



This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 314678



BYGNINGSFYSIKK DAG – Oslo 2016

ENERGY EFFICIENCY FOR EU HISTORIC DISTRICTS SUSTAINABILITY

## TECHNICAL RESULTS FROM EFFESUS PROJECT WITH FOCUS ON IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

Cezary Misiowiecki, Arild Gustavsen

OSLO, 24 November 2016





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### INTRODUCTION

[EFFESUS MOVIE](#) (5 min introduction movie)



**EFFESUS (23 partners, 13 European states, 7 case studies)**

EFFESUS is a research project investigating the energy efficiency of European historic urban districts and developing technologies and systems for its improvement.

### Motivation:

More than 40% of our residential buildings have been constructed before the 1960s.

(BPIE. Europe's buildings under the microscope)

European building stock, 24% of residential buildings are pre 1945, and about half of these are of historic value

(Housing Statistics in the European Union 2010)



## INTRODUCTION

### Objectives:

The four **main scientific objectives** are:

- Categorization of European historic districts and development of a multiscale data model
- Evaluation, development and implementation of cost-effective technologies and systems for significantly improving energy efficiency in historic districts
- Development of a methodology and a software tool to assess energy retrofitting interventions in historic districts
- Overcoming technical and nontechnical barriers for the implementation of project results

The **main output** of the project will be a **Decision Support System (DSS)**, a software tool, which includes all the parameters needed to select suitable energy efficiency interventions for historic districts.



## EFFESUS INNOVATIONS FOR ENVELOPE RETROFITTING

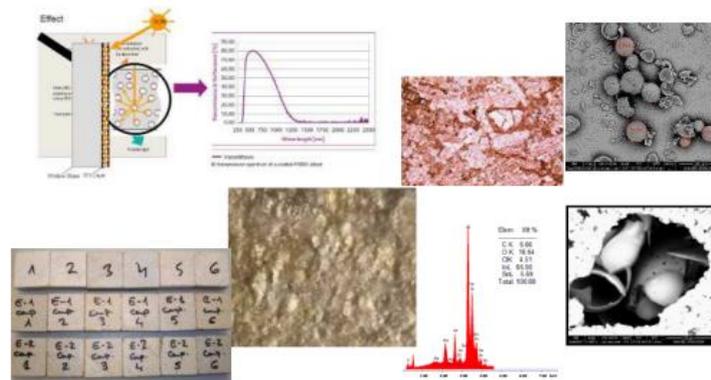
- Advanced **aerogel** as blow in insulation to optimise the insulations performance both in terms of used space as well as security for structural health and reversibility of intervention
- New **hydraulic lime-based** mortar with optimal insulating properties for use as plaster and render





## EFFESUS INNOVATIONS FOR ENVELOPE RETROFITTING

- New transparent and reversible **radiation selective coating** compatible with historic buildings to reduce the transfer of heat in façades, with the additional self-cleaning property and high water repellence



- **Efficient window** with new secondary glazing system for existing windows with minimal visual impact and maximum energy saving effect as well as flexible framing solutions in combination with use of low-energy coatings





## EFFESUS INNOVATIONS FOR ENVELOPE RETROFITTING

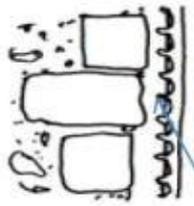
- Advanced **aerogel** as blow in insulation to optimise the insulations performance both in terms of used space as well as security for structural health and reversibility of intervention





## DEVELOPMENT OF ADVANCED AEROGEL AS BLOWN IN INSULATION

The intention of this task is to evaluate end proto-type a number of possible solutions including, but not limited to, aerogel band recycled scrap aerogel blanket.



Original wall  
Lath and plaster

Area to be insulated with  
injected insulation.





## DEVELOPMENT OF ADVANCED AEROGEL AS BLOWN IN INSULATION

### Early thoughts

- the aerogel blanket with an industrial wood chipper
- aerogel blanket in a smaller dimension 10mm cubes
- AST looked to create a more suitable aerogel as shown
- APG looked at the blowing machine manufacturers to adapt the machine to our requirements





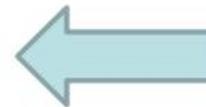
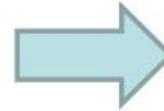
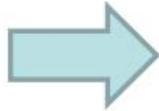
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## DEVELOPMENT OF ADVANCED AEROGEL AS BLOWN IN INSULATION

Final process of the Spacefill





## DEVELOPMENT OF ADVANCED AEROGEL AS BLOWN IN INSULATION

### Advantages:

- Conductivity down to  $0.0255 \text{ W/m}^2\text{K}$
- Fire Class E
- Easy to work with, limited dust,
- Good vapour transmission
- Reversible





## EFFESUS INNOVATIONS FOR ENVELOPE RETROFITTING

- New **hydraulic lime-based** mortar with optimal insulating properties for use as plaster and render





## NEW INSULATING MORTAR - ISOCAL

### GOALS FOR INSULATING MORTAR

- Technical compatible on historic substrates
- Acceptable in Cultural Heritage (cosmetic & technical/reversible)
- Applicable (normal requirements-conditions substrate, professional execution)
- Preferably inside & outside, if possible all relevant substrate types
- Affordable
- Innovative (items above + optimal insulation property)





## NEW INSULATING MORTAR - ISOCAL

### FORMULATION TEST NHL5-EPS INSULATING MORTAR - ISOCAL

#### Achievements

- develop mortar composition with high vol% EPS
- prepare mortar bars, flex.strength  $0.17 \text{ N/mm}^2$  (28d)  $0.22 \text{ N/mm}^2$  (90d)
- lambda-value  $0.063 \text{ W/m}^2\text{K}$

#### Advantage

- EPS cheap-available, light weight (building logistics, health-safety)

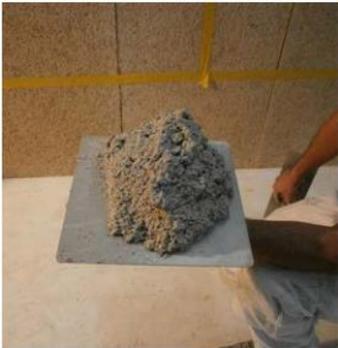




## NEW INSULATING MORTAR - ISOCAL

### APPLICATION TEST ISOCAL INSULATING MORTAR

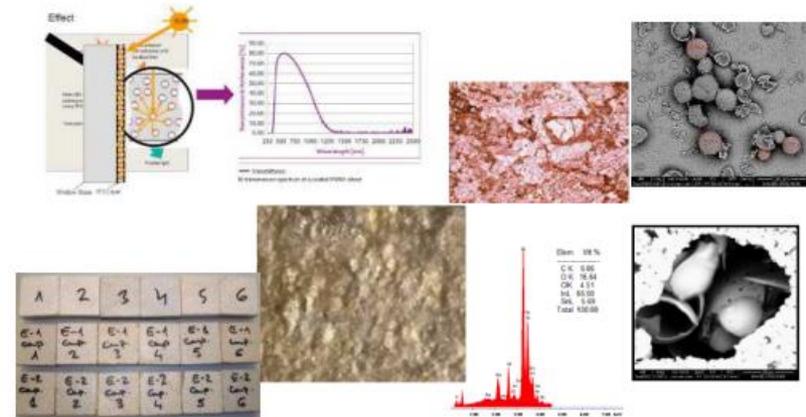
- Results**
- sticky, but general applicability OK
  - good consistency and flattening/levelling
  - apply by hand and spray (contact layer to increase surface on substrate)
  - 3cm in one layer





## EFFESUS INNOVATIONS FOR ENVELOPE RETROFITTING

- New transparent and reversible **radiation selective coating** compatible with historic buildings to reduce the transfer of heat in façades, with the additional self-cleaning property and high water repellence

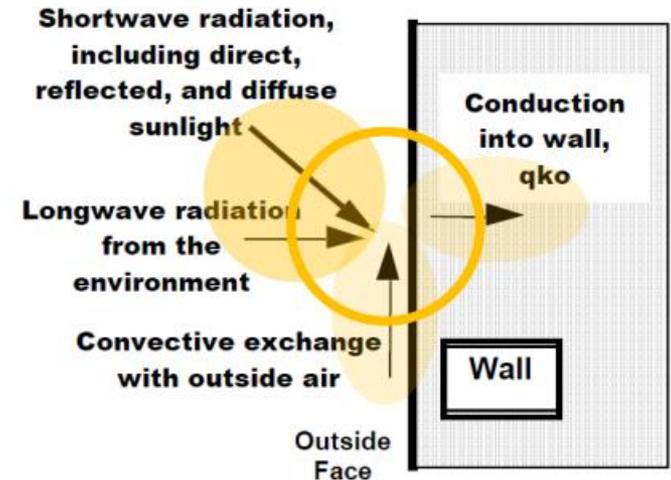




## Development of a new radiation cost-effective selective coating

### Scope:

To develop new exterior wall and roof coatings compatible with historic values and materials in order to reduce the transfer of heat and improve the thermal properties of the external elements of the building.

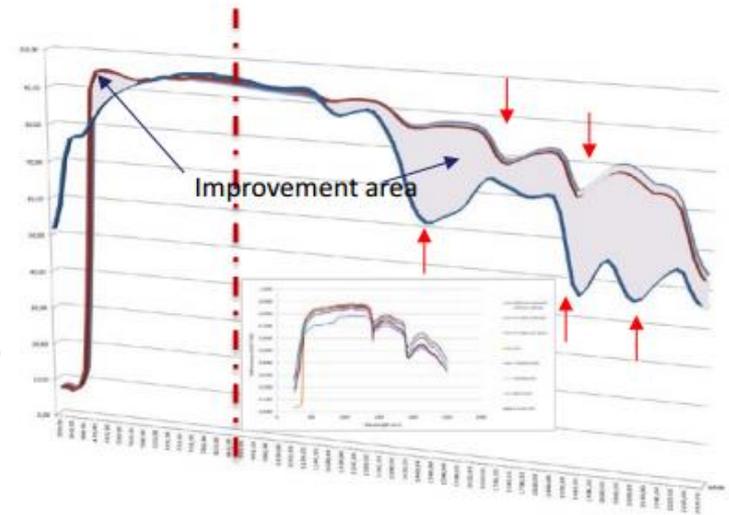




## Development of a new radiation cost-effective selective coating

### Process / Challenges:

- Identifying facade roof materials and their properties
- Testing current „cool paints” in defining they properties (thermal behaviour, morphology, IR-reflectance, Antibacterial properties)
- Developing new selecting coating with better reflective properties

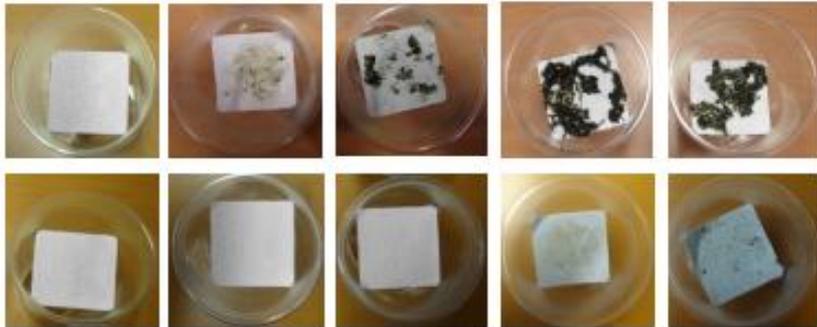




## Development of a new radiation cost-effective selective coating

### Process / Challenges:

- Anti-mold (anti-bacterial) enhancement



#### Without any antibacterial agent:

Algae coverage  $\pm$  30% at 1<sup>st</sup> month, >50% at 2<sup>nd</sup> month, <75% at 3<sup>rd</sup> month

#### With antibacterial agent

< 1% coverage of surface with algae

Algae growth after 3<sup>rd</sup> month (3 years of endurance)

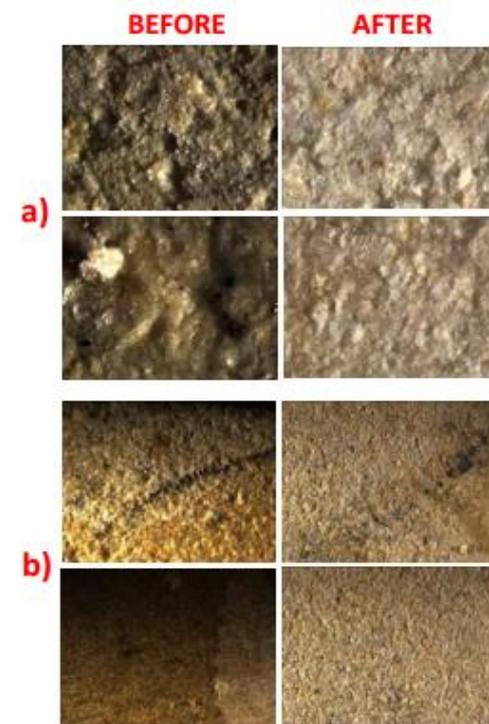
Algae growth is controlled (Characterized as CAT 1)



## Development of a new radiation cost-effective selective coating

### Process / Challenges:

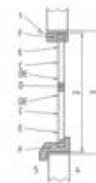
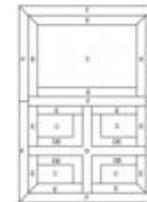
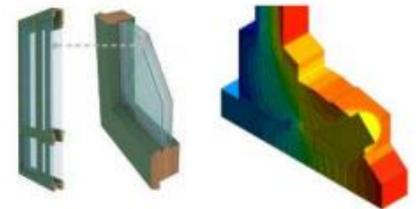
- **Reversibility (research)**
  - ✓ Both 2 primers were applied to all substrates and tested for:
    - i. Colorimetry by measuring the CIELAB system colorimetric coordinates.
    - ii. Reversibility, determined by cleaning them with:
      - a) *Methylcellulose*: cold water using a soft brush and tissue.
      - b) *Paraloid B-72*: acetone using a soft brush and tissue.
  - ✓ Reversibility results
    - i. **Both primers proved reversible on all the substrates applied**
    - ii. Some gloss appearance recorded on Istanbul limestone when methylcellulose was used, but after some more intensive cleaning was completely removed.
    - iii. Colorimetry measurements indicated some minor differences on color coordinates (in most cases below **3 ΔEab**) on the substrates, but they are not human eye visible.
  - ✓ As the performance of the the two primers was relatively the same, it was decided to both be tested with coating application on the substrates, to determine our best possible option.





## EFFESUS INNOVATIONS FOR ENVELOPE RETROFITTING

- **Efficient window** with new secondary glazing system for existing windows with minimal visual impact and maximum energy saving effect as well as flexible framing solutions in combination with use of low-energy coatings





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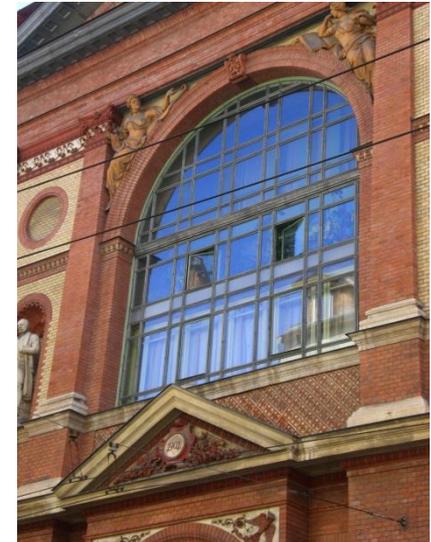
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### Improvement of moisture and thermal properties of original windows



#### Scope:

- developing efficient window improvement solutions,
- developing solutions for different window types,
- developing low-energy glazing systems,
- Building and testing 5-6 different solutions,
- providing efficient windows for classroom at Budapest University of Technology and Economics





## INTRODUCTION

### Why windows in buildings with historic values are important?

- Defining style of the building
- Providing view out
- Providing daylight and fresh air
- Protecting indoor environment from weather conditions





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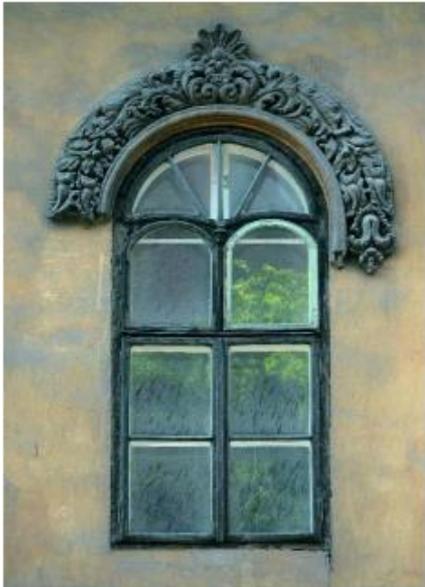
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### INTRODUCTION



Lőrinczi Zsuzsa



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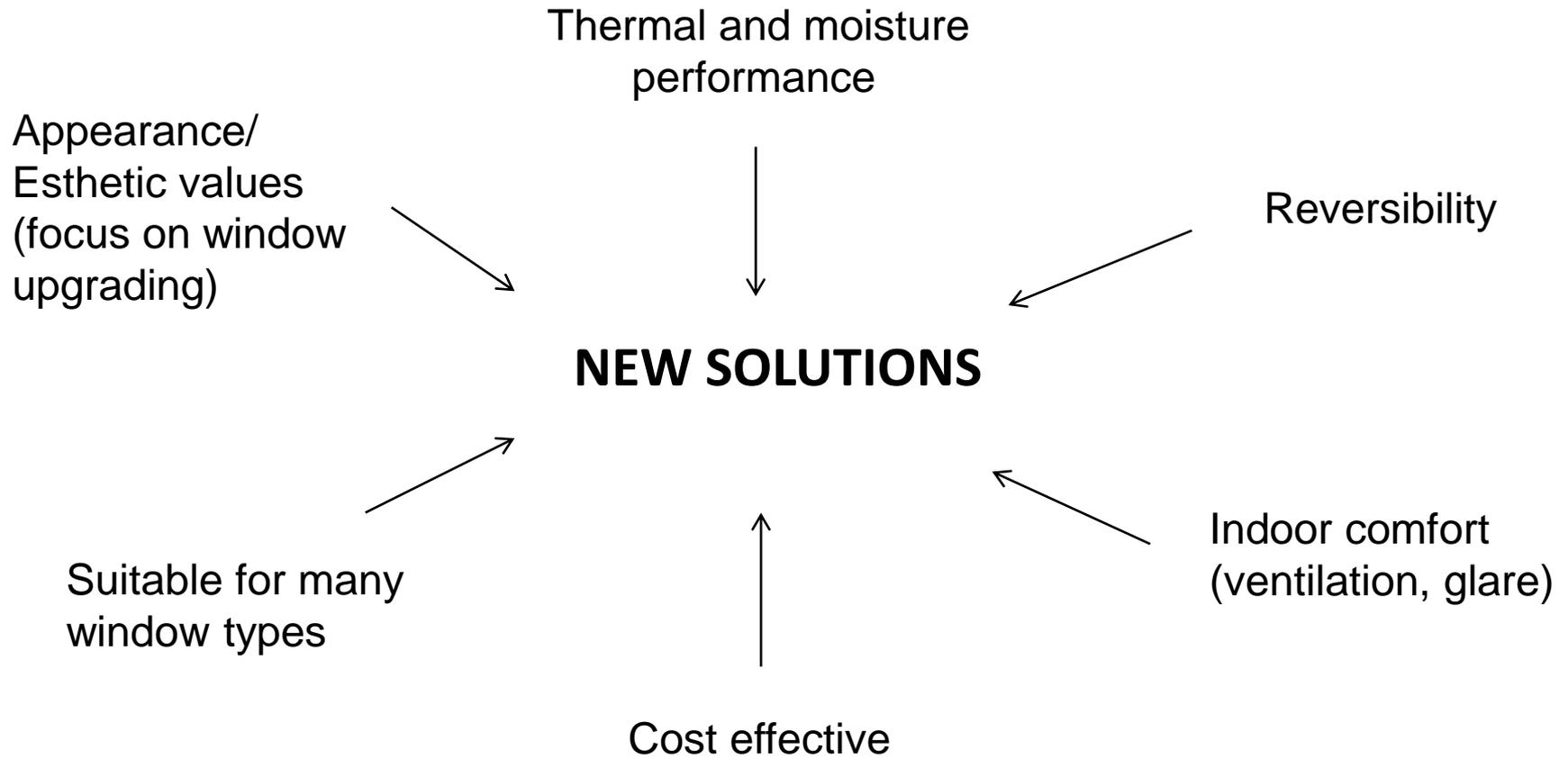


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Lőrinczi Zsuzsa





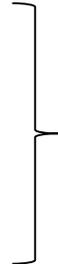
# IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

## • 5 prototypes have been developed and evaluated:

- U – Value
- Moisture properties
- G – Value
- Visual Transmittance



Lab testing



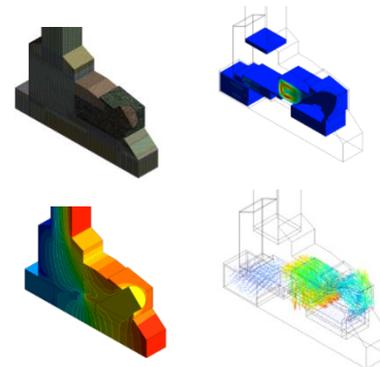
Modeling



- Esthetic influence
- Reversibility
- Durability
- Maintenance
- Legislation compatibility

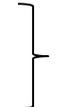


+ Architects  
+ Practitioners  
+ Engineers



▪ Cost assessments

▪ Modeling procedure



THERM, WINDOW, CFD, standards,  
best practices



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## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

- **Prototype 0 – “Original Window”**





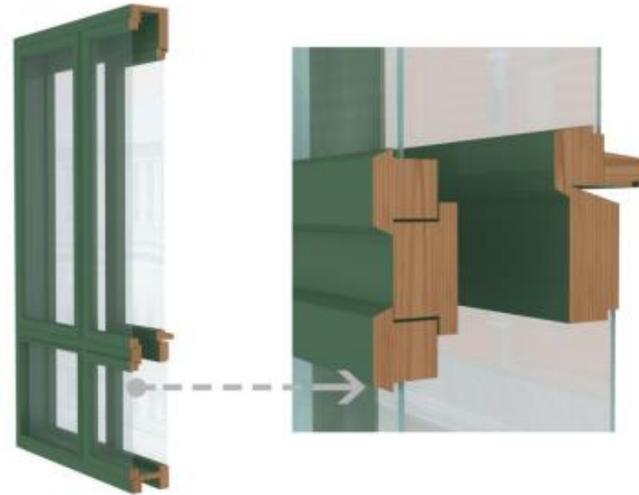
## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

### ● Prototype 0 – “Original Window”

#### Short prototype description:

This prototype is a reconstruction of the original window of the test room in Budapest. The prototype is as similar to the original as possible and it provides a baseline of comparison for the calculations and measurements of the performance of the other prototypes.

#### Detail of original window in Budapest:



#### Prototype performance:

PROPERTY	VALUE	COMMENTS
$U_w$ - value	2.47 W/(m <sup>2</sup> K)	no shading (measured value)
$G$ - value	0.78	centre of glazing value without shading (calculated value)
Visual Transmittance	0.81	centre of glazing value without shading (calculated value)
$\Theta_{si,min}$	10.71 °C	The lowest surface temperature ( $\Theta_{si,min}$ ) and dimensionless temperature or temperature factor ( $f_{R,si}$ ) on internal side of the window: no shading (measured values)
$f_{R,si}$	0.54	
climate zone	Hot	Climatic zone in which window fulfils Passive House Institute requirements regarding hygiene (measured value)

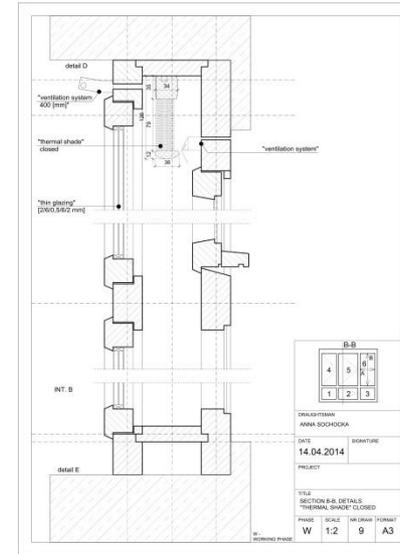
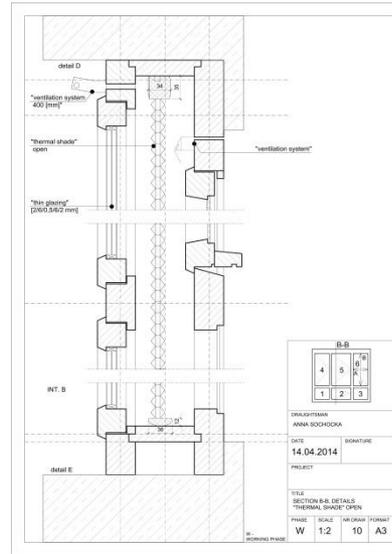


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# IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

## Prototype 1 – “Thermal Shades”



One-row



[www.atfastwindowcoverings.com](http://www.atfastwindowcoverings.com)

Two-row



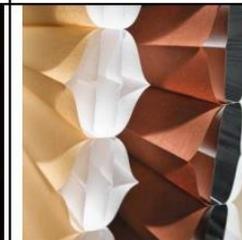
[www.homesimprovedtoday.com](http://www.homesimprovedtoday.com)

Three-row



<http://www.amadeintheshade.net/>

Cell in cell



[www.themost10.com](http://www.themost10.com)

Cell in cell+



[www.valueblinddesign.com](http://www.valueblinddesign.com)





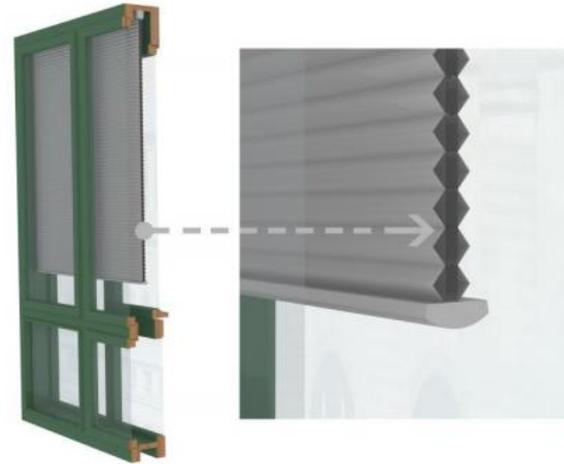
## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

# Prototype 1 – “Thermal Shades”

### Short prototype description:

The prototype includes thermal shades installed in the air gap between the glass layers in the box window. Thermal shades, in this case cellular shades (type: cell in cell), adds thermal resistance to the window and reduces solar heat gain in the summer.

### Detail:



### Prototype performance:

PROPERTY	VALUE	COMMENTS
$U_w$ - value	1.92 / 2.47 W/(m <sup>2</sup> K)	closed shade/open shade (measured value)
$G$ - value	0.58 / 0.78	centre of glazing value for closed shade/open shade – this value can be lowered by using other shade fabrics – and open shade (calculated values)
Visual Transmittance	0.54 / 0.82	centre of glazing value for closed shade/open shade – this value can be lowered by using other shade fabrics – and open shade (calculated values)
$\Theta_{si,min}$	11.48 °C	The lowest surface temperature ( $\Theta_{si,min}$ ) and dimensionless temperature or temperature factor ( $f_{R,si}$ ) on internal side of the window: shade closed / shade open (measured value)
$f_{R,si}$	0.57	
climate zone	Warm	Climatic zone in which window fulfils Passive House Institute requirements regarding hygiene (measured value)

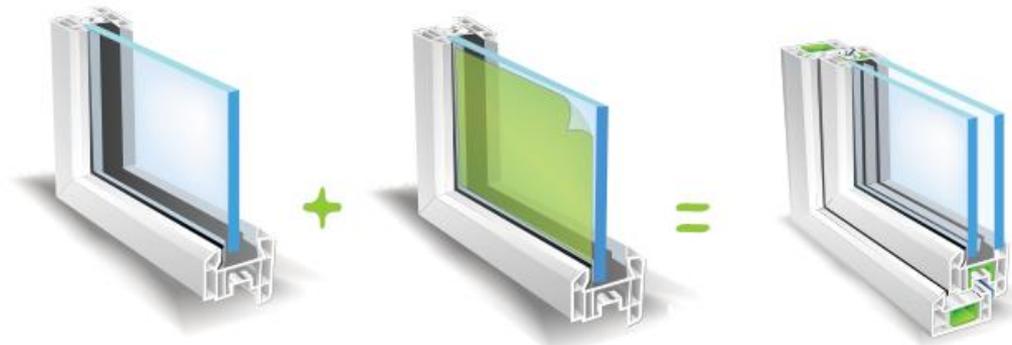


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# IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

## Prototype 2 – “Adhesive low-emissivity films”

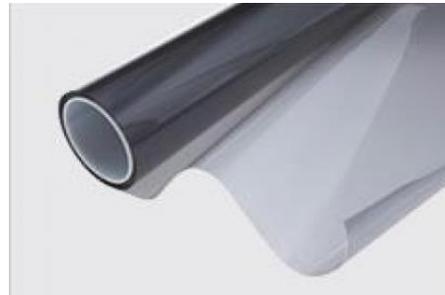


Standard window with no film applied (single glazed).

With EnerLogic 35 Window Film applied to existing window.

The same thermal performance as double glazing.

[www.dallaswindowfilm.com](http://www.dallaswindowfilm.com)





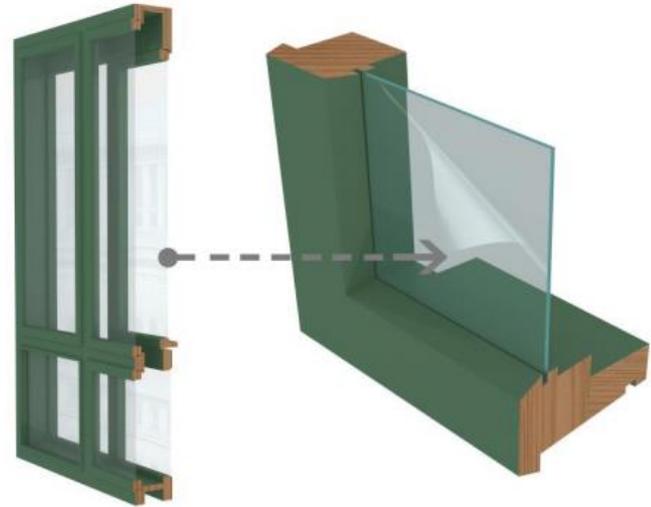
## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

### Prototype 2 – “Adhesive low-emissivity films”

#### Short prototype description:

The prototype uses adhesive plastic films with low emissivity properties. The advantage of this solution over low-e coatings on the glass surface is that those films can be added to the existing glass, while low-e coatings can only be applied during the manufacturing process.

#### Detail:



#### Prototype performance:

PROPERTY	VALUE	COMMENTS
$U_w$ - value	<b>2.37</b> W/(m <sup>2</sup> K)	no shading (measured value)
$G$ - value	<b>0.47</b>	centre of glazing value without shading (calculated value)
Visual Transmittance	<b>0.63</b>	centre of glazing value without shading (calculated value)
$\Theta_{si,min}$	<b>10.85 °C</b>	The lowest surface temperature ( $\Theta_{si,min}$ ) and dimensionless temperature or temperature factor ( $f_{R,si}$ ) on internal side of the window: no shading (measured value)
$f_{R,si}$	<b>0.54</b>	
climate zone	<b>Hot</b>	Climatic zone in which window fulfils Passive House Institute requirements regarding hygiene (measured value)



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## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

### Prototype 3 – “Multi-layered thin glazing”



[www.bbc.com](http://www.bbc.com)



[www.ceramicindustry.com](http://www.ceramicindustry.com)



[www.southwall.com](http://www.southwall.com)



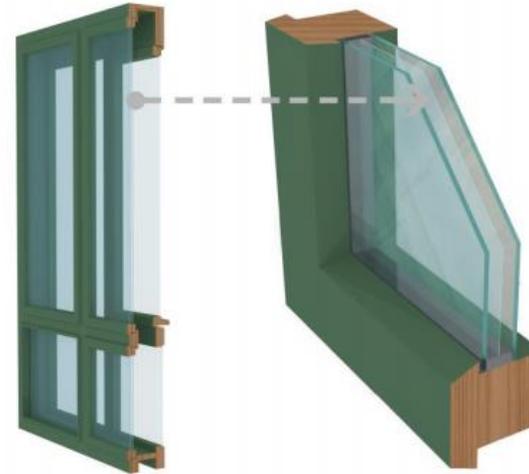
## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

### Prototype 3 – “Multi-layered thin glazing”

#### Short prototype description:

The prototype uses insulated glazing units which include thin plastic or glass panes (glass thickness from 0.1 to 1 mm) in a multi-layered unit. Ultra-thin glass panes or suspended plastic films are used as the middle panes in a multi-layered glazed unit. This provides high insulation levels while keeping the unit lightweight and narrow. In some cases this allows the original design of the historic window to be preserved while providing a substantial thermal improvement.

#### Detail:



#### Prototype performance:

PROPERTY	VALUE	COMMENTS
<i>U - value</i>	<b>1.27</b> W/(m <sup>2</sup> K)	no shading (calculated value)
<i>G - value</i>	<b>0.67</b>	centre of glazing value without shading (calculated value)
<i>Visual Transmittance</i>	<b>0.70</b>	centre of glazing value without shading (calculated value)
$\Theta_{si,min}$	<b>15.4 °C</b>	The lowest surface temperature ( $\Theta_{si,min}$ ) and dimensionless temperature or temperature factor ( $f_{R,si}$ ) on internal side of the window: no shading (calculated values)
$f_{R,si}$	<b>0.77</b>	
<i>climate zone</i>	<b>cold</b>	Climatic zone in which window fulfils Passive House Institute requirements regarding hygiene (calculated value)

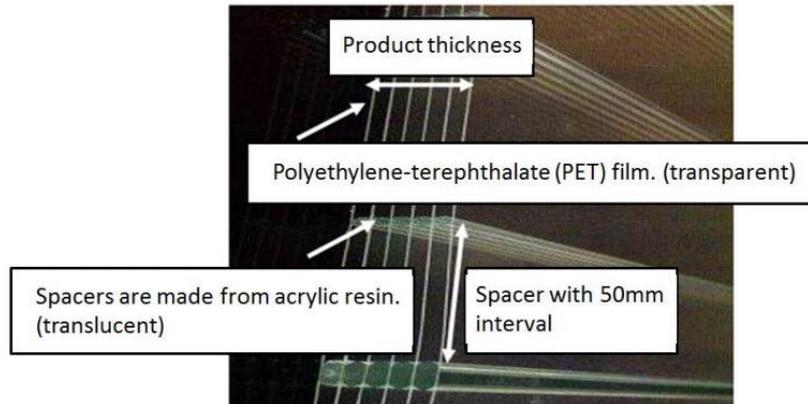
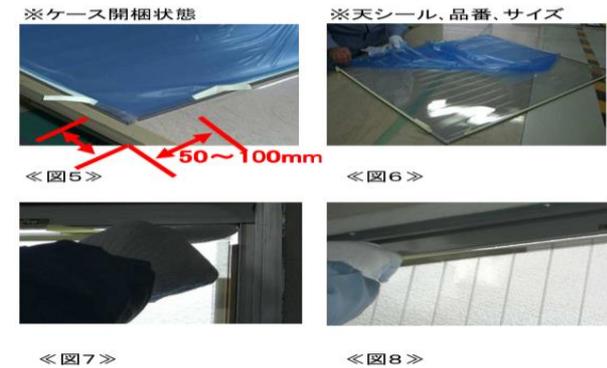


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# IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

## Prototype 4 – “Air Sandwich”





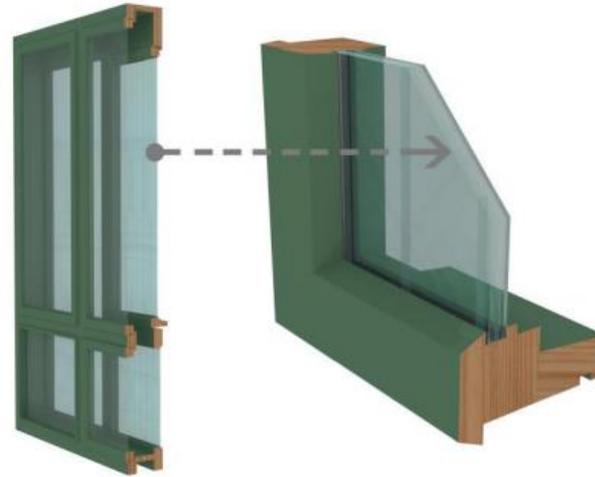
## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

# Prototype 4 – “Air Sandwich”

### Short prototype description:

The prototype integrates a product called the “Air Sandwich” which consists of five transparent thin plastic layers glued to the original panes with plastic frames sealed with a secondary sealant.

### Detail:



### Prototype performance:

PROPERTY	VALUE	COMMENTS
<i>U - value</i>	<b>1.84</b> W/(m <sup>2</sup> K)	no shading (measured value)
<i>G - value</i>	<b>0.49</b>	centre of glazing value without shading (calculated value)
<i>Visual Transmittance</i>	<b>0.57</b>	centre of glazing value without shading (calculated value)
$\Theta_{si,min}$	<b>12.39 °C</b>	The lowest surface temperature ( $\Theta_{si,min}$ ) and dimensionless temperature or temperature factor ( $f_{R,si}$ ) on internal side of the window: no shading (measured value)
$f_{R,si}$	<b>0.62</b>	
<i>climate zone</i>	<b>Warm-temperate</b>	Climatic zone in which window fulfils Passive House Institute requirements regarding hygiene (measured value)

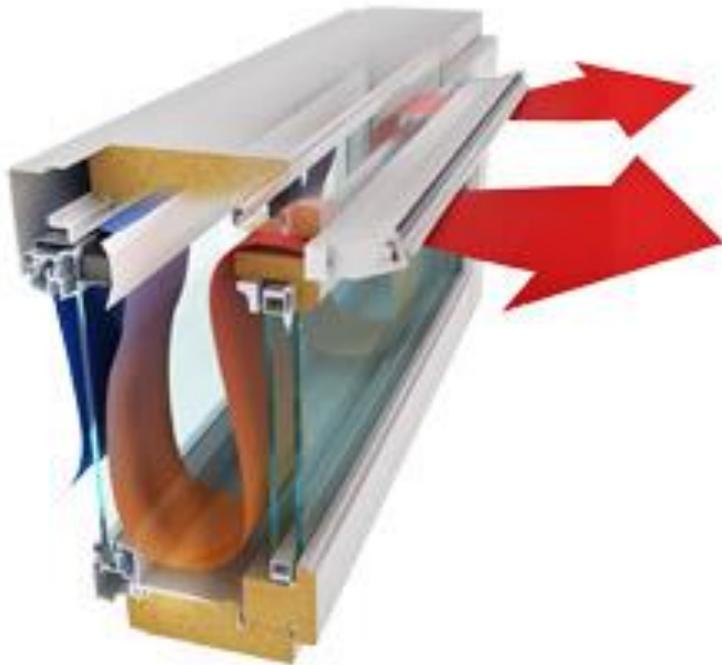


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## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

### Prototype 5 – “Supply Air Window”



[www.dir-air.fi](http://www.dir-air.fi)





## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

# Prototype 5 – “Supply Air Window”

### Short prototype description:

The prototype uses specially designed valves which allows fresh air to flow from outside to inside in the designed gap between two panes of glazing. As it flows from the bottom of the window to the top it recovers heat that is flowing through the glass towards the outside. If the window happens to receive direct solar radiation it also acts as an air solar collector, but this is not its primary operating mode or function.

### Detail:



### Prototype performance:

PROPERTY	VALUE	COMMENTS
$U$ - value	2.47 W/(m <sup>2</sup> K)	no shading (measured value) *valves might slightly increase the U-value due to frame penetration.
$G$ - value	0.78	centre of glazing value without shading (calculated value)
Visual Transmittance	0.81	centre of glazing value without shading (calculated value)
$\Theta_{si,min}$	10.71 °C	The lowest surface temperature ( $\Theta_{si,min}$ ) and dimensionless temperature or temperature factor ( $f_{R,si}$ ) on internal side of the window: no shading (measured values)
$f_{R,si}$	0.54	
climate zone	Hot	Climatic zone in which window fulfils Passive House Institute requirements regarding hygiene (measured value)



# IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

- Classroom auxiliary system connected to windows:

- Exhaust fan: (CO2 controlled)



TD SILENT  
500 / 160



reduction  
fi160 / 250



silencer  
fi250



Duct pipe  
fi250 – 0.5m



90 pipe  
fi200



90 pipe  
Fi250 – 0.5m



Air intake  
Fi250 – 0.5m

- Shading controlling system (time control)



Notebook, PC, Tablet PC,  
Smartphone



TaHoma Box





## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

### • Windows for Budapest Demonstration

EnerLogic Film	Thermal Blinds	Thin glazing units	Air sandwich	Ventilation window
<small>thewindowfilmspecialists.com</small>	<small>www.themost10.com</small>	<small>www.glassmagazine.com</small>	<small>www.sekisui.co.jp</small>	



### • Assessment criteria (desired functions of the demonstration windows):

- providing look through -> glass,
- controlling glare -> shades/coatings,
- providing ventilation -> air – supply window,
- Careful design of window – to – wall connection,
- fulfilling local legislation (energy/esthetic aspects)
- providing optimal thermal conditions (heat losses – heat gains)

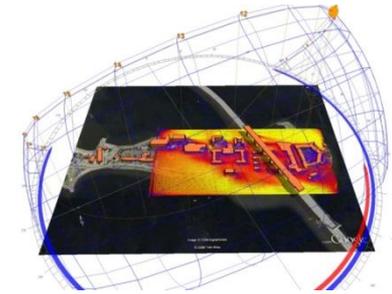


# IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

## • Full year dynamic modeling simulations,

### THERMAL:

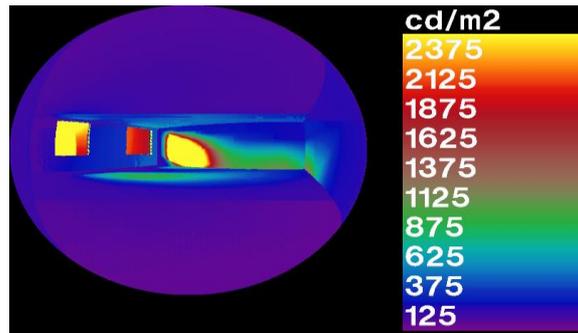
- Defining the most suitable product properties (U-value, G-value, Visual transmittance) to provide energy savings,
- Thermal comfort – (overheating (no cooling system))



[eypenergy.com](http://eypenergy.com)

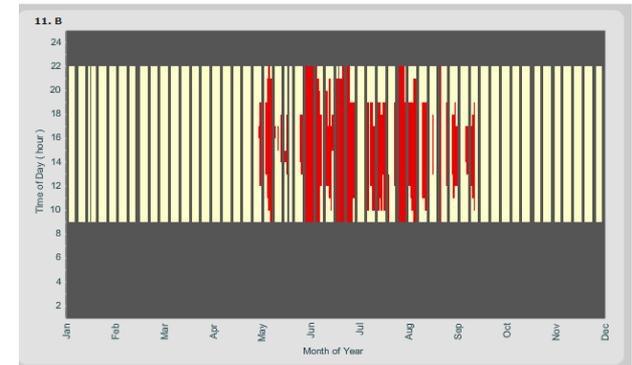
### DAYLIGHT:

- Glare prediction



### SHADING OPERATION

- Connecting thermal and daylight issues

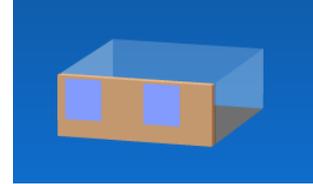


(--->for more details see next slides)



## IMPROVEMENT OF MOISTURE AND THERMAL PROPERTIES OF ORIGINAL WINDOWS

### • Energy modeling – results



Summary energy savings for each scenario

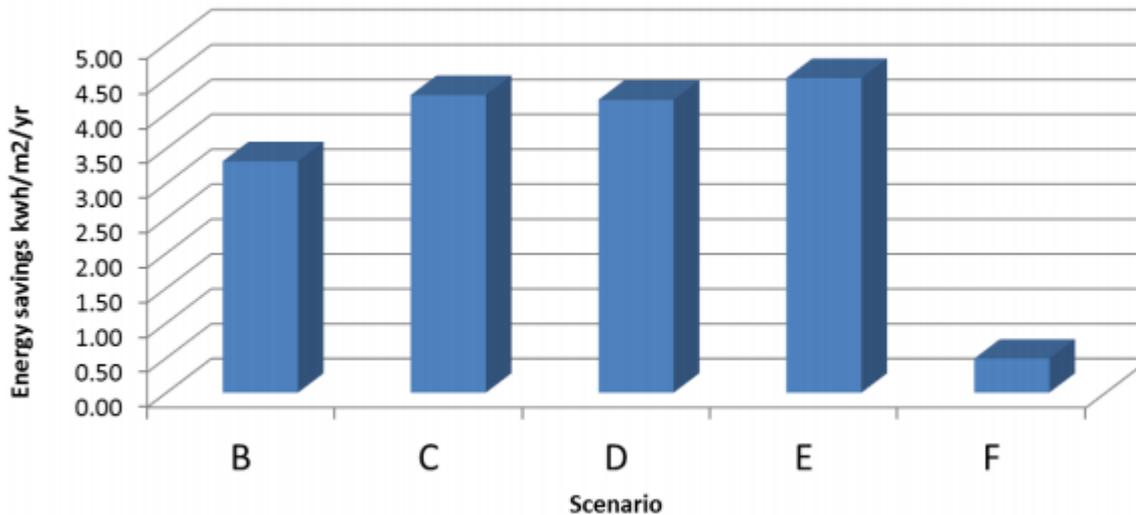


Figure 39 – Annual heating energy savings for each glazing specification

Scenario:	A	B	C	D	E	F
Temp over 25°C [h]	764	783	749	700	668	621
Avg. Daylight Ill. [lux]	290	264	255	237	211	157

A: Original box window (prototype 0)

B: Original box window with thermal shade (prototype 1)

C: Original box window with thermal shade and adhesive plastic films (prototype 1 + 2)

D: Box window with 2P glazing (1 low-e) unit in inner sash, solar shade

E: Box window with 3P glazing (2 low-e) unit in inner sash, solar shade (prototype 4 + a solar shade)

F: Box window with 3P glazing (2 low-e, spectral selective coatings – low heat gain unit)



## Conclusions:

- **5 prototypes has been developed and investigated, which represents variety of possible upgrade strategies for different windows/cases**
- **demonstration example was shown using case study in Budapest**
- **There are two report versions available:**
  - > **short version (30 pages) the most important result,**
  - > **full version (80 pages including extensive background and testing procedure)**



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- Thank you
- Questions?

