CESB16

Central Europe towards Sustainable Building 2016
Innovations for Sustainable Future

Development and performance of a curtain wall system using modern wood products and other progressive materials with respect to the environment

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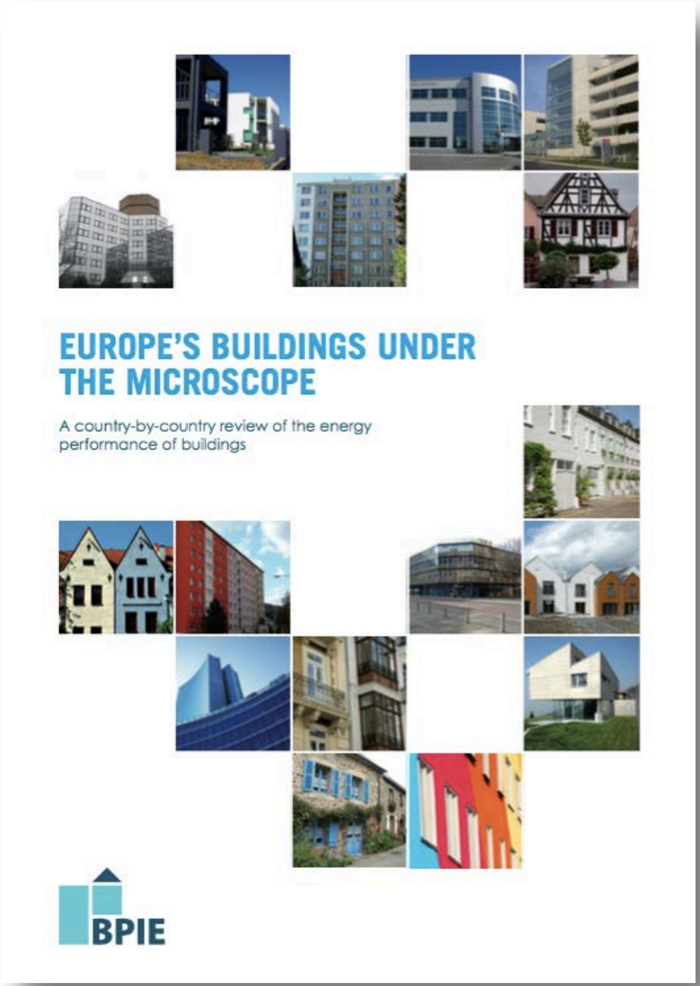
INTRODUCTION

Faculty of Civil Engineering

University Centre for Energy Efficient Buildings

BACKGROUND



EU targets

- **20% reduction in primary energy** consumption in EU **until 2020**
- Focus on sectors with the highest saving potential for the lowest investment – transportation and **construction industry**

EU Building stock

- 25 % non-residential
- 45 % built between 1961 and 1990

SCOPE

Central European non-residential buildings built in 1960's – 1980's featuring light curtain walls

Typical for:

- schools
- kindergartens
- office buildings
- medical centers
- firemen and police stations
- railway facilities
- hotels
- restaurants

Public elementary school in Pilsen

Elementary school in Prague

Office building in Köln am Rhein

Office building in Beograd

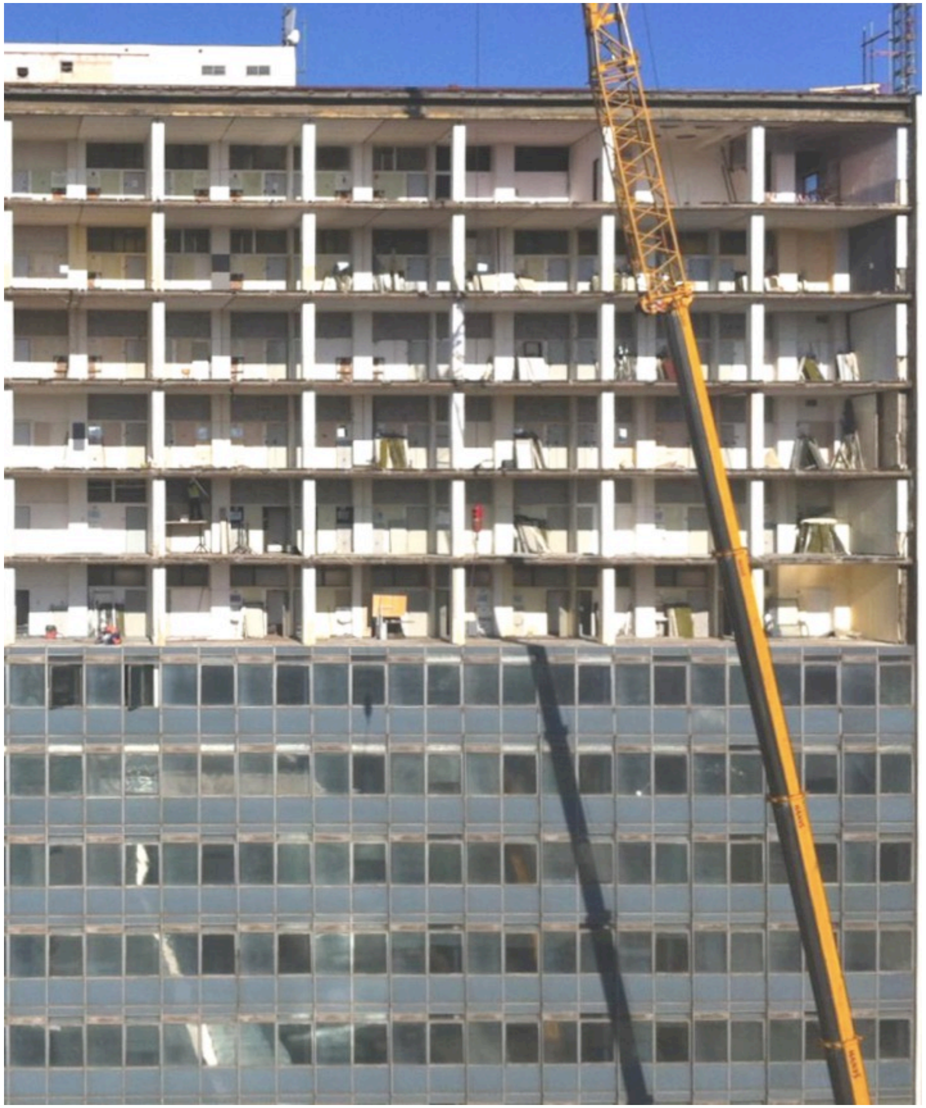
Railway station in Munich

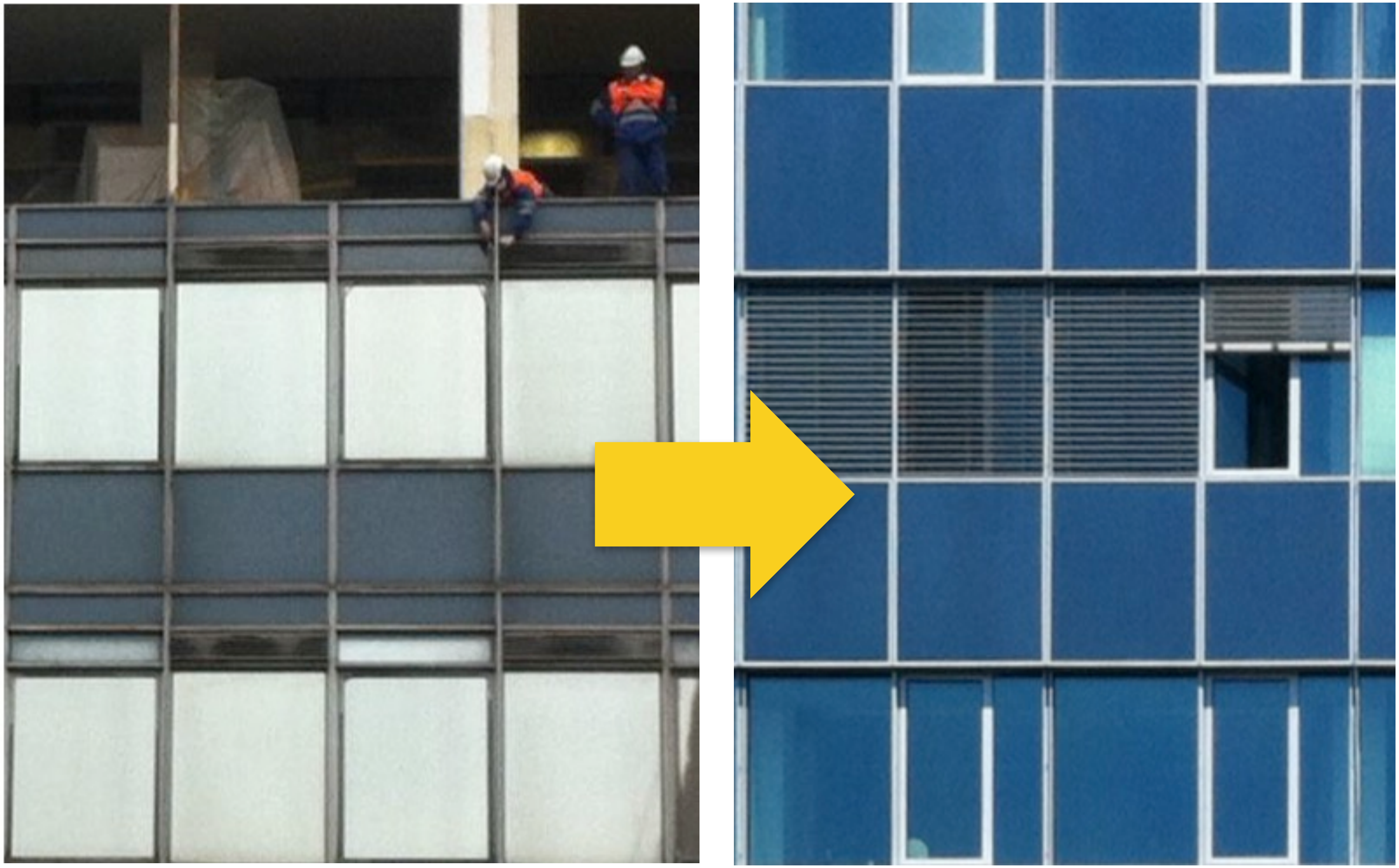
TYPICAL ISSUES OF CURTAIN WALLS

- Insufficient thermal insulation and insufficient air tightness and related winter discomfort and high operation cost
- Lack of shading devices resulting in summer overheating
- Malfunction of window hinges and locks rendering some windows out of order
- Asbestos contents and related health risks
- Glazing units failures, failures of fixing and seal elements, water leakages
- Faded colors, obsolete look and loss of attractiveness for potential tenants

TYPICAL RENOVATION SCENARIOS

- **Low-cost scenario**
  Application of a supplemental cladding
  (when existing framing is in good shape and capable of supporting additional layers)
- **Economic scenario**
  Curtain wall replacement by mullion walls made of light autoclaved aerated concrete bricks with external thermal insulation system (ETICS) and plastic windows
- **Standard scenario**
  Complete removal of the existing CW and replacement by modern CW system (usually aluminium or steel)





$U_{em} \approx$ **3.0** $W/(m^2K)$

Opaque U = 0.6

Glazing U = 4.0

$U_{em} \approx$ **0.7** $W/(m^2K)$

Opaque U = 0.19

Glazing U = 0.5

(+ thermal couplings)

Metals have drawbacks in vulnerability to systematic thermal bridges due to their high thermal conductivity and significant environmental impacts

Could we make it better?

R&D objectives:

- Lower environmental impacts in comparison with conventional CWs
- Over 50% of the mass to consist of renewable materials
- Maximum utilization of local materials
- The CW production technology to generate minimum waste
- Easy maintenance
- Dismantling and recyclability of the CW to be as simple as possible

DESIGN STRATEGY

57 Annex 57 IEA EBC Annex 57

Evaluation of Embodied Energy and CO_{2eq} for Building Construction

EBC Energy in Buildings and Communities Programme

Design strategies for reduction of embodied energy and embodied carbon

- Reduction of amount of needed materials throughout entire life cycle
- Substitution of traditional materials for alternatives with lower environmental impacts
- Reduction of construction stage impact

→ More details at www.annex57.org

DESIGN STRATEGY

Substitution of traditional materials for alternatives with lower environmental impacts

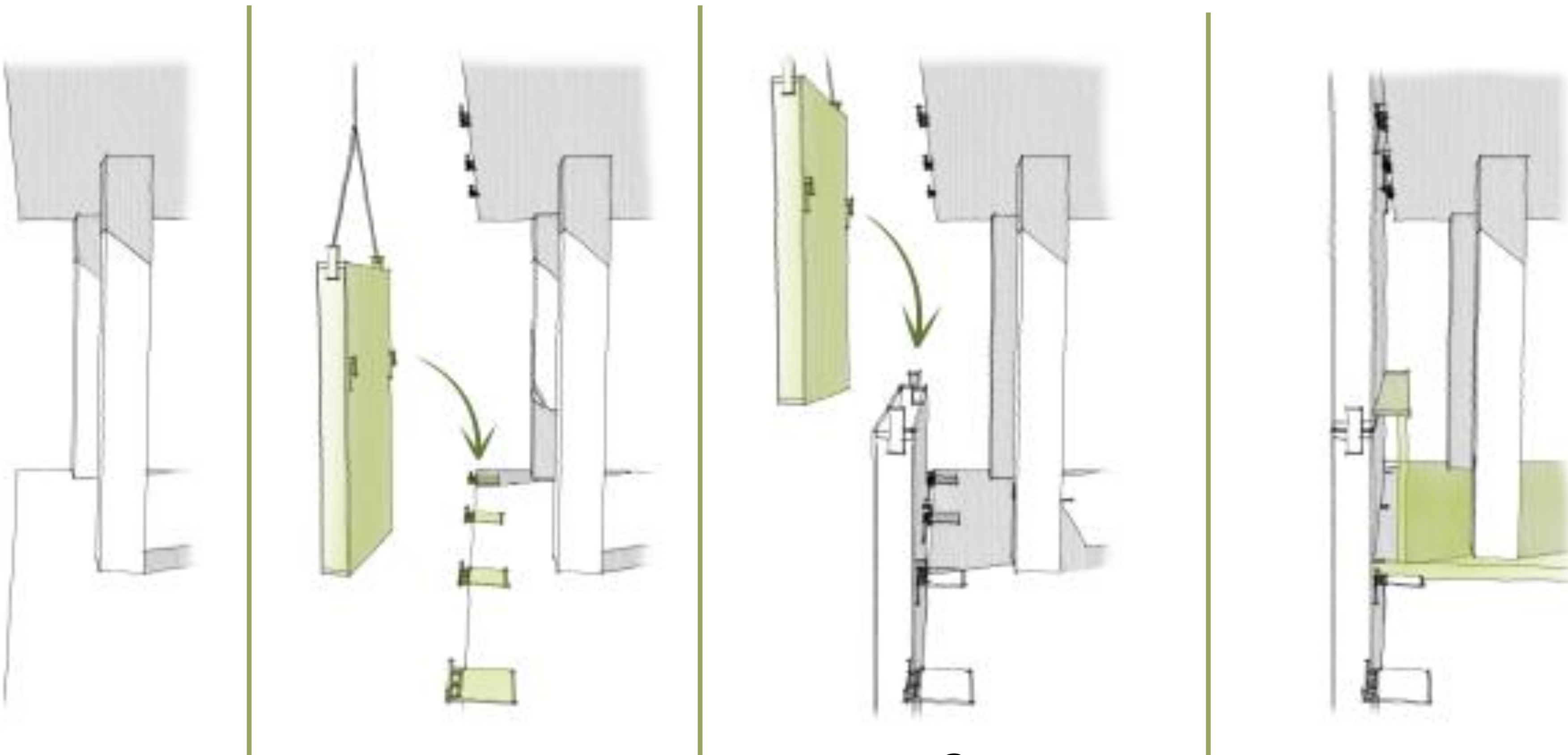
- **Frame:** laminated veneer lumber (LVL)
- **Plates:** DHF fibreborad, OSB
- **Thermal insulation:** wood fiber 240 mm, vacuum panels, cork
- **External cover:** Thermowood
- **Windows:** wooden, triple glazing, PHI certified
- **Shading devices:** integrated venetian blinds
- **Renewables:** BIPV





DESIGN STRATEGY

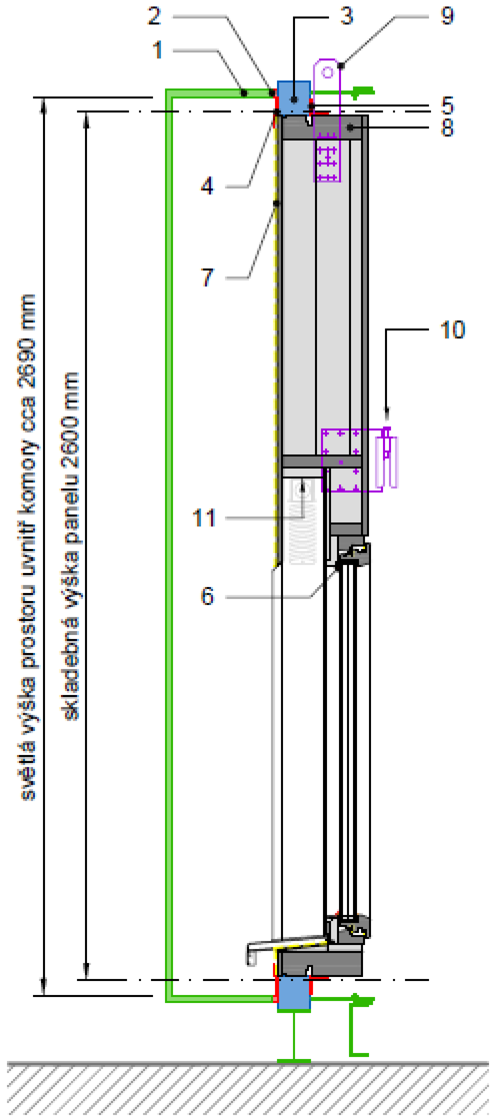
Reduction of construction site impact

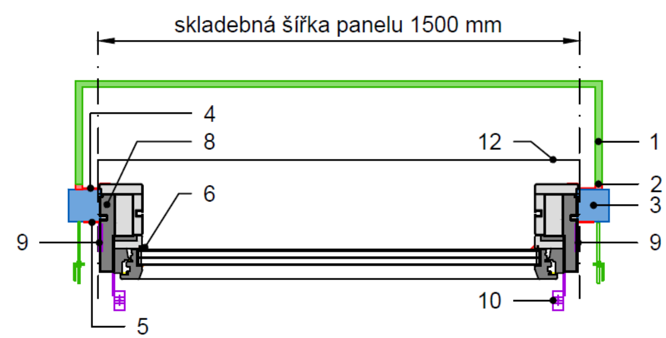


1 **2** **3** **4**

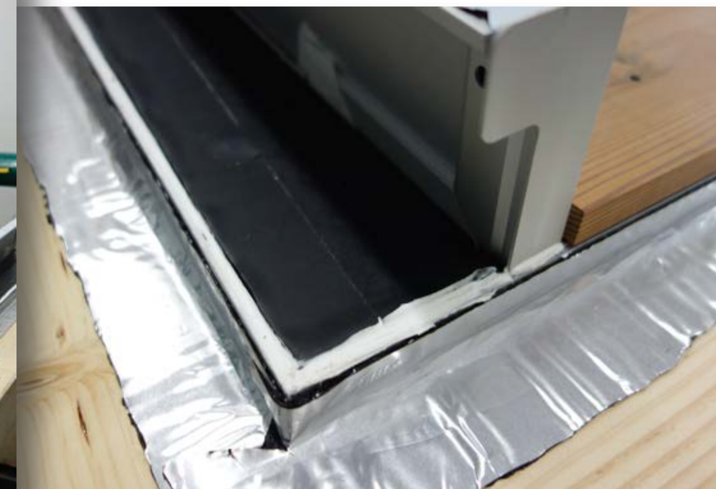
4 steps of assembly onsite

SAMPLING AND PROTOTYPING

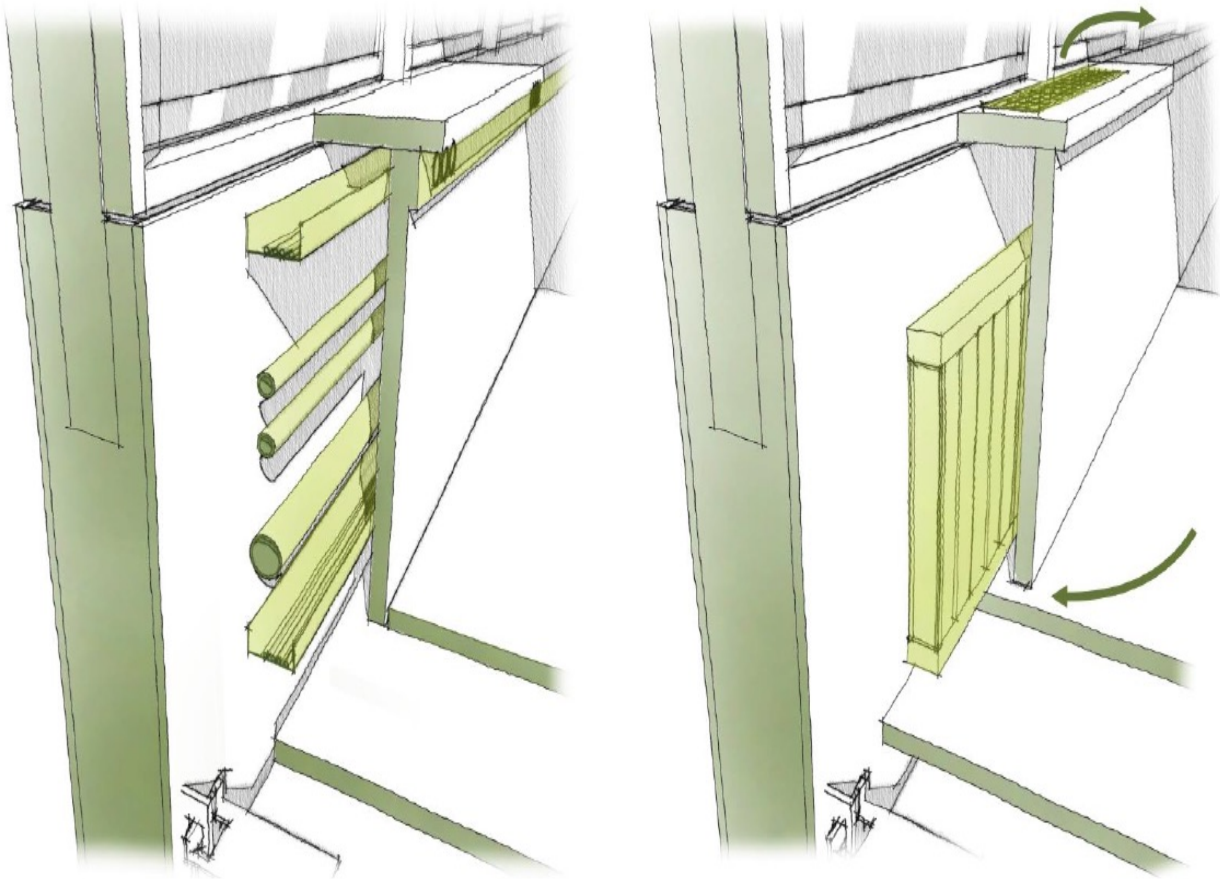




SAMPLING AND PROTOTYPING

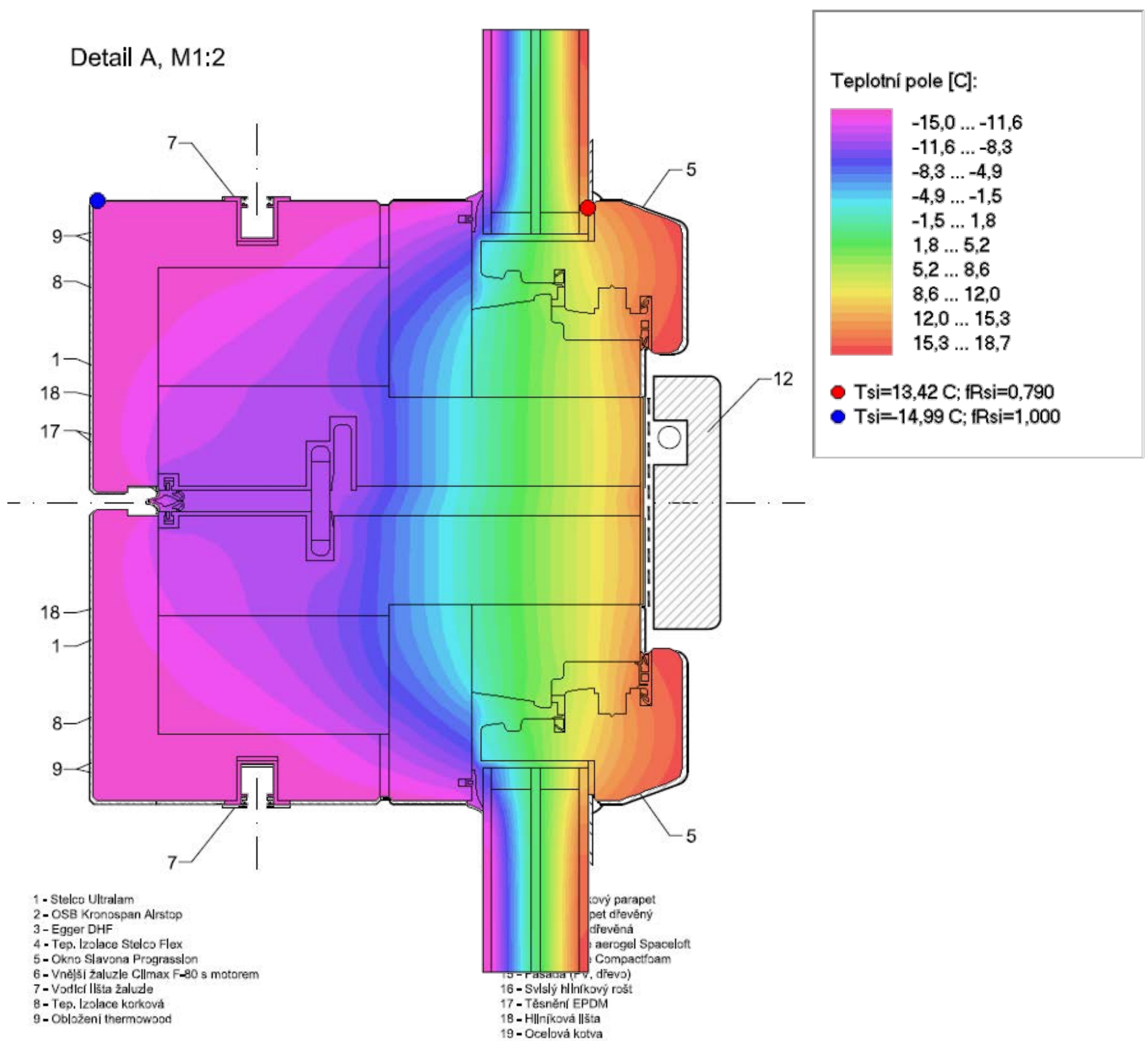


SKETCHING AND MODELLING



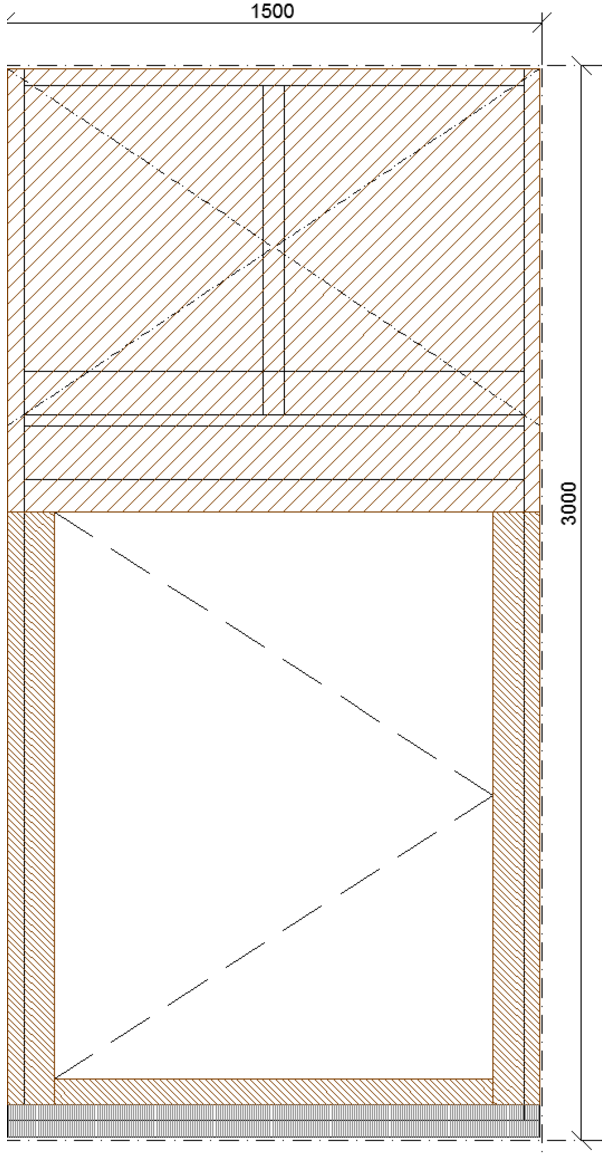
SIMULATIONS

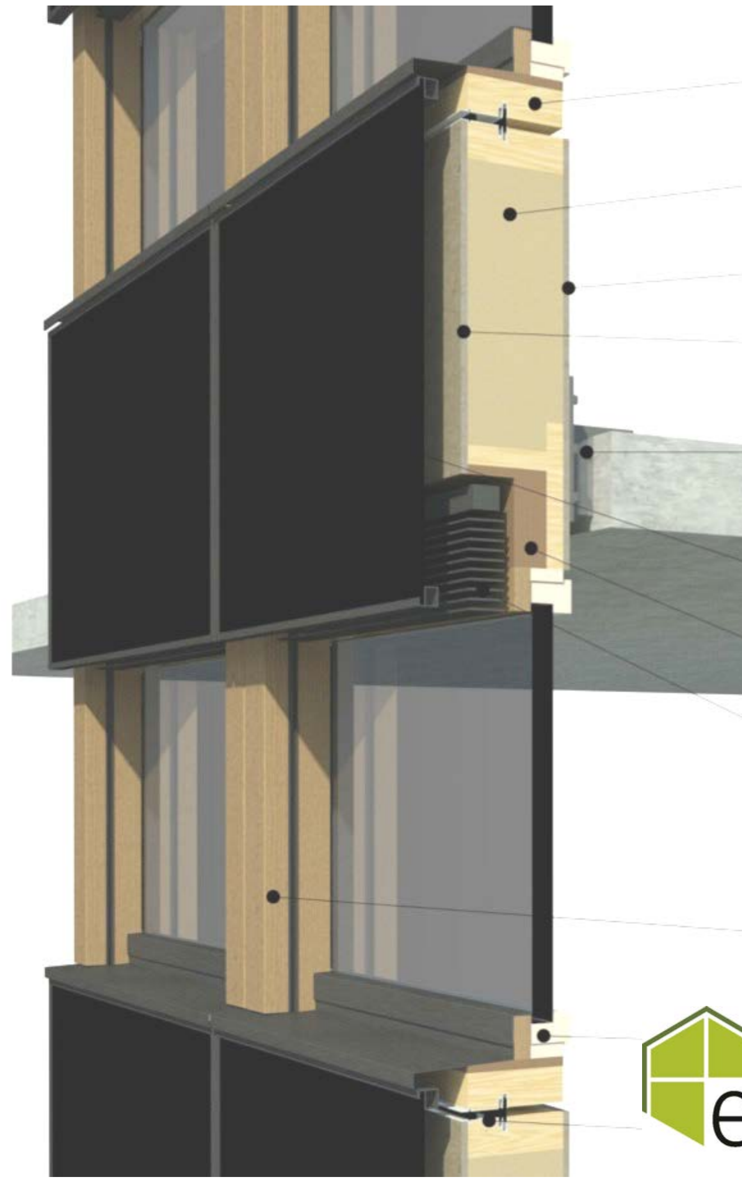
Joint of two panels (horizontal section)



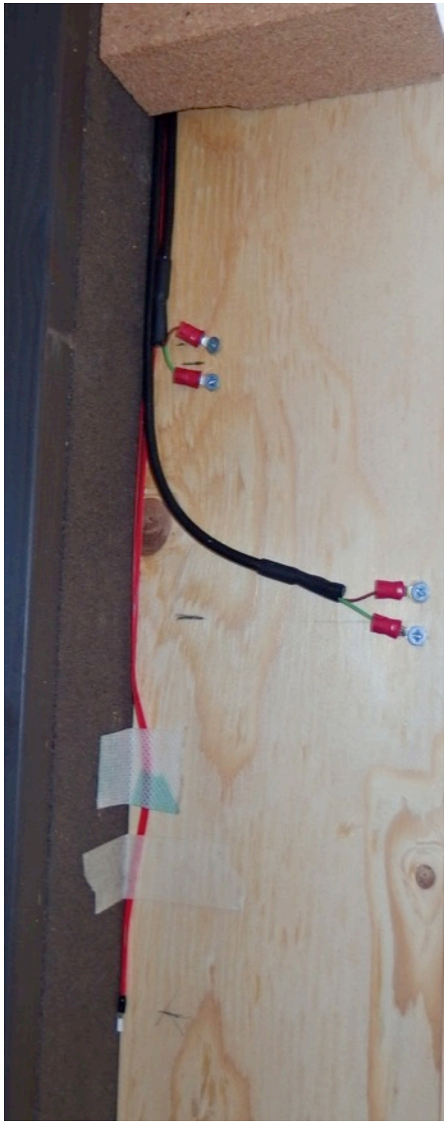
FINAL DESIGN

FULL-SCALE ASSEMBLY AND MONITORING





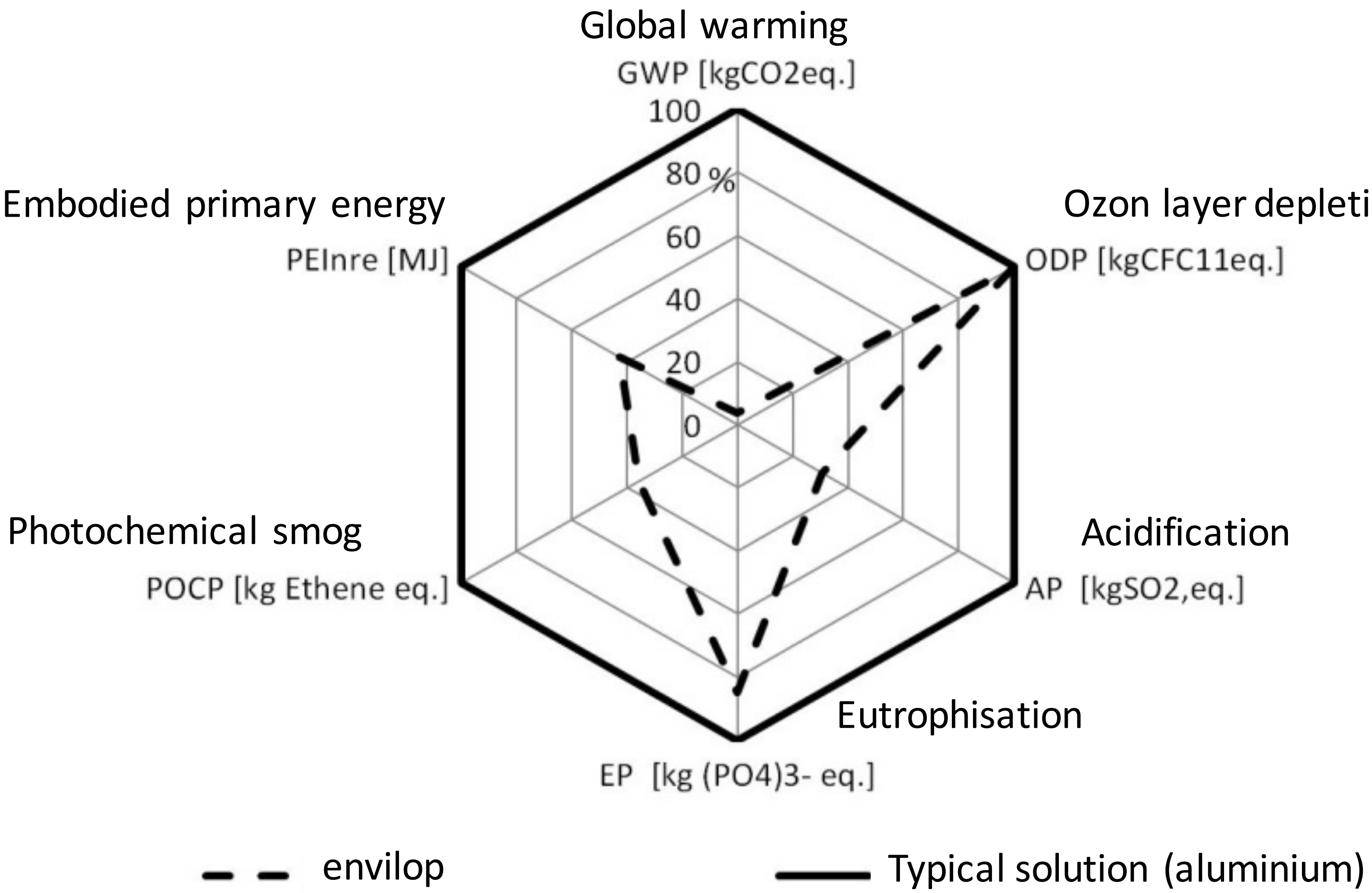
FULL-SCALE ASSEMBLY AND MONITORING



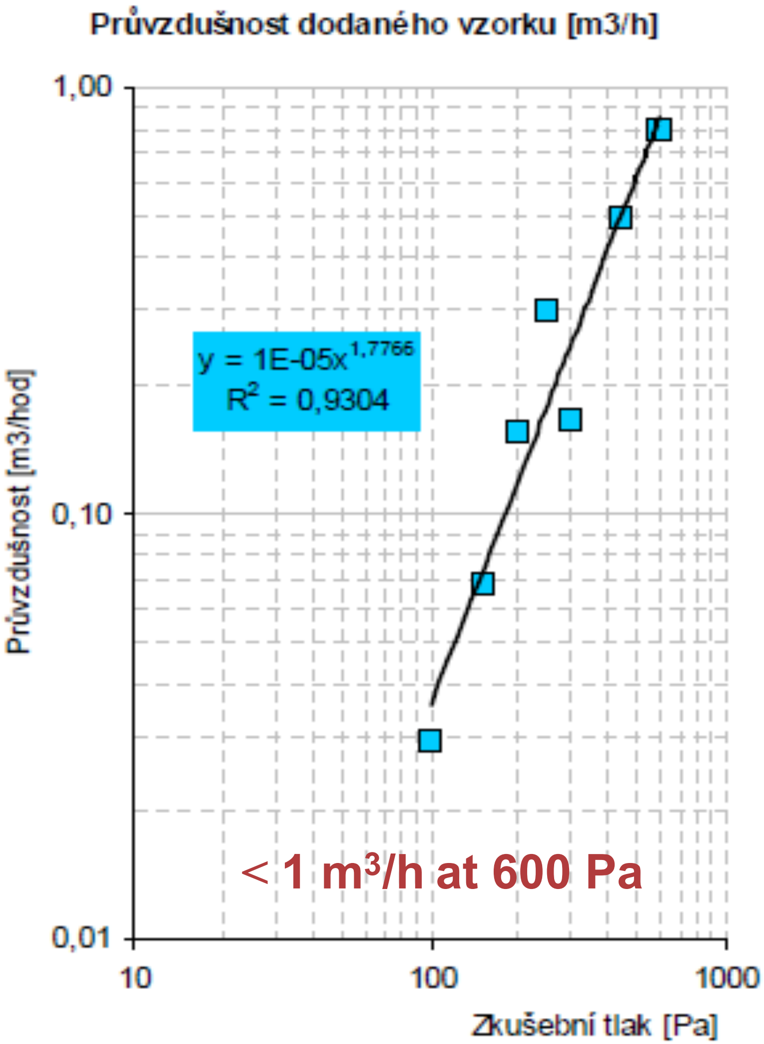
FULL-SCALE ASSEMBLY AND MONITORING

LIFE CYCLE ASSESSMENT

Functional unit: 1 CW panel with of 3.3 x 1.5 meters with an integrated transparent part (window of 1.8 m^2) and thermal performance expressed by thermal transmittance of U= 0.57 W/m^{2}K.



TESTING OF AIR- AND WATER-TIGHTNESS



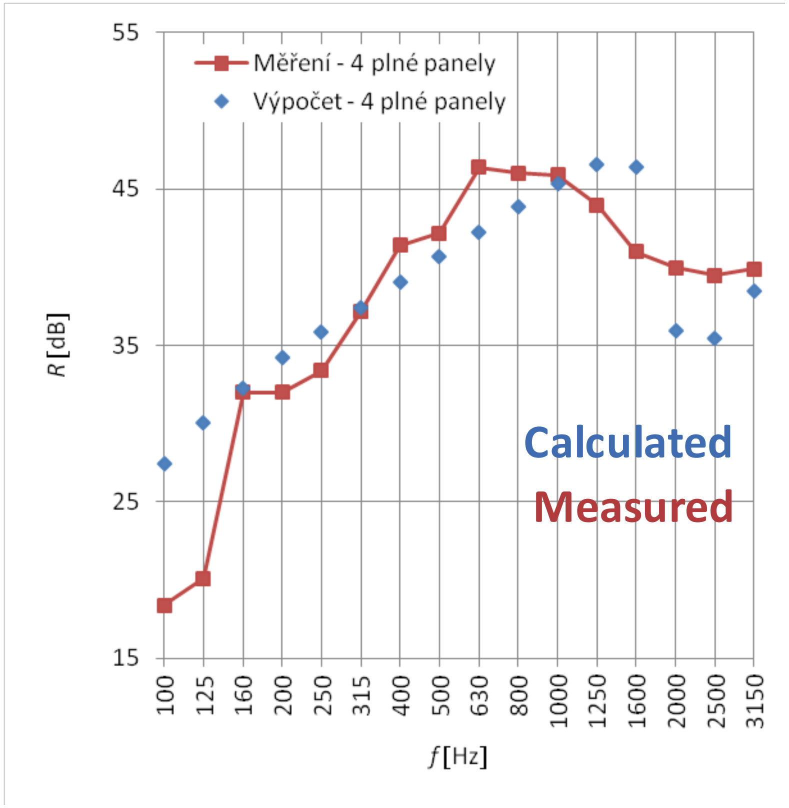
< 1 m³/h at 600 Pa

TESTING OF AIR- AND WATER-TIGHTNESS

- Air intake: --
- Water intake: only in horizontal joint without airstop tapes, only for gap 12 mm by pressure 1200 Pa → improved design

TESTING OF ACOUSTIC PROPERTIES

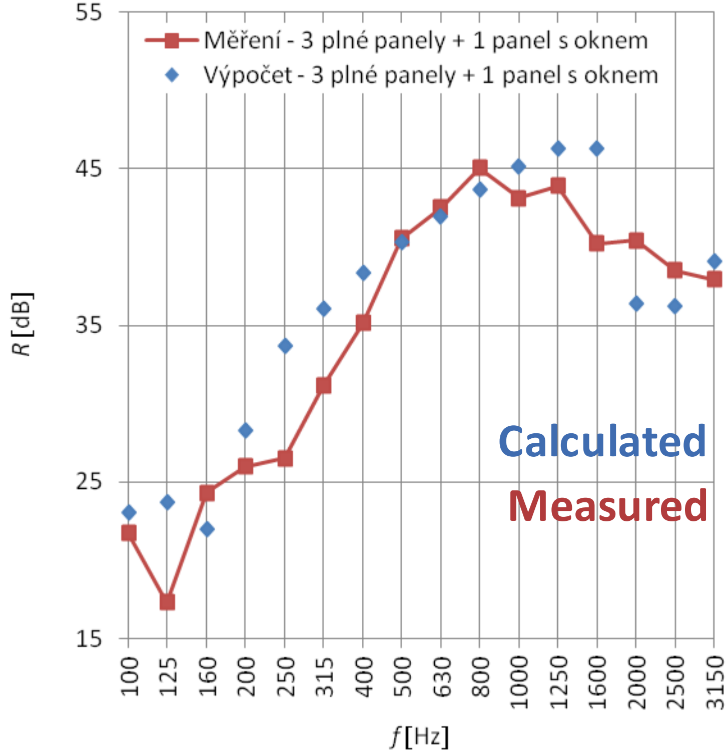
Opaque panel



R_w $(C;\ C_{tr})$ = **41** (-2; -6) dB

TESTING OF ACOUSTIC PROPERTIES

Transparent panel



R_w $(C; C_{tr})$ = **38** (-2; -5) dB

TESTING OF ACOUSTIC PROPERTIES

Required airborne sound insulation of external walls, R'_w (dB)

Equivalent A-weighted sound pressure level 2 m in front of the building facade, L_{Aeq} (dB)							
Daytime or operation	≤ 50	> 50 ≤ 55	> 55 ≤ 60	> 60 ≤ 65	> 65 ≤ 70	> 70 ≤ 75	> 75 ≤ 80
Night time	≤ 40	> 40 ≤ 45	> 45 ≤ 50	> 50 ≤ 55	> 55 ≤ 60	> 60 ≤ 65	> 65 ≤ 70
Hotel rooms							
Day	30	30	30	30	33	38	43
Night	30	30	30	30	33	38	43
Classrooms, lecture rooms (kindergartens, schools, universities)							
Operation time	30	30	30	30	33	38	(43)
Meeting rooms and offices							
Operation time	-	-	30	30	30	33	38

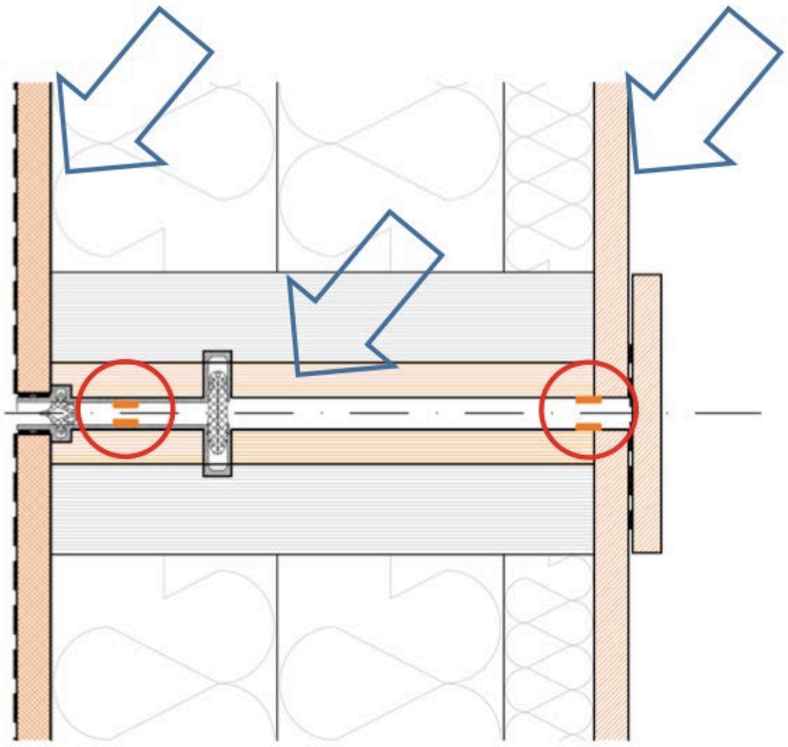
FIRE RESISTANCE

FIRE RESISTANT VERSION

National limitations for timber structures:

- Max height 12 m above ground (without active fire protection systems)
- Restrictions on min distance to other buildings – **can be reduced, if EI(W) 45 min. is reached**

→ Design of fire resistant alternative



Alterations

- OSBs replaced by gypsum and cement boards
- Added expandable strips in joints

envilop fire

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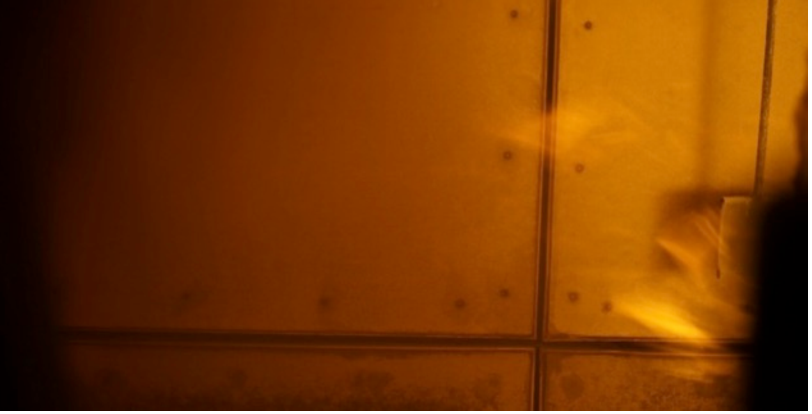
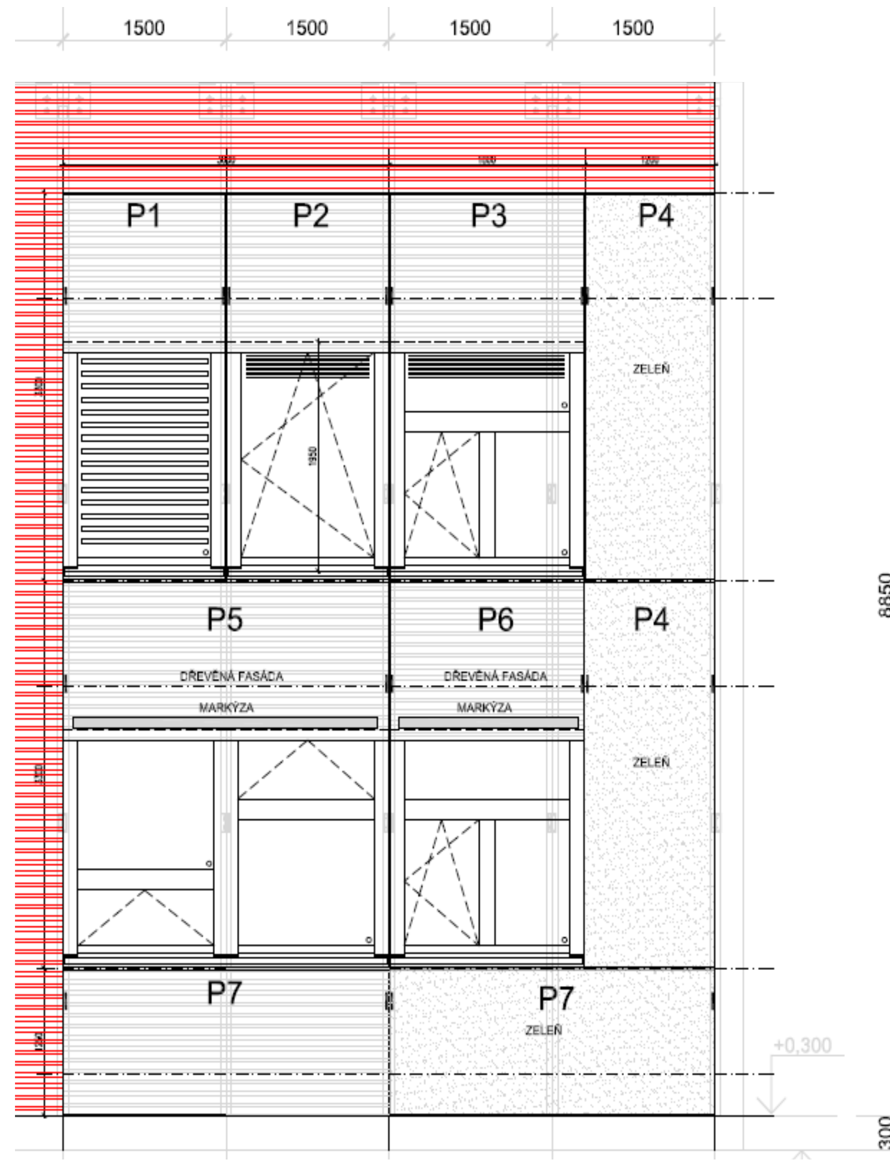


Measured fire resistance (according to ČSN EN 1364-3:2014)

- Fire from exterior side at least **90 min** EI(I<O) 90 DP3
- Fire from interior side at least **60 min** EI(I>O) 60 DP3

LARGE SCALE PILOT



CONCLUSIONS

- Alternative building envelope system has been successfully developed, tested and is being brought to market
- The project proved that bio-based envelopes for buildings represent a viable alternative to the traditional metallic systems
- Synergy of natural materials with advanced technologies is viable way to explore
- Designed envelope system matches or surpasses the state of the art in technical parameters and decreases the environmental impacts at the same moment
- Building envelope design is a complex task, requires multidisciplinary team and close cooperation with testing facilities


Thank you for attention
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