increasing prices, energy and food crises. To reduce these issues, scientists, politicians and decision-makers develop strategies asking for “sustainable development” or “circular economy”. Construction sector plays a vital role in these strategies. European statistics show its approx. 40% share on energy consumption and 36% share on total waste production. Particularly, in the V4 countries it is responsible for 9.7% of total waste generated in Poland, 41.7% in Czechia, 4.4% in Slovakia and 33.2% in Hungary. [1]



Age of buildings in Visegrad Countries according to the year of construction. [3]

Governments are introducing ever stricter standards and requirements to improve (energy) efficiency of buildings: e.g. the Energy Performance of Buildings Directive (EPBD) adopted by the EU countries, which requires that all new buildings and major renovations approved after 2020 should fulfil so called nearly-Zero Energy Building (nZEB) standard. [2]. This means minimizing energy consumption of buildings and unprecedented application of renewable sources like photovoltaics. Major problem of such measures is that they take decades to produce notable results due to rather slow rate of change of the building stock. Even a building from early 2000 would require renovation to comply with nZEB requirements and results of population censi in Visegrad countries (and rest of EU as well) show that most of our building stock is more than 50 years old.

Easiest way of improving energy efficiency of a building

One of the easiest ways for improving energy efficiency of a building is insulation of its envelope with a suitable material that would reduce the heating energy losses, related costs, greenhouse gas emissions, etc. Contemporary guidelines on refurbishing buildings to nZEB standard focus mostly on using conventional thermal insulation materials, such as polystyrene, polyurethane, or mineral wool. In fact, these materials completely dominate the insulation market with 36% share belonging to glass wool, 27% to expanded polystyrene (EPS), 22% to stone wool, 8% to polyurethane/polyisocyanurate (PUR/PIR), 6% to extruded polystyrene (XPS) and only 1% to other materials, including all the bio and natural-based thermal insulations were in 2015. However, this dominance comes at a price. Supply chain issues (related with COVID-19 outbreak) resulted in material scarcity, extending delivery times to many months and increasing costs several times.

Current situation can be considered as an opportunity to diversify the market, lower the prices and environmental impacts. The reason is that there are many other thermal insulation materials available [4] with lower embodied environmental impacts and costs or better recycling potential. A prime example of these materials is a whole group of natural bio-based thermal insulations that emerged during last two decades. A market survey performed during preparation of this booklet shows that (as of April 2022) there are more than 100 thermal and acoustic insulation products made of bio-based materials available in the Czech market. The situation in other Visegrad countries is rather similar. The performance of these unconventional, yet sustainable materials is comparable to common artificial materials, while their environmental impacts are lower and waste management easier (composting, incineration), [5].

[1] *Waste statistics, available at https://ec.europa.eu/eurostat/statistics-explained*

[2] *EU building factsheets, available at https://ec.europa.eu/energy/eu-buildings-factsheets_en*

[3] *Energy efficient buildings, available at https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings_en*

[4] *Schiavoni, S., D´Alessandro, F., Bianchi, F. Asdrubali, F., Insulation materials for the building sector: A review and comparative analysis. Renewable and Sustainable Energy Reviews 62 (2016)*

[5] *Asdrubali, F., D´Alessandro, F., Schiavoni, S., A review of unconventional sustainable building insulation materials. Sustainable Materials and Technologies 4 (2015)*

In the research, we selected and reviewed 12 thermal insulation materials available in the V4 countries and suitable for façade applications during building refurbishments. Many of them are available and sold in multiple countries. However, some of them are not made in V4 countries.

Capatect Hanf Wall is a hemp fibre panel designed for thermal insulation of external and internal walls. The high content of natural hemp fibres (87%) ensures good permeability and resistance to moulds and pests. Its higher density (compared to polystyrene or mineral wool) also provides good acoustic parameters and thermal capacity, especially in timber buildings.

Ecopanely combines precisely cut compressed straw panels with recycled cardboard casing. As such, they provide minimal environmental impacts, easy transport, and on-site handling. Combined with local production and minimal environmental impacts, it makes them desirable from the point of view of sustainable construction.

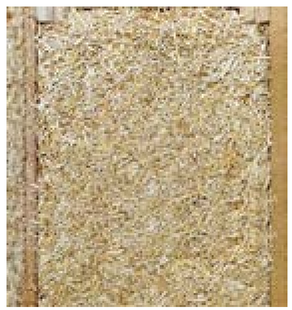
Juta Naturizol is a flax-based thermal (and acoustic) insulation panel applicable in building envelopes and floors. It needs to be installed between wooden spacers to ensure façade usability. A combination of flax and 11-13% of Bi-Co fibres ensure its low environmental profile and resistance to moulds and pests. It uses 3-5% of sodium carbonate as a flame retarder.

Nordtex Konope Panel is a solid boarded product which can be plastered and made of hemp fibres designed for thermal and acoustic insulation. Hemp is an extremely fast-growing annual plant. Therefore, the products can provide carbon sequestration. It uses PES or corn starch to provide bonding and <1% ammonium salt to provide better fire resistance.

UdiTherm SK is a versatile vapour permeable wood-fibre insulation board with a flat, smooth edge around the whole circumference suitable for façades, roofs and floors. It uses PVAC glue for the binder. It is designed as a thermally insulating sub-base for the direct application of plasters. It could also be used to eliminate thermal bridges in timber frame walls.

SSH Terra Szalmapaplan is made of wheat straw by stitching the fibres together with 80-100 kg/m3 density. Therefore, this product does not use a binder, and the fire resistance is only provided by applying an external lime plaster layer. It is advised to be used on facades fixed with mechanical fasteners. However, it has relatively low and varying compression strength.

Steico Protect Dry is one of the most popular wood wool insulation suitable for external thermal insulation composite systems (ETICS). Its eco-friendly manufacturing process uses fresh softwood and uses wood waste. The wood fibres are bonded together using polyurethane resin to form a robust insulation board, while the performance is enhanced using paraffin wax.



Tepore Fúkaná slamená izolácia is a blown straw thermal insulation. It is a long-developed product using a new production process that achieves high application bulk density of the insulation, which provides excellent protection against overheating during the summer and high protection from noise. However, it needs additional construction for the external walls to which it will be applied. It is advantageous for wooden buildings, where openings are pre-prepared for application to cavities in the structure.

Vermeko ThermoVerm is a thermal insulation board made of vermiculite, which is gaining popularity as a fire-resistant material since it is non-combustible (A1 class). On the other hand, its thermal performance is less competitive. The manufacturing process of board production is ecological-friendly, and the producer declares that they are using ecological materials as a binder instead of formaldehyde or sodium fluorosilicate.

Vestaeco Wall is an impact-resistant, vapour-permeable thermal insulation for façade applications. It is made using the patented DefibraTech technology, as the product is made of lignocellulosic fibres from straw and uses PMDI resin as the binder and compressed to dense boards. The product has high heat capacity and is advertised as it does not absorb water. Although during construction, it should be protected against water to avoid conservation issues.

W-heat Board is a fire-resistant, biodegradable and moisture permeable thermal insulation board made of specially treated and cut wheat straw fibres. A novel natural, environmental-friendly inorganic binder composition containing recycled glass makes the board fire-resistant and durable. It is also a good sound absorber and has a high compression strength.

Woolstyle Gold isolation normal is thermal and acoustic insulation made from 100% natural sheep's wool. Sheep wool has excellent heat-insulating and thermoregulatory properties and low density but needs additional construction to which it will be applied. Therefore, it is advantageous for wooden buildings. It is not so much used in classical constructions due to its price and construction technological needs.

The authors presented the performance data of the selected bio and natural based thermal insulation materials in the Table 1. The comparison of the data with the conventional materials like EPS, XPS, mineral wool or polyurethane can reveal that the thermal conductivity and density of most of the natural and bio based materials is slightly higher. This may be considered an obstacle to their use as insulation for external walls. However, if we compare the diffusion resistance, which for the materials we are considering is much lower than for conventional materials, then these materials can arouse considerable interest. It should be borne in mind that with the increasing use of usable areas in buildings, the moisture of these spaces increases, and therefore materials that have a natural ability to transport moisture outside are sought after by designers. Moreover, materials of natural and bio origin have a higher specific heat. This is especially beneficial when considering the energy efficiency of passive systems in buildings. High specific heat combined with high density of materials enables their use as heat buffers. It should be borne in mind that the nZEB standard does not mean buildings covered with very thick thermal insulation, but also those with heat storage systems.

Table 1. Parameters of selected bio -based thermal insulations according to producer information (as of April 2022).

Product name	Producer	Material	Thermal conductivity [W/mK]	Heat capacity [J/kgK]	Vapour dif. resistance [-]	Bulk density [kg/m³]	Compres. strength [kPa]	Market price [€/m³]
Hanf Wall	Capatect (AT)	hemp panel	0.040	1 700	3.9	92-130	-	281
Ekopanel	EKOPANELY SERVIS s.r.o. (CZ)	straw panel	0.099	1 700	9.7	379	30	310
Naturizol	Juta a.s. (CZ)	flax panel	0.039	1 550	2.2	250	-	105
Konope Panel	Nordtex S.R.L. (IT)	hemp panel	0.040	1 900	3.9	100	-	520
UdiTherm SK	UdiDÄMMSYSTEME GmbH (DE)	wood wool	0.038	2 100	5.0	160	50	256
SSH Terra Szalmapaplan	SSH-System Kft. (HU)	straw panel	0.041	-	4.4	80-100	25-38	135
Protect Dry	Steico SE (DE)	wood wool panel	0.040	2 100	3.0	140	100	350
Fúkaná slamená izolácia	TEPORE s.r.o. (SK)	blown straw fibre	0.055	2 000	1.3	105-140	-	150
ThermoVerm	Vermeko Sp. z o.o. (PL)	vermiculite panel	0.090	1 000	-	375	1500	-
Vestaeco Wall	VestaEco COMPOSITES Sp. z o.o. (PL)	straw panel	0.043	2 100	5.0	140	30	180
Board	W-heat (HU)	straw panel	0.039	1 380	10.0	145	100	250
Gold isolation Normal	Wool Style s.r.o.	sheep wool mat	0.040	1 720	1.0-2.0	16	-	-

All Visegrad countries are located in the Central European region with its temperate climate. Statistical data [6] show that their agriculture and forestry are well developed and provide significant amount of raw materials that could be potentially used for for production of bio-based insulation products. Even though, the conditions (area, weather) in each country differ, all four countries could easily produce insulation from sheep wool, wood wool or straw:

- **Sheep wool** is the only representative of animal-based materials available in the Visegrad countries. 10-year (2012-2021) average population of sheep is 214 thousand in Czechia, 1 106 thousand in Hungary, 245 thousand in Poland and 357 thousand in Slovakia. Considering 3 kg average annual wool yield per sheep, this means that the four countries could have produced 57 729 thousand tons of sheep wool in past 10 years.

- **Wood wool** and cellulose is preferably produced using waste wood at saw mills, recycled paper, etc. Therefore, the production of wood in each country is an important parameter to follow. 10-year (2011-2020) harvest of wood (both deciduous and coniferous) was 208 million m^3 in Czechia, 75 million m^3 in Hungary, 386 million m^3 in Poland and 96 million m^3 in Slovakia. Considering average densities of harvested wood species, this equals approximately to 403 million tons of wood.

- **Straw** can come from various sources. It could be a waste from wheat production, it could be excessive grass from pastures and meadows, etc. As such, it is rather hard to get clear data on overall straw production so following data illustrate the availability of straw based on average harvest from permanent grasslands in a 10-year period (2011-2020): 3 174 tons annually in Czechia, 1 333 tons annually in Hungary, 109 700 tons annually in Poland and 1 149 tons annually in Slovakia. Considering that drying to suitable levels reduces the weight of grass by approx. 70 %, this results in a staggering amount of 1 575 million tons of straw harvested in 10 years.

Production of other crops is rather limited and statistical data fragmented. Still, they show that there is a number of other materials available in small quantities. For example, Czech statistics show that 3 861 tons of **hemp** harvested between 2012 and 2021 and Polish statistics show 83 026 tons of **flax** (seeds and straw) harvested during the same time period.

[6] *For details see statistics available at https://www.czso.cz, https://www.ksh.hu, https://bdl.stat.gov.pl and http://datacube.statistics.sk*

Previous page illustrates the amounts of resources (hypothetically) available for production of bio-based insulation products. Following example will try to put these data into context. It is based on data available in Tabula Web Tool [7], which is a database of residential buildings typical for particular time periods in European countries. The building selected in this example is a Czech single-family house from 1950s. The house has brick walls, concrete floors and timber roof truss (< 45° slope) with little to no thermal insulation. Following table shows parameters of its envelope and compares them with Czech nZEB requirements.

View of the selected single-family house and parameters of its external envelope.

Structure	Surface area [m²]	U-value [W/m²K]	nZEB U-value [W/m²K]
Roof	35	1.25	0.17
Ceiling	37.2	0.94	0.42
Wall 1	132.3	1.36	0.21
Floor 1	67	1.03	0.32

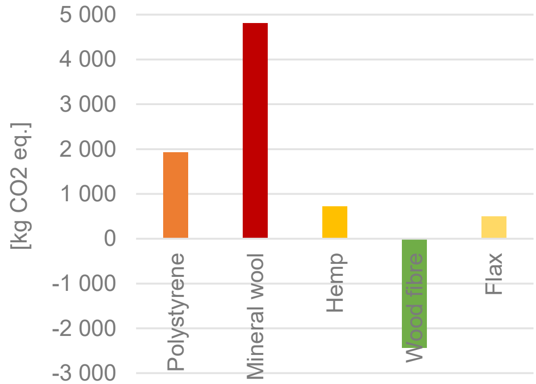
Data in the table show that a significant amount of thermal insulation has to be added to the envelope to fulfil contemporary requirements. Particular amounts of insulation are visible in the following table. Up to five tons of (straw) insulation might seem a lot. However, consider this in the context of previously presented statistics: Annual harvests in Visegrad countries could supply thousands similar renovations!

Comparison of thermal insulation materials necessary to reduce heat loss of the house.

Insulation material	Thermal conduct. [W/mK]	Added insulation thickness [m]	Added insulation volume [m³]	Added insulation weight [t]
Polystyrene	0.031	0.04 – 0.20	36.36	0.65
Mineral wool	0.039	0.04 – 0.20	36.36	2.54
Straw	0.044	0.04 – 0.24	44.39	4.88
Hemp	0.039	0.04 – 0.22	39.70	2.38
Wood fibre	0.036	0.04 – 0.20	36.36	2.18
Flax	0.039	0.04 – 0.22	34.32	1.27
Sheep wool	0.034	0.04 – 0.18	39.70	1.03

[7] *Tabula Web Tool, available at https://webtool.building-typology.eu*

Use of bio-based materials could not only ease the strain on traditional supply chains. It also brings notable environmental benefits as these materials require less demanding processing and also sequester pollutants and greenhouse gases during growth (this greatly differs depending on particular species). This is illustrated in the chart below showing greenhouse gas emissions (represented by so called global warming potential) related with production of the selected insulation materials. Moreover, application of the considered amount of insulation to the building envelope would potentially save up to 55 MJ of heating energy and 483 kg of CO_2, eq. each year (if gas heating is considered) due to reduction of heat losses.



Global warming potential of selected materials from the presented comparison calculated based on data available in the ecoinvent database [8]

Complex multi-criteria assessments are often subjective. Environmental impacts are not the only thing to compare when assessing materials of thermal insulation. Statistics, the long-term impact of the built-in and the behaviour of the insulation in the structure could be used to be more precise. You can find information about the project in the attached QR code.

[8] *ecoinvent database, available at https://ecoinvent.org/the-ecoinvent-database/*

One of the project aims was to disseminate the findings through workshops at involved universities. Part of the workshops was introduction of involved universities and their portfolio to increase mutual mobility and cooperation. Research cooperation is planned by PhD. Students and academics.

supported by Visegrad Fund

Adoption of V4 buildings to nZEB standard using natural and bio-based materials:

Olsztyn, Poland, 10th September 2021
09. – 12. 09. 2021

University of Warmia and Mazury in Olsztyn
Olsztyn, Poland

UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN

Budapest, Hungary, 26th April 2022
24. – 26. 04. 2022

Budapest University of Technology and Economics
Budapest, Hungary

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Bratislava, Slovakia, 27th April 2022
26. – 27. 04. 2022

Slovak University of Technology in Bratislava
Bratislava, Slovakia

STU SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

Brno, Czechia, 28th April 2022
27. – 30. 04. 2022

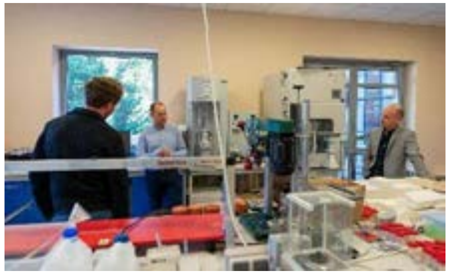
Brno University of Technology
Brno, Czechia

BRNO UNIVERSITY OF TECHNOLOGY FACULTY OF CIVIL ENGINEERING

Olsztyn, Poland, 10th September 2021

The initial workshop took place in Olsztyn at the University of Warmia and Mazury, Faculty of Geoengineering. The workshop was attended by the university staff, including few experts in the field of civil engineering. We also had guests from the National Association of Natural Building in Poland.

Lukáš Bosák presents in Olzstyn.



Visiting material research lab at UWM.

Budapest, Hungary, 26th April 2022

The second meeting took place at the Budapest University of Technology and Economics. Presentation and dissemination of the project findings and project related studies to Hungarian audience (academic staff, university students, representatives of associations and experts). Introduction of involved universities and their portfolio to increase mutual mobility and cooperation.

New material samples tested at BME labs.

Balázs Nagy presents in Budapest.

Bratislava, Slovakia, 27th April 2022

The third meeting took place at the Slovak University of Technology in Bratislava. Presentations and workshop of the project findings to the Slovak audience (academic staff, students and experts). Introduction of involved universities and their portfolio to increase mutual mobility and cooperation. Meetings with research colleagues in laboratories of the Department of Building Construction and in the central laboratories of STUBA Faculty of Civil Engineering.

Piotr Kosiński presents in Bratislava.

Visiting a weather simulation lab at STU.

Brno, Czechia, 28th April 2022

The final workshop and meeting of the project took place in the premises of Brno University of Technology, Faculty of Civil Engineering. The workshop itself was attended by students and academics from various programmes and universities. It was followed by a visit to the university premises and laboratories at AdMaS research centre.

The audience in Brno.

Final photo: The team at the BUT rooftop.

Piotr Kosinski, Ph.D.

Assistant Professor at Institute of Geodesy and Civil Engineering, University of Warmia and Mazury in Olsztyn, Poland

piotr.kosinski@uwm.edu.pl

Research Interests: Building physics, Hygrothermal diagnostics, Thermal Insulation, Bio-based materials.

Biography: Former student and now the researcher and teacher at the University of Warmia and Mazury in Olsztyn. In his work, he is mostly focus on the hygrothermal performance of thermal insulations, especially fibrous materials. Still interested in researching materials that have not been widely used to insulate houses so far. Experienced in the building diagnostics, including IR, air tightness, ventilation and thermal comfort assessment.

Lukáš Bosák, Ph.D.

Assistant Professor at Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Slovakia

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Research Interests: Building physics, Roof Insulation, Thermal Insulation, Bio-based materials.

Biography: Former student, now researcher and lecturer at the Department of Building Constructions, Faculty of Civil Engineering, Slovak University of Technology in Bratislava. As part of the teaching, he deals with construction and technical subjects, BIM, virtual reality, 3D printing and design. In his scientific activity, he deals with the issue of BIM, research in the field of roof constructions and biocomposites.

Balázs Nagy, Ph.D.

Assistant Professor at Faculty of Civil Engineering, Budapest University of Technology and Economics, Hungary

nagy.balazs@epito.bme.hu

Research Interests: Building physics, Building energy efficiency, Construction technologies.

Biography: Former student and lecturer from the Budapest University of Technology and Economics (BME), Faculty of Civil Engineering. Nowadays, doing research at the Department of Construction Materials and Technologies (formerly Architectural Engineering) and in the Building Physics and Material Testing Labs, major research interests are heat-, air-, moisture transfer measurements and numerical simulations of construction materials and building constructions, thermal insulation, reinforced concretes, natural-based materials, as well as energy performance and building energetics and the issues of passive solar energy.

Karel Struhala, Ph.D.

Assistant professor at Faculty of Civil Engineering, Brno University of Technology, Czechia

struhala.k@fce.vutbr.cz

Research Interests: Building renovations, Life-Cycle Assessment, Natural construction materials, Sustainable development.

Biography: Former student and now a lecturer and researcher at Brno University of Technology. Work experience lead him to his current field of work: evaluating environmental impacts of construction sector. His research and work activities include evaluation of anything from individual materials to whole building evaluation, new construction as well as end-of-life evaluation, Environmental Product Declarations and building sustainability certification such as SBToolCZ or BREEAM. As a lecturer, he tries to transfer all this experience to students.

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