Optimization of construction compositions for design of green building

The 1st World Sustainability Forum

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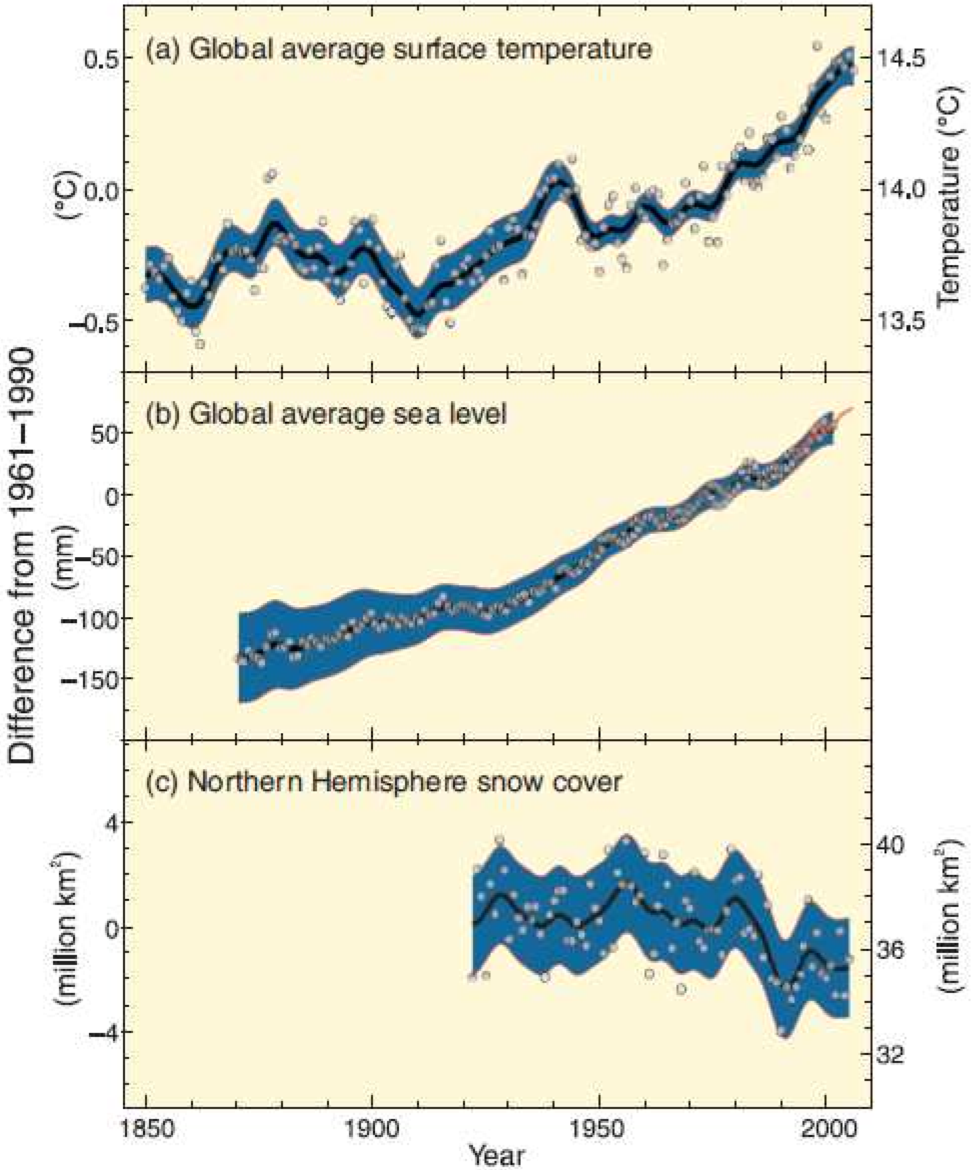
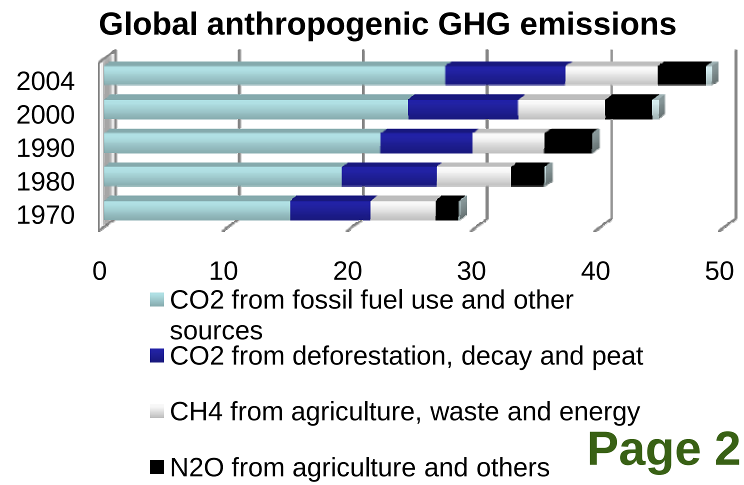
BACKGROUN TO ENVIRONMENTAL ISSUES



SOURCE:
IPPC 2007, Synthesis Report

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.
The linear warming trend over the **50** years from 1956 to 2005 (0.10 to 0.16°C per decade) is nearly **twice** that for the **100** years from 1906 to 2005.

Drivers of climate change = GHGs = **greenhouse gas emissions (CO_2-eq.)**



IMPACT OF BUILDINGS

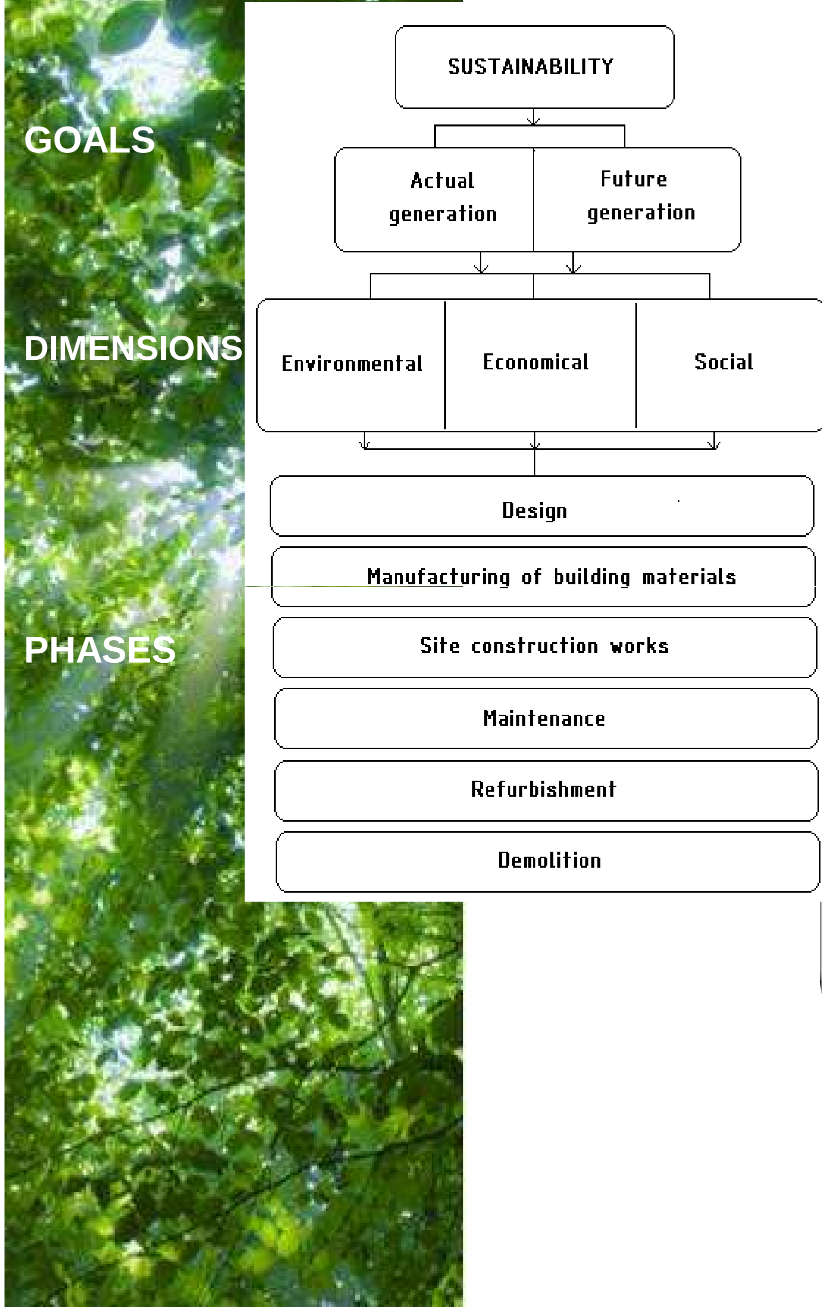
- **major user of land**
- **the second largest consumer of raw materials**
  (about **32%** of the world's primary resources**)**
- **generate a great amount of waste (45%** of solid waste**)**
- **consume more than 40% total energy and 12% water**
- **produce minimal 30% of greenhouse gas emissions**

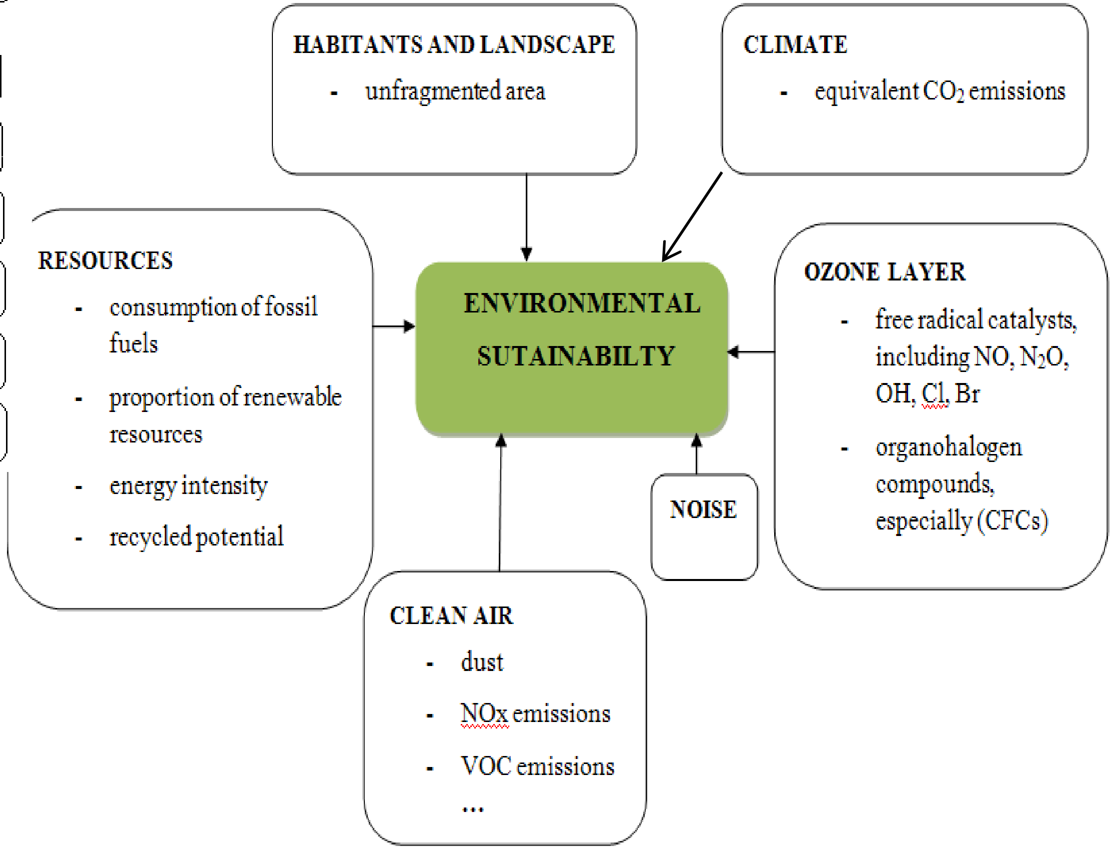
The **increase of population with increasing requirements** on living and degree damage to the environment direct to urgent need for revalue civilizing activities of human, which they could have irreversible impact on change climate, extinction of some countries and so on.

That's why **sustainable construction** has recently been identified as one of the lead markets for the near future of the whole world.

Environmental considerations have called for new developments in building sector to bridge the gap between this need for lower impacts on the environment and ever **increasing comfort**. These developments were generally directed at the reduction of the energy consumption during operations. While this was indeed a mandatory first step, complete environmental life cycle analysis raises new problems .

STRUCTURE OF BUILDING SUSTAINABILITY





STUDIES OF ENERGY CONSUMPTION

T. RAMESH et. al. 2010

Operating energy has major share **80–90%** in life cycle energy use of buildings followed by **embodied energy 10–20%**, whereas demolition and other process energy has negligible or little share.

A. DIMOUDI et. al. , 2008

Embodied energy correspondence varies between **12,55 and 18,50%** of the energy needed for the operation of an office building over a **50 years** life.

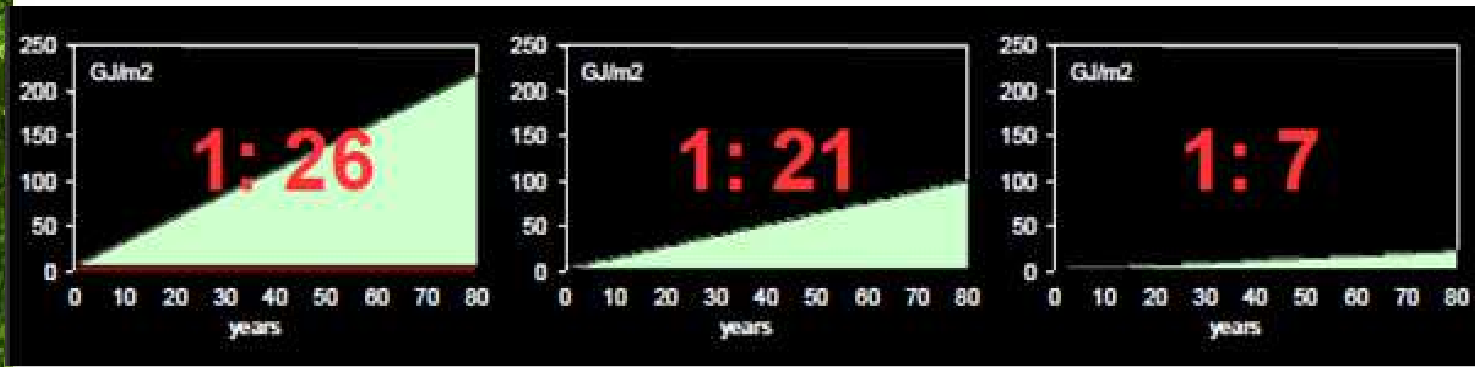
I.Z. BRIBIÁN et. al. 2011

60 studies of different buildings located **in 9 countries** have been performed and found that the proportion of **embodied energy** in materials used and life cycle assessed varied between **9% and 46%** of the overall energy used over the building's lifetime when dealing with low energy consumption buildings and between **2% and 38%** in conventional buildings.

M. VONKA, 2009

Ratio between embodied and operational energy

mansory flat - building, 1927 without thermal insulation | **mansory flat - building, 1999 without thermal insulation** | **low-energy house,2002 with wooden frame**



STUDIES OF CO_2 eq. EMISSIONS

H. YAN et. al., 2011

The results from case study in Hong Kong show that **82–87%** of the total GHG emissions are from **embodied GHG emissions of building materials**, **6–8%** are from **transportation** of materials, and **6–9%** are due to **energy consumption** of construction equipment.

I. ZABALZA, et. al., 2001

It's estimated that **1 m^2** produce **1,5 tons of CO_2** during useful life span building

M.J.GONZÁLEZ et. al. 2006

Selection of **low environmental impact** materials can result at a reduction up to **30% of CO_2 emissions** in the construction phase.

L. GUSTAVSSON et al 2006

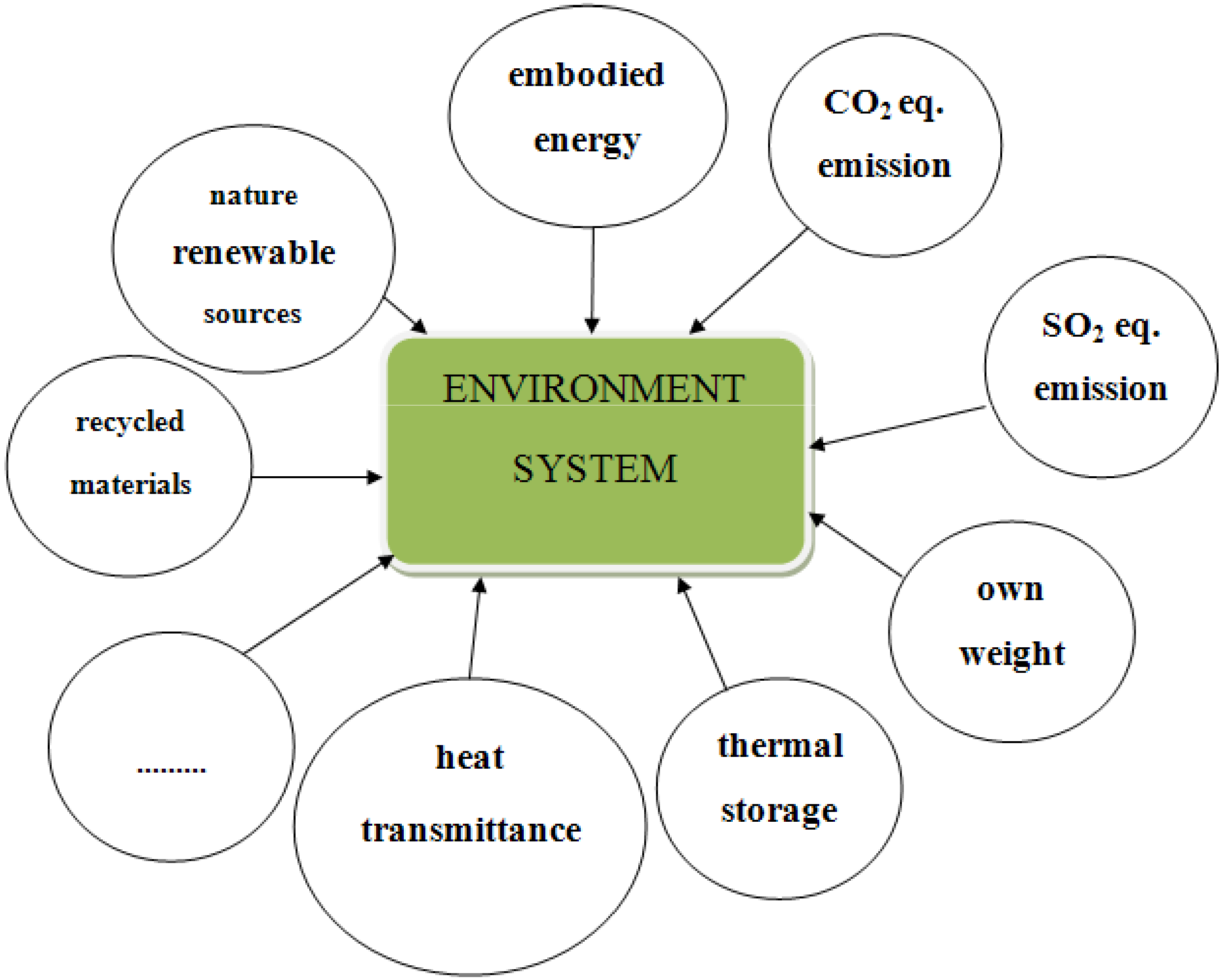
The results of **energy and CO_2 emissions** comparisons of apartment buildings made with wood or concrete frames, by taking into account the energy available from biomass residues from the wood products chain as well as cement process reactions including calcination and carbonation, prove that the **wood buildings have lower energy use and emission**.

B. BERGE, 2009

A conventional **timber frame** house contains about **150 kg/m^2** of timber. Thus a **120 m^2** house 'stores' about **32 tons of CO_2**. If a building is constructed in **logs**, or the increasingly popular system of massive timber then this can be increased to about **550 kg/m^2**. This means carbon storage of nearly **120 tons of CO_2**.

ASSESSMENT OF ENVIRONMENTAL PERFORMANCE

Systematic model for multi–criteria assessment



BUILDING MATERIALS ON PLANT BASE

Pao Li Dung

“The forest gives generously products of its life and protects us all.“

Main environmental advantages>

- ✓ sustainable or green materials
- ✓ healthy and safety
- ✓ lock in carbon in mass/ absorb CO_2
- ✓ reduce of greenhouse effect
- ✓ renewable (straw, hemp, flax - annual)
- ✓ locally available
- ✓ low energy intensity
- ✓ breathable – absorbing and releasing air moisture
- ✓ non-toxic and non-irritating
- ✓ not destroy negative ions in air
- ✓ low toxicity levels and low emission e.g. VOCs
- ✓ low water use in manufacture
- ✓ low wastage in manufacture and in assembly
- ✓ biodegradability of the material at the end of its life-cycle

OPTIMIZATION OF CONSTRUCTIONS

- by maximal application of plant base materials

- the basic data for each evaluated constructions:

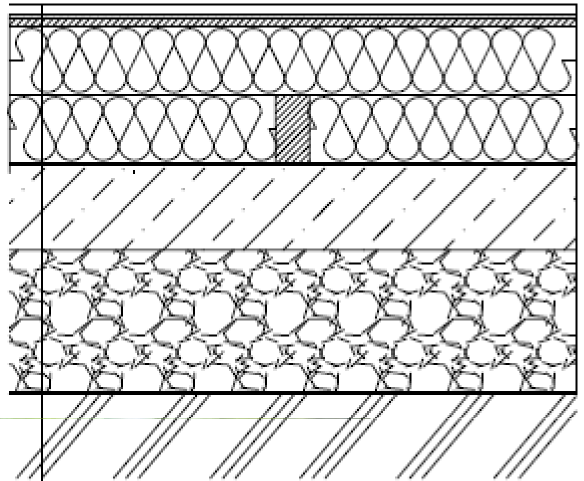
❖ passive standard
❖ load-bearing function – timber
❖ thermal physical data according Slovak valid standards

Environmental evaluation is based on the Life Cycle Assessment (LCA) - described in ISO 14040 -14049:2006, with boundary : “Cradle to Site”

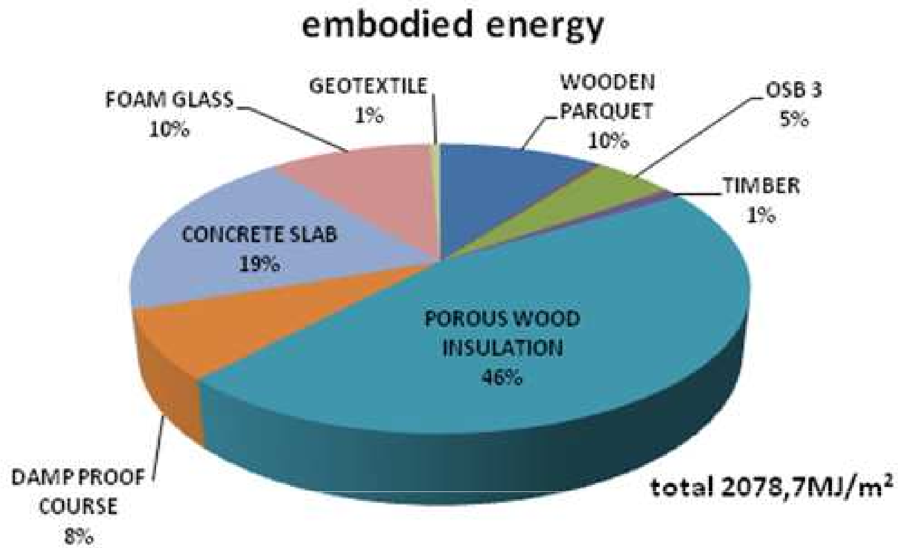
Input data of embodied energy, CO_2- eq.(GWP), SO_2 –eq. emissions (AP) for building materials are from available databases:
❖Bauteilkatalog - Austrian Institut,
❖Öbox - Öko-institut Darmstadt
❖ only for straw bale are from Wihnan’s case study and Center for Appropriate Technology (GrAT)

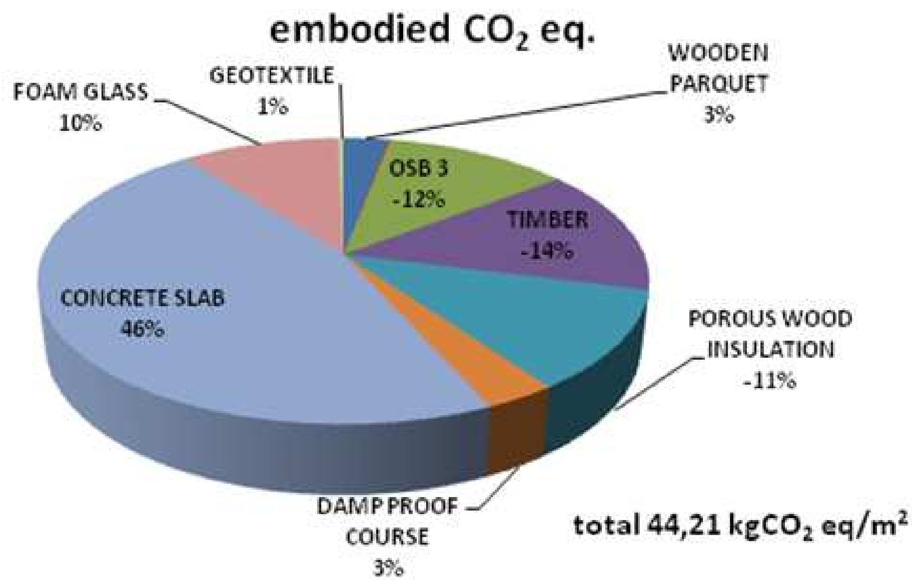
OPTIMIZATION OF FLOOR CONSTRUCTION

1A



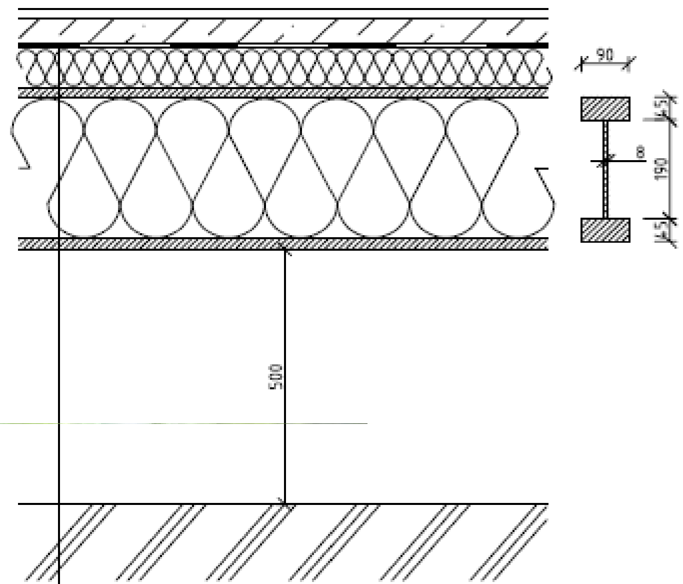
WOODEN PARQUET (BEECH)	16mm
INSULATION LAYER MIRELON	3mm
OSB 3 with tape -airstop	18mm
POROUS WOOD INSULATION	280mm
DAMP PROOF COURSE	1,2mm
CONCRETE SLAB + reinforcing grid	150mm
GRANULATED FOAM GLASS	250mm
GEOTEXTILE	
SUBSOIL	



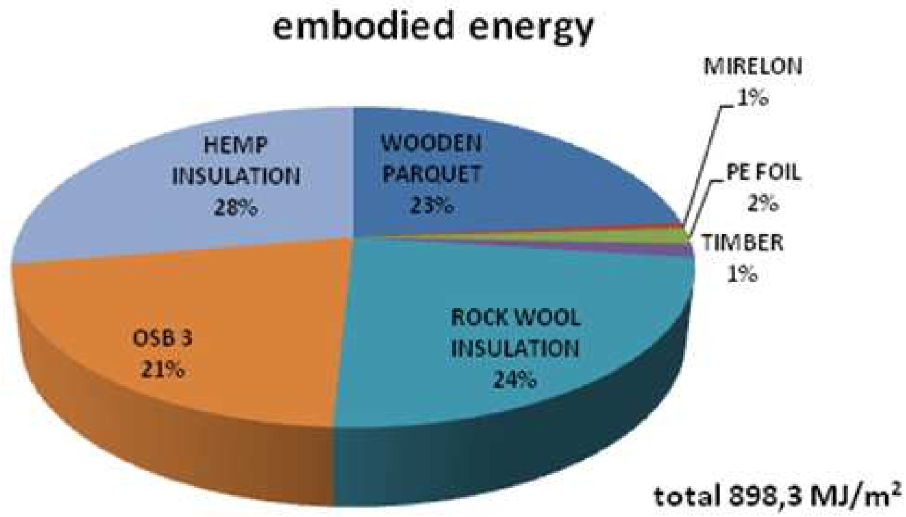


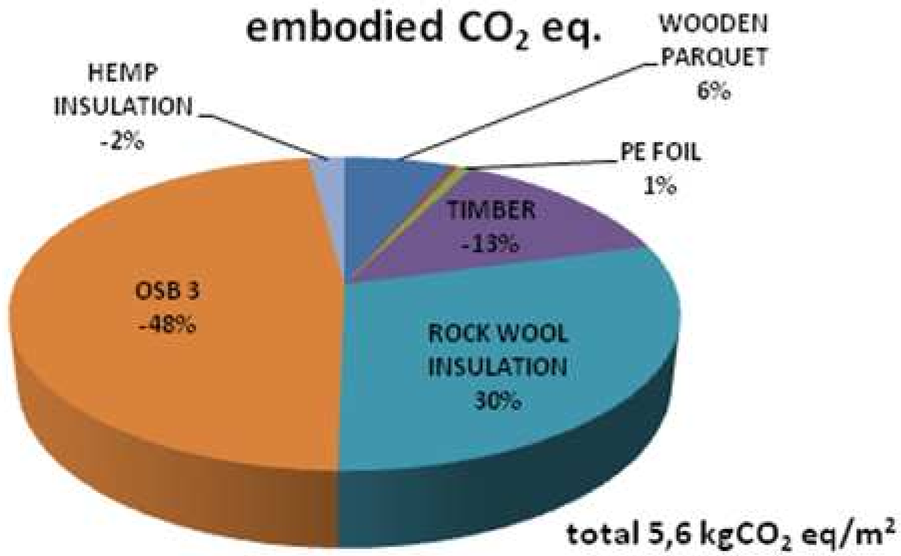
OPTIMIZATION OF FLOOR CONSTRUCTION

1B



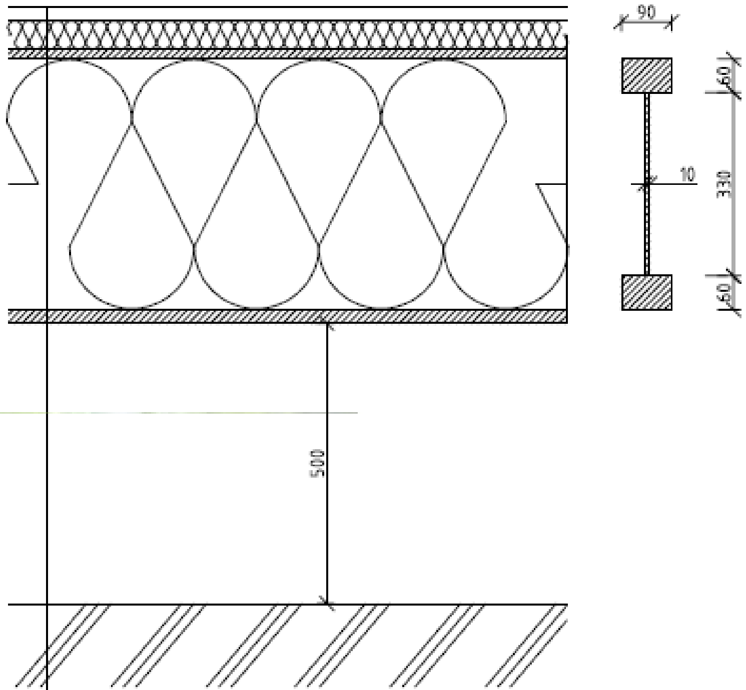
WOODEN PARQUET (BEECH)	14mm
INSULATION LAYER MIRELON	3mm
SELF- SMOOTHING SCREED	3mm
CONCRETE SCREED	50mm
SEPARATE FOIL PE	
ROCK WOOL INSULATION	80mm
OSB 3	15mm
HEMP INSULATION WITH PE	280mm
OSB	18mm
VENTILATION GAP	500mm
SUBSOIL	





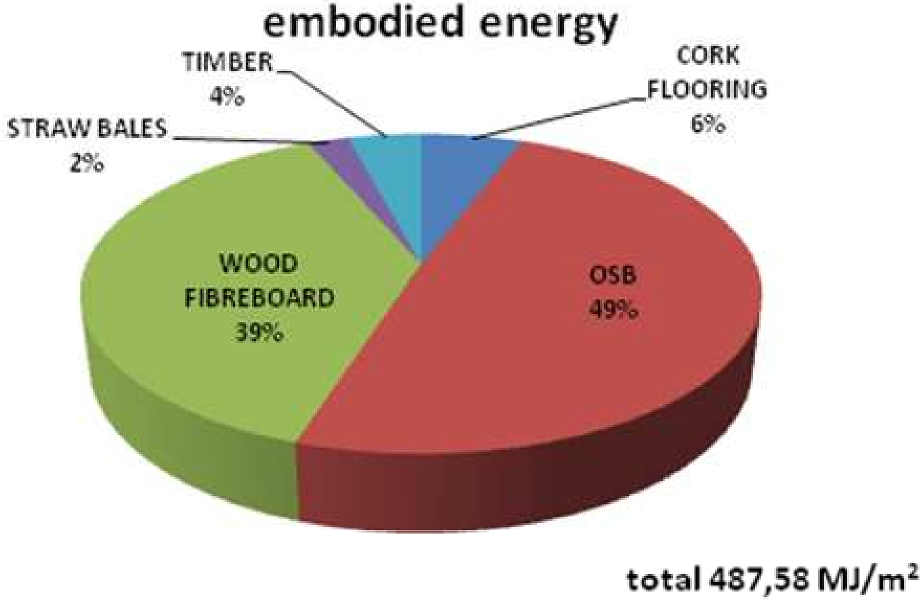
OPTIMIZATION OF FLOOR CONSTRUCTION

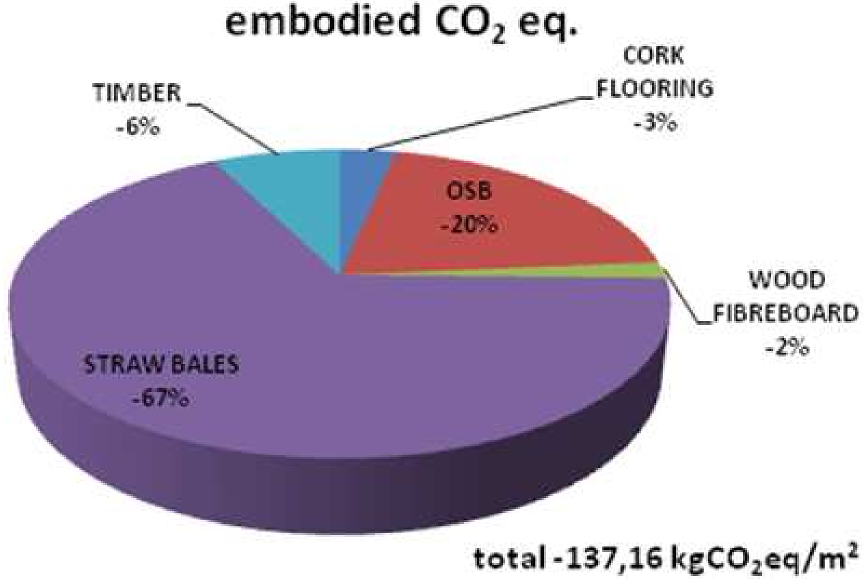
1C



- CORK FLOORING 25mm
- POROUS WOOD FIBREBOARD 50mm
- OSB 3 with tape-airstop 15mm
- STRAW BALES- INSULATION 450mm
- OSB 22mm
- VENTILATION GAP 500mm

SUBSOIL



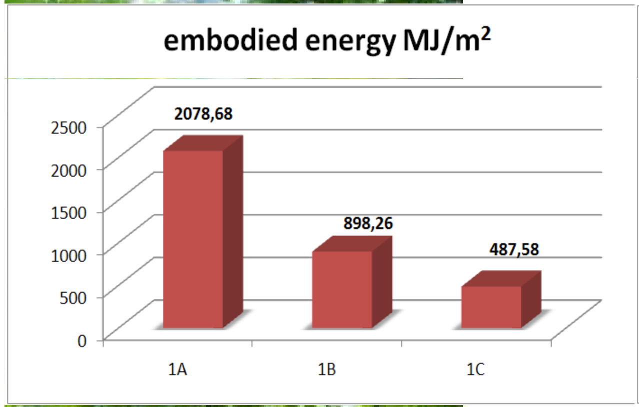


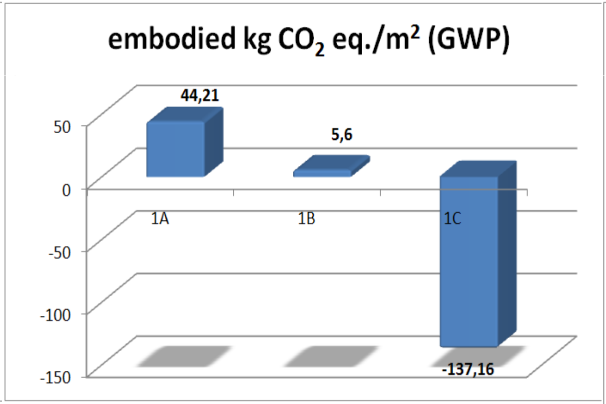
RESULTS OF ASSESSMENTS OF FLOOR CONSTRUCTION

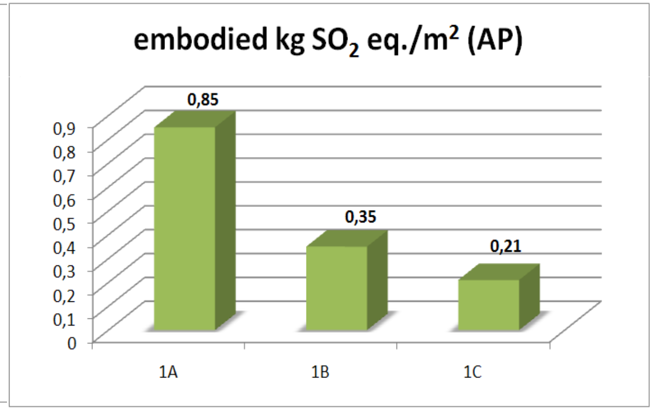
Selected thermal-physical parameters for floor construction alternatives

	m [kg/ m²]	U [W/(m²K)]	Q [kJ]	D [-]
1A	485,77	0,010	579,36	13,37
1B	158,00	0,010	170,85	5,35
1C	96,30	0,091	182,04	11,02

Total results of environmental assessment for floor construction alternatives

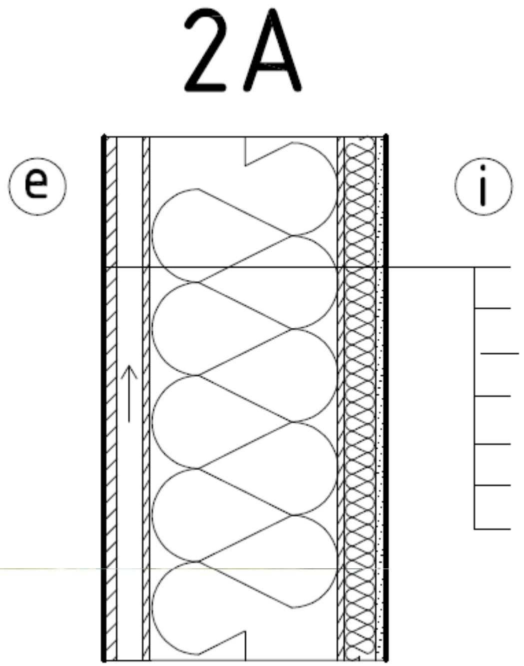




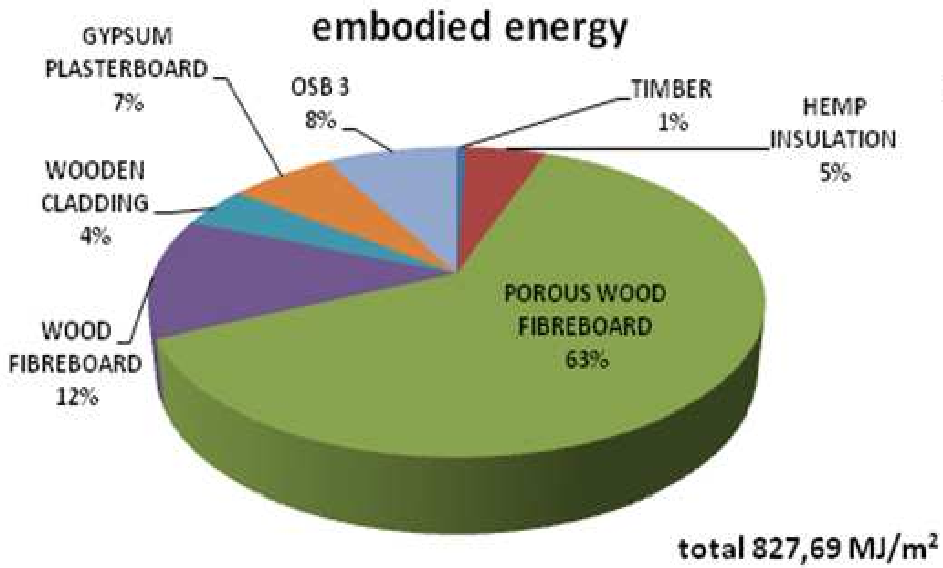


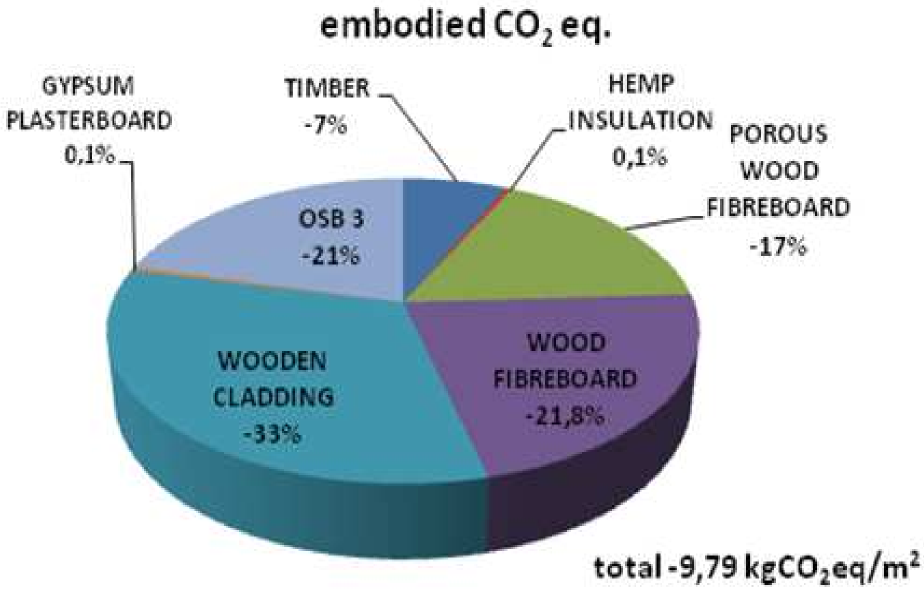
The construction alternative **1A** proves the worst results from environmental sustainability but represents the best value of thermal storage. The most environmental suitable alternative is variant **1C** and demonstrates a possible way to optimization of construction for green building design. It is about **85%** preferable to alternative **1B** in terms of embodied energy from non-renewable resources and only this variant is able to **absorb a lot of CO_2 eq. emissions**.

OPTIMIZATION OF EXTERNAL WALLS



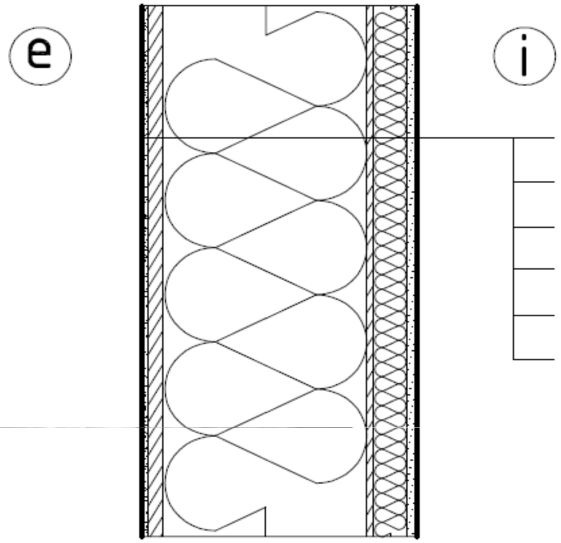
WOODEN CLADDING (LARCH)	22mm
VENTILATION AIR GAP,WOOD LATHES	50mm
WOOD FIBREBOARD MDF	15mm
POROUS WOOD FIBREBOARD BETWEEN I-JOISTS	340mm
OSB 3 WITH AIRSTOP TAPE	15mm
HEMP INSULATION WITH PE	60mm
GYPSUM PLASTERBOARD	12,5mm



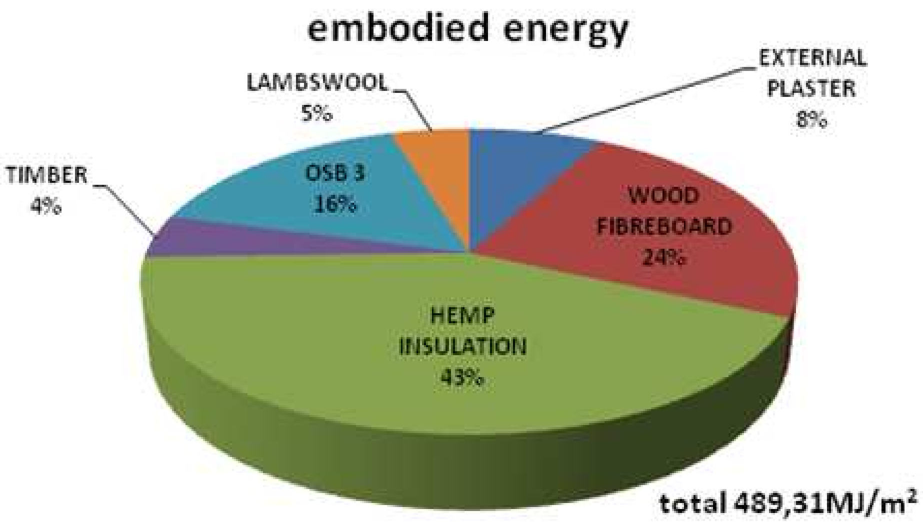


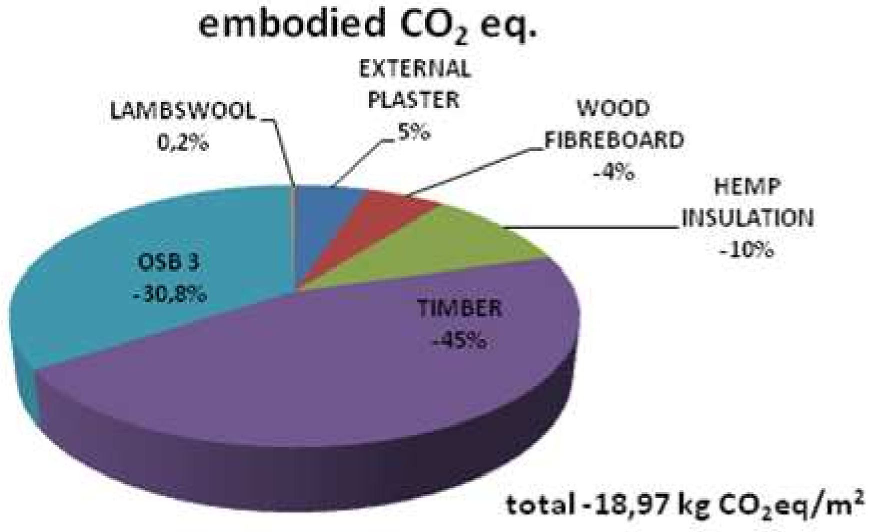
OPTIMIZATION OF EXTERNAL WALLS

2B



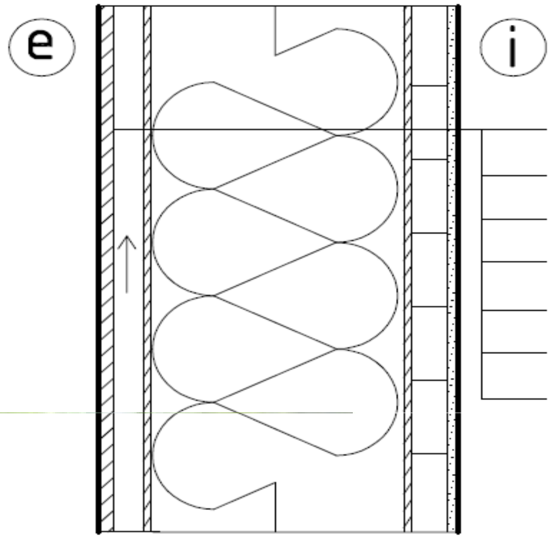
EXTERNAL DIFFUSION PLASTER	8mm
WOOD FIBREBOARD MDF	25mm
HEMP INSULATION BETWEEN I JOISTS	300mm
OSB 3 WITH TAPE- AIRSTOP	12,5mm
INSTALATION GAP WITH LAMBSWOOL	60mm
PLASTERBOARD	15mm



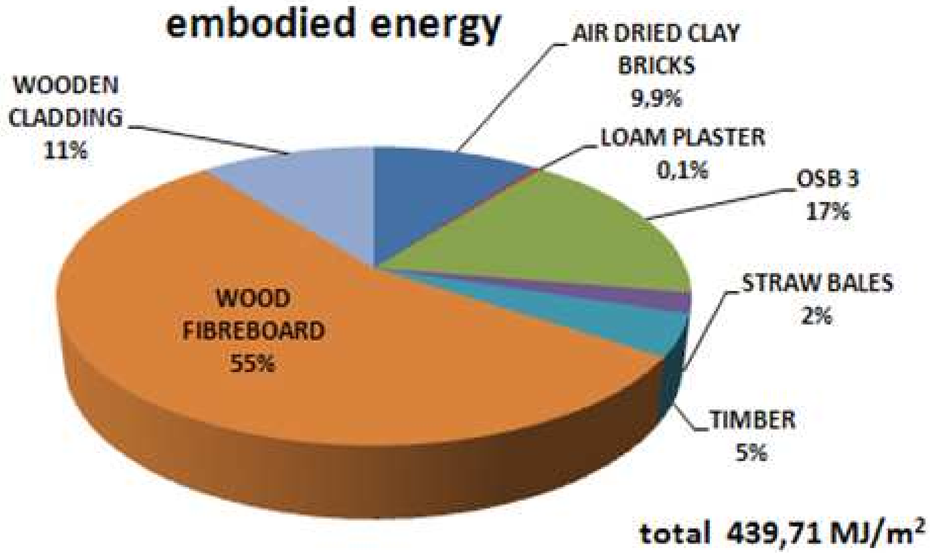


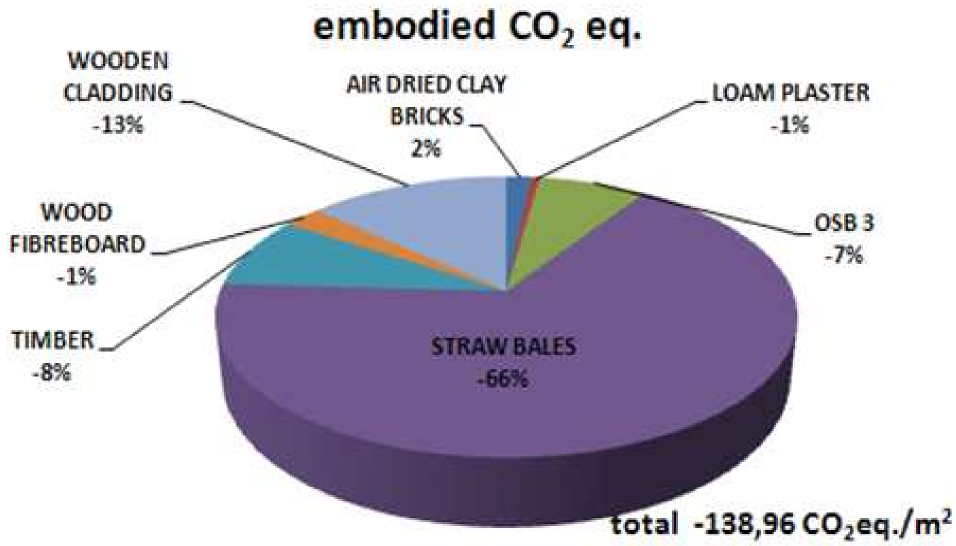
OPTIMIZATION OF EXTERNAL WALLS

2C



WOODEN WALL CLADDING (LARCH)	22mm
VENTILATION AIR GAP, WOOD LATHES	50mm
WOOD FIBREBOARD – pressed	18mm
STRAW BALES BETWEEN I-JOISTS	450mm
OSB 3 WITH AIRSTOP TAPE	12,5mm
AIR DRIED CLAY BRICK	65mm
LOAM PLASTER	10mm



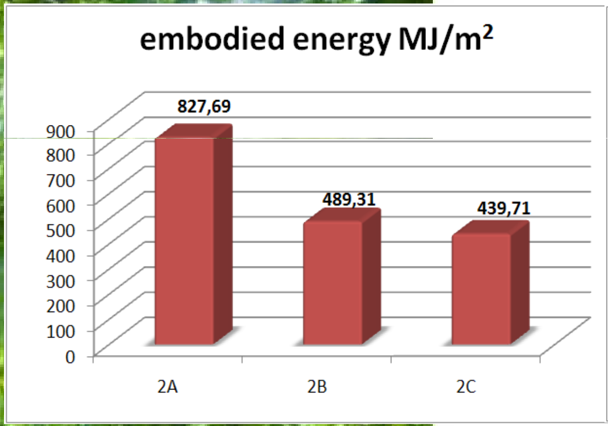


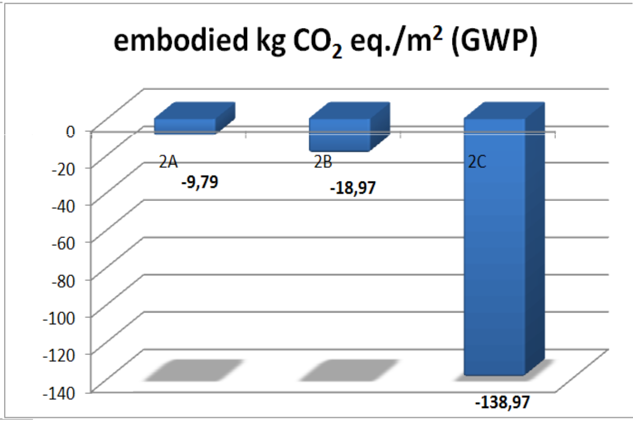
RESULTS OF ASSESSMENTS OF EXTERNAL WALLS

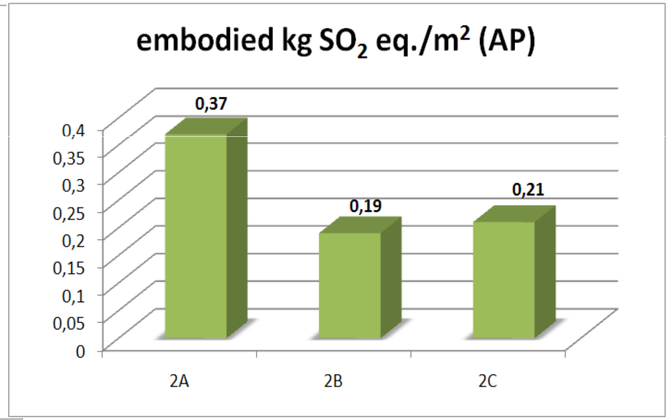
Selected thermal-physical parameters for external wall alternatives

	m [kg/ m²]	U [W/(m²K)]	Q [kJ]	D [-]	Ψ [hrs]	g_v [kg/m².yr]	g_k [kg/m².yr]
2A	90,15	0,099	133,41	9,23	24,94	<0,5	0
2B	40,41	0,102	60,60	4,56	12,30	<0,5	0
2C	211,20	0,106	263,12	9,03	24,38	8,597	0,010

Total results of environmental assessment for external wall alternatives



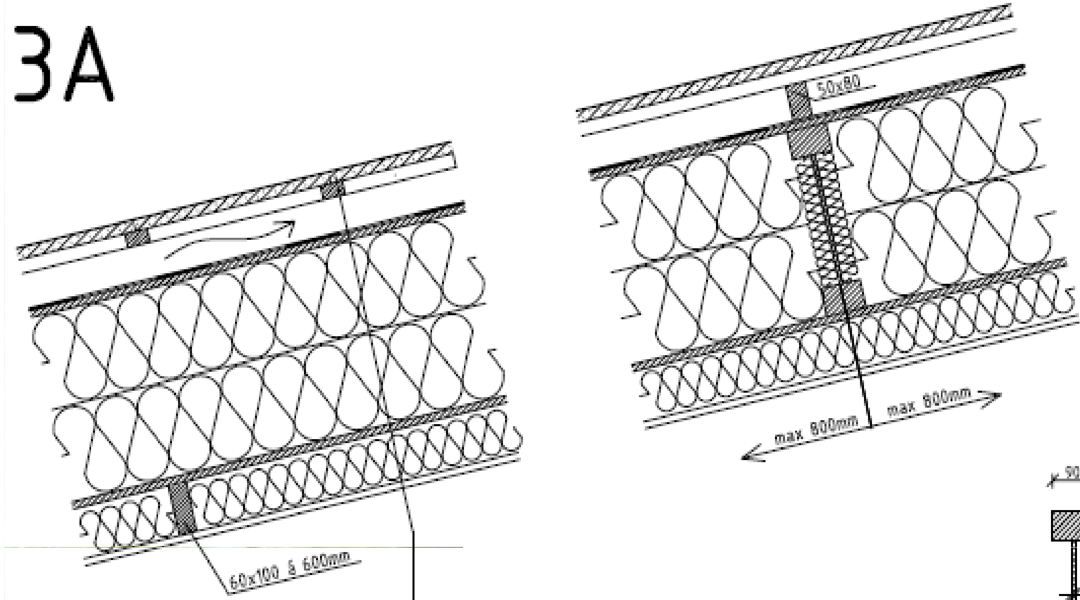


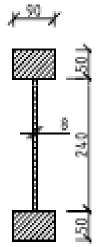


The construction alternative **2C** is the most sustainable from evaluated alternatives. This variant achieves the best results in terms of GWP because participates in reducing of more than **130 kg CO_2 eq. emis**sions. It is about **11%** preferable to alternative **2B** in terms of embodied energy and about more than **630%** in terms of embodied CO_2 eq. emissions. The alternative 2C accounts positive influence on the future operational energy consumption.

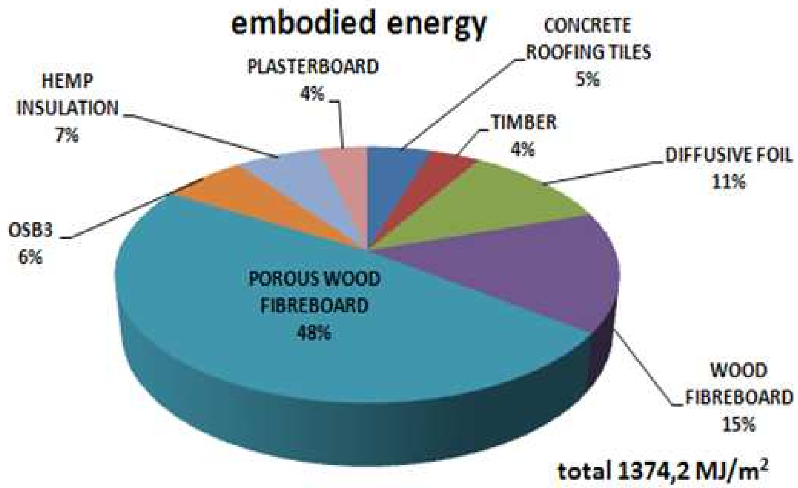
OPTIMIZATION OF ROOF CONSTRUCTION

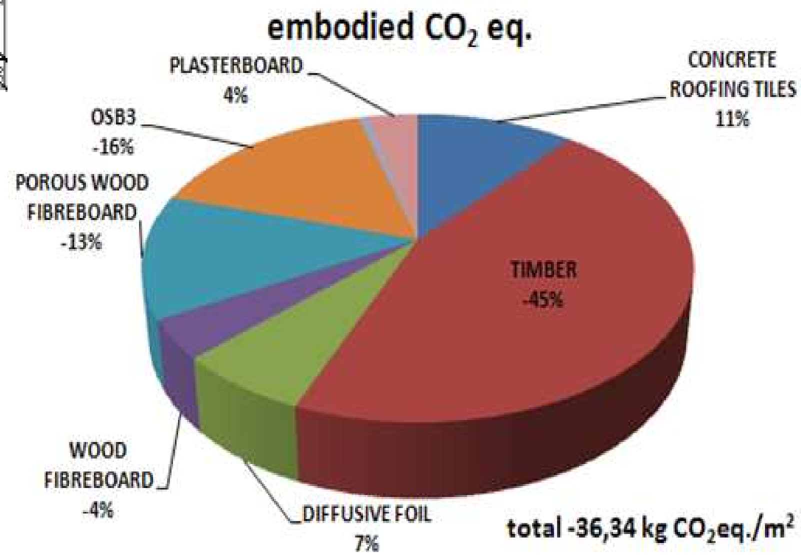
3A





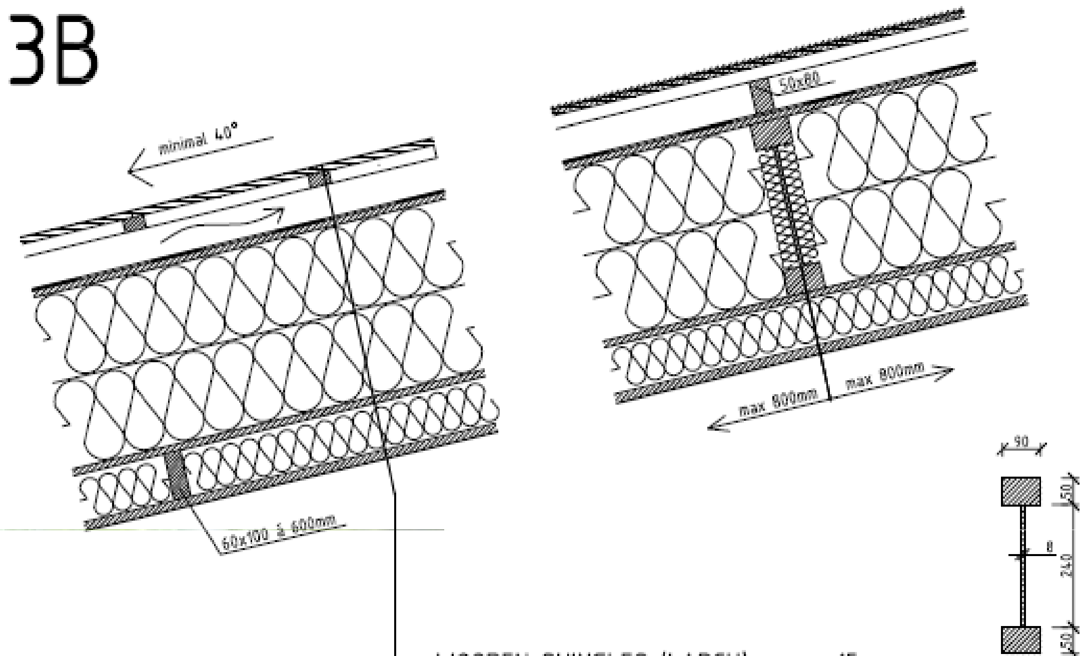
CONCRETE ROOFING TILES	25mm
CONTRALATHES	30mm
VENTILATION AIR GAP	100mm
DIFFUSIVE FOIL	
(INSURED DAMP PROOF COURSE)	8mm
WOOD FIBREBOARD-pressed	16mm
POROUS WOODEN FIBREBOARD	340mm
OSB 3 WITH TAPE- AIRSTOP	15mm
HEMP INSULATION WITH PE	100mm
PLASTERBOARD	15mm



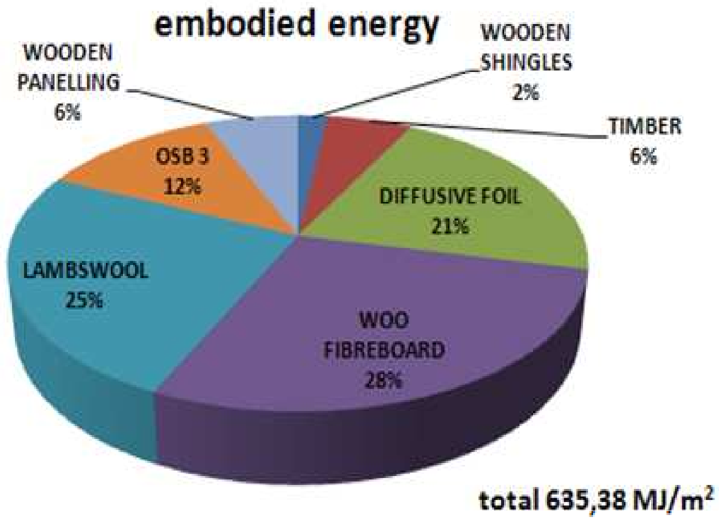


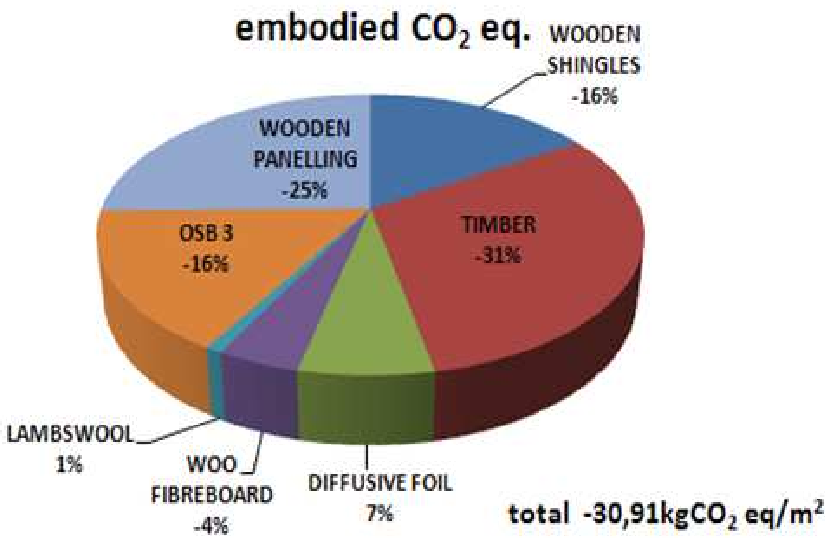
OPTIMIZATION OF ROOF CONSTRUCTION

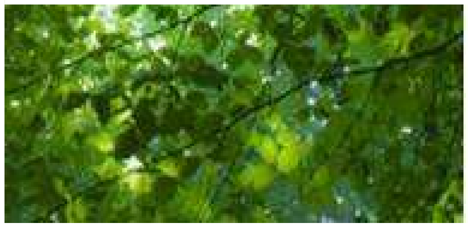
3B



WOODEN SHINGLES (LARCH)	15mm
CONTRALATHES	30mm
VENTILATION AIR GAP	100mm
DIFFUSIVE FOIL	
(INSURED DAMP PROOF COURSE)	8mm
WOOD FIBREBOARD-pressed	16mm
LAMBSWOOL INSULATION	340mm
OSB3 WITH TAPE- AIRSTOP	15mm
LAMBSWOOL	100mm
WOODEN PANELLING (BEECH)	22mm

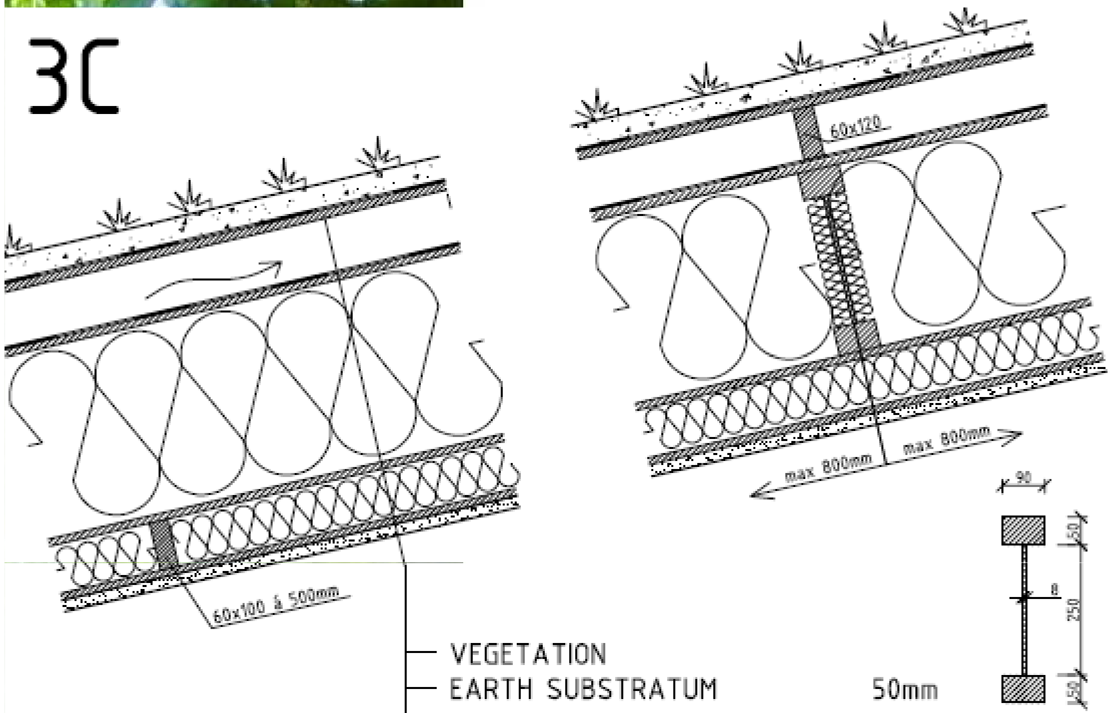




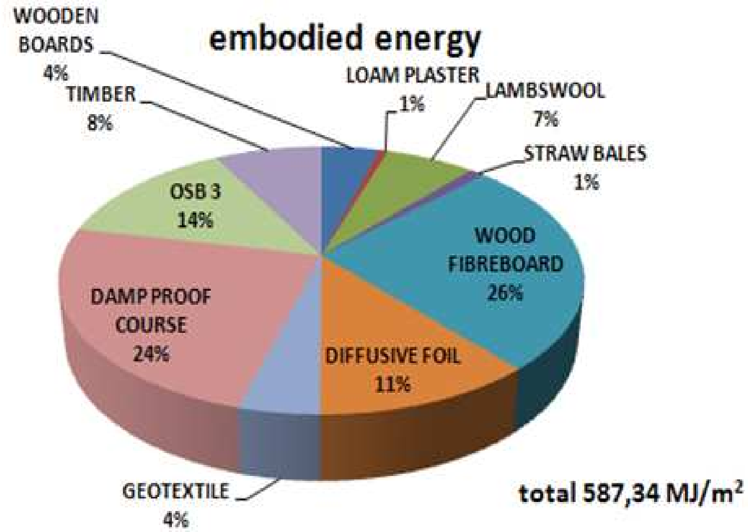


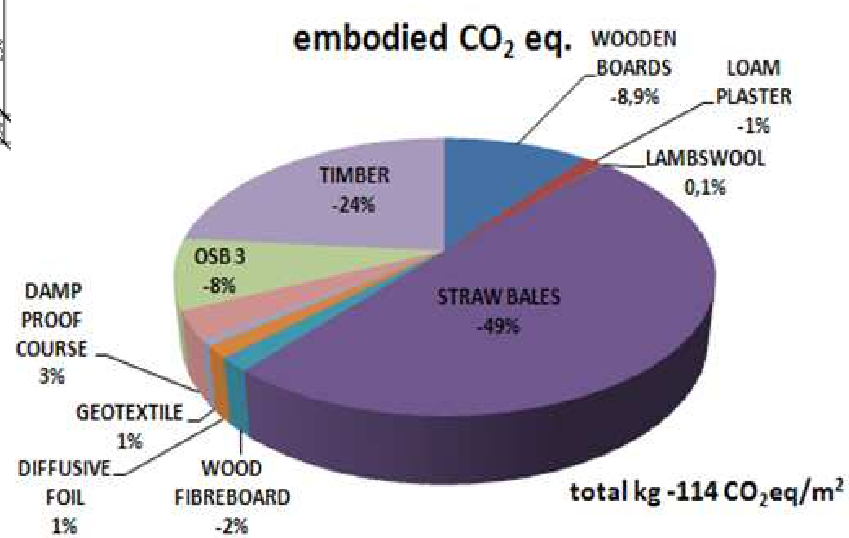
OPTIMIZATION OF ROOF CONSTRUCTION

3C



VEGETATION	
EARTH SUBSTRATUM	50mm
GEOTEXTILE	
DAMP PROOF COURSE -PVC	1,5mm
GEOTEXTILE	
WOODEN BOARD	18mm
VENTILATION GAP	120mm
DIFFUSIVE FOIL (INSURED DAMP PROOF COURSE)	8mm
WOOD FIBREBOARD-pressed	16mm
STRAW INSULATION	400mm
OSB 3 WITH TAPE - AIRSTOP	15mm
LAMBSWOOL	120mm
LOAM PLASTER+JUTE	25mm



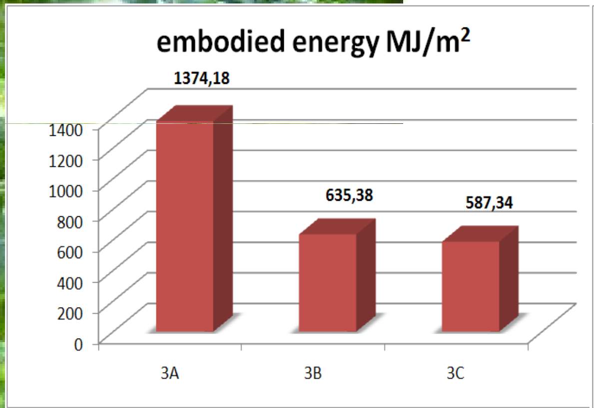


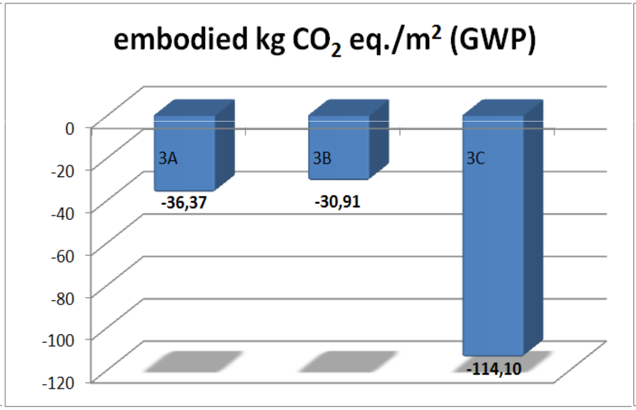
RESULTS OF ASSESSMENTS OF ROOF CONSTRUCTIONS

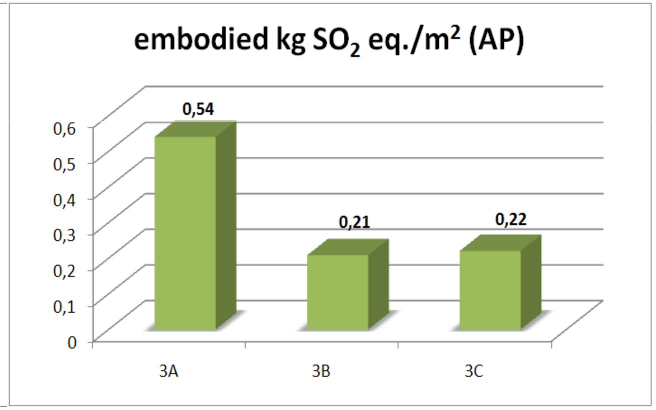
Selected thermal-physical parameters for roof construction alternatives

	m [kg/ m^2]	U [W/(m^2K)]	Q [kJ]	D [-]	Ψ [hrs]	g_v [kg/m^2.yr]	g_k [kg/m^2.yr]
3A	139,89	0,089	165,25	9,96	26,90	8,432	0,002
3B	65,88	0,087	102,02	5,59	15,09	‹0,5	0
3C	224,08	0,085	192,81	9,47	25,59	3,255	1,264

Total results of environmental assessment for roof construction alternatives





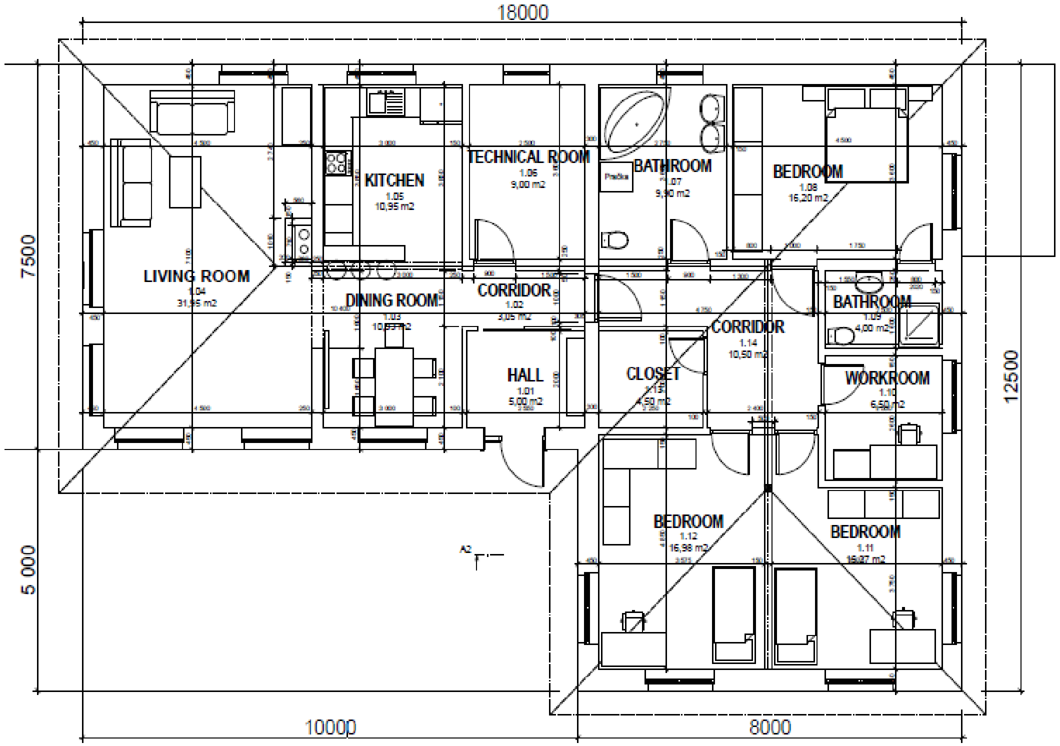


The alternative of roof construction **3C** is the most sustainable from designed alternatives. This alternative of extensive green roof proves the most suitable results of environmental and thermal-physical assessment. It is about more than **8%** preferable to alternative **3B** in terms of embodied energy and is about **214%** preferable to alternative **3A** from this point of GWP. The variant **3C** achieves excellent results in terms of thermal-physical assessment.

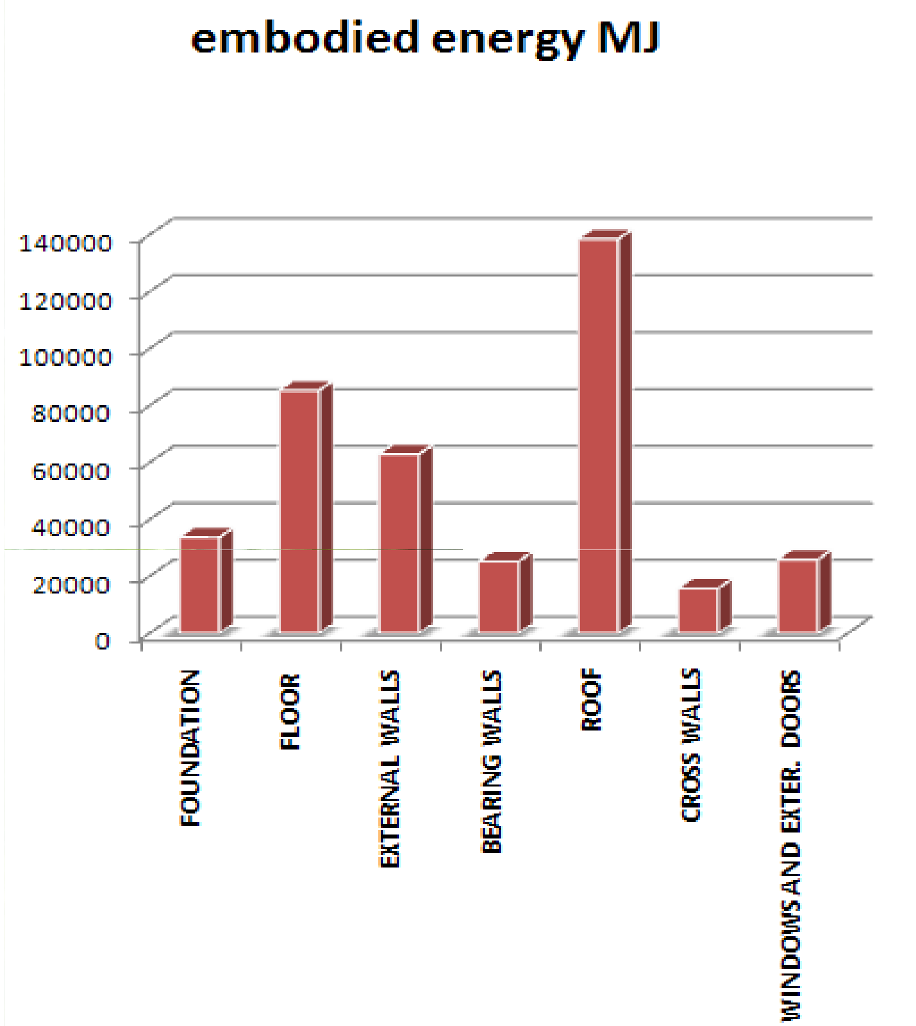
CONCLUSION

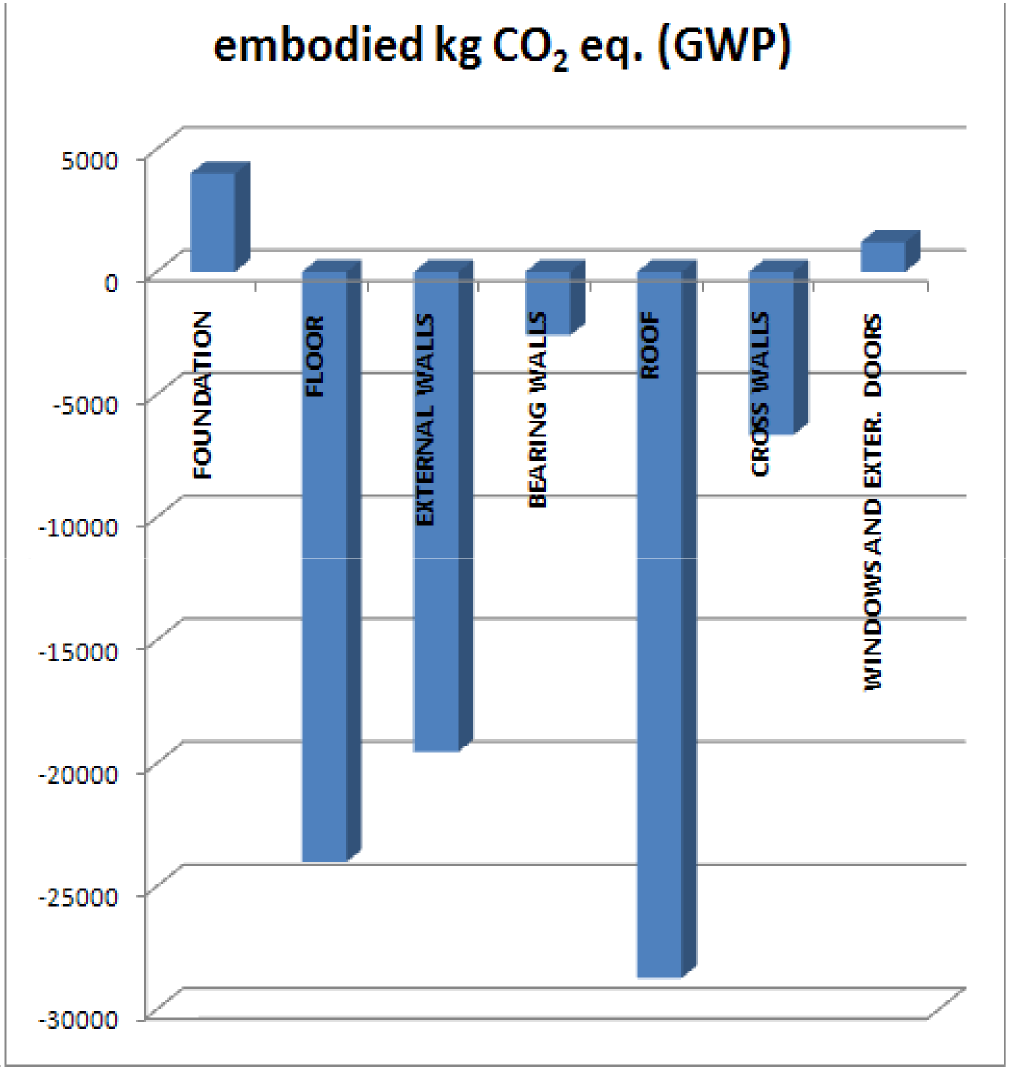
The results of **environmental** and **thermal-physical** assessments and decision analysis demonstrate that the alternative of floor **1C** of external wall **2C** and of roof construction **3C** are the best from long-term point for **green residential building**.

The optimized construction alternatives are used for designed passive bungalow which is situated **in Košice**, in Eastern part of Slovakia. The average summer temperature is about 20.5° C and average winter temperature is about -13° C.



RESULTS OF EMBODIED ENERGY AND EMBODIED CO_2 eq. FOR PARTICULAR CONSTRUCTIONS OF BUNGALOW





Total embodied energy MJ	Total embodied kg CO_2 eq. emissions
387 374.489	**-76 291.390**

CONCLUSION

The applied clearly natural plant materials are achieved to store great amount of CO_2 emissions as locked carbon in envelope of house after phase of demolition. This wood-framed house determines reduction of more than **76 to**n of CO_2 eq. emissions what corresponds to approximately **550 kg** of CO_2 eq. emissions per square meter of its floor area.

The **plant** and other **clearly natural** building materials are perspective way to **optimization design of green building** in conditions of the Slovak Republic.

green wood-framed house → philosophy of healthy housing

The principle of **optimization of material and energy flows within whole life** cycle is one of the basic principles **of sustainable development. Sustainable or green construction** is thus one of the most important challenges we face. And the potential for improvement is huge.


THANK YOU
FOR YOUR ATTENTION