Existing and replicable technologies for energy efficiency improvements in historic districts

Alexandra Troi, Senior Researcher, EURAC research
EFFESUS

- researching energy efficiency of historic districts
- European FP7 project with 23 partners running from 2012 to 2016

EURAC research

- research institute
- 4 groups on energy – building | thermal | PV | urban

→ FOCUS on Historic Buildings
Existing and replicable technologies for energy efficiency improvements in historic districts

Recovering of old architectural solutions
• Understand the building and enhance built-in solutions

Technologies, systems & tools for supplying energy in historic district
• Renewable sources and district heating & cooling

Technologies, systems and tools for retrofitting historic buildings
• Look at the whole building, chose the right solution, mind the details
Recovering of old architectural solutions

Traditional architecture found passive solutions for local climate

- Passive Solar Heating
- Thermal Mass (heat storage)
- Shading – Solar Control
- Air movement
- Evaporative Cooling
- Insulation
Recovering of old architectural solutions

Traditional architecture found passive solutions for local climate

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Lead partner

NTNU
Recovering of old architectural solutions

Warm Mediterranean Climate

- Warm dry summer
- Mild, humid winters
- Rarely beneath 0°C
- Occasionally strong seasonal winds

- Heavy construction materials
- Seasonal pattern users
- Small apertures
- Light colours
- Ventilation paths

Santorini houses
Recovering of old architectural solutions

Oceanic Climate

• Short cool summer
• Mild, rainy winter
• Changeable weather, high precipitation
• Often strong winds throughout the year

• Protection from high humidity and strong winds
• Windows - where possible large for light and sun
• High-pitched roof
• Shutters – prevent heat losses & protect from rain
Recovering of old architectural solutions

Humid Continental Climate

- Warm, humid summer
- Cold, humid, snowy, windy winter
- Changeable weather closer to seas

- Insulation – prevention of heat loss
- High-pitched roof, roof overhangs
- Buildings around a courtyard
- Living quarters – oriented towards south

Danish wing-house
Technologies, systems & tools for supplying energy in historic district

• Renewable energy technologies & complementary tools
  solar | wind | geothermal | biomass | CHP | seasonal thermal storage

• Supply to the district
  District heating | integrating renewables | district cooling

• Renewable energy in historic districts
  Heritage protection | supply | integration
Solar technologies

Major issue: Integration & design!

• Think well about where and how to integrate solar panels
• Use areas which are not visible to the viewers
• Prefer an outbuilding or detached architectural element
• Avoid scattering and follow existing architectural lines
• Sometimes it might even be possible to follow traditional functions as e.g. the eave flashing [Traufblech]

(Source: blfd.bayern.de)
Technologies, systems & tools for supplying energy in historic district

Solar technologies

Choose carefully the right technology for aesthetical integration!

Both PV and solar thermal panels area available with various surfaces

shiny | dull | black | coloured | with patterns ...

(Source: eternit.de)
(Source: Bluenergy-ag.net)
(Source: maiersolartechnik.de)
(Source: news.indiamart.com)
Technologies, systems and tools for retrofitting historic buildings

Development aim

• Look at the whole building
• Chose the right solution
• Mind the details
Technologies, systems and tools for retrofitting historic buildings

Look at the whole building – be guided by retrofit steps

A Energy Management
B Airtightness
C Ventilation
D Daylight & shading
E Solar reflectance of external materials
F Thermal performance of external envelope
G Moisture behaviour
H Thermal Mass of building
I Efficient Energy generation, distribution & emission
J Electrical Equipment
K Renewable Energy sources
Technologies, systems and tools for retrofitting historic buildings

Chose the right solution -> database for EFFESUS DSS

It CAN PROVIDE technology description & information needed to do an assessment

WHAT – description

WHY – advantages and disadvantages

WHEN – conditions

WHERE – conservation aspects

Energy saving potential

Cost

Best practice examples
Technologies, systems and tools for retrofitting historic buildings

Chose the right solution -> database for EFFESUS DSS

It CAN PROVIDE technology description & information needed to do an assessment

WHAT – description

WHY – advantages and disadvantages

It CANNOT PROVIDE a-priori assessment

3.5 Assessment is possible only for the specific building

With the technology description and characterisation the basic information needed to do an assessment in the specific case can be given – not the assessment itself. This is true both for the evaluation of economic aspects, of energy saving potential and especially for compatibility with the fabric as well as with conservation principles.
Technologies, systems and tools for retrofitting historic buildings

Assessment depends on circumstances

- example window replacement (or enhancement)

Proposed measure

Retrofitting a window to a U-value of 1.3 W/m²K

A) Existing window: single glas, U-value ~ 5 W/m²K

→ reduction of heating demand by nearly factor 4
   = to 25% of demand

B) Existing window: Coupled window, U-value ~2.6 W/m²K

→ reduction of heating demand by factor 2
   = to 50% of demand

With the same end performance starting from situation A
three times more energy is saved than in situation B
Assessment depends on circumstances
- example window replacement (or enhancement)

Proposed measure

Retrofitting a window to a U-value of 1.3 W/m²K

A1) Existing window: single glas, U-value ~ 5 W/m²K in \textit{Bolzano} with 2600 HDD

→ reduction of heating demand from 310 to 80 kWh/m² (window)
= 230 kWh/m² (window) saved

A2) in \textit{colder} climate with 4000 HDD

→ reduction of heating demand from 480 to 125 kWh/m² (window)
= 355 kWh/m² (window) saved

A3) in \textit{warmer} climate with 1500 HDD

→ reduction of heating demand from 180 to 45 kWh/m² (window)
= 135 kWh/m² (window) saved
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Assessment depends on circumstances

- example window replacement (or enhancement)

Proposed measure

Retrofitting a window to a U-value of 1.3 W/m²K

A1’) Existing window: single glas, U-value ~ 5 W/m²K in Bolzano

small stone building with 10% windows’ area

→ total heating demand from 587 kWh/m² (floor)

    thereof 107 kWh/m² (floor) through windows reduced to 27 kWh/m² (floor)

= 80 kWh/m² (floor) saved → -13%

A1’’) larger brick building with 30% windows’ area

→ total heating demand from 295 kWh/m² (floor)

    thereof 175 kWh/m² (floor) through windows reduced to 45 kWh/m² (floor)

= 130 kWh/m² (floor) saved → -44%
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Assessment depends on circumstances

- example window replacement (or enhancement)

Proposed measure

Retrofitting a window to a U-value of 1.3 W/m²K → Embodied Energy = 720 MJ/m² = 200 kWh/m² (window)

A1) Existing window: single glass, U-value ~ 5 W/m²K
    in Bolzano with 2600 HDD, 230 kWh/m² (window) saved per year
    → energy payback 0.9 years

A2) in colder climate with 4000 HDD, 355 kWh/m² (window) saved
    → energy payback 0.6 years

A3) in warmer climate with 1500 HDD, 135 kWh/m² (window) saved
    → energy payback 1.5 years

B1) Existing window: compound window, ~2.6 W/m²K
    in Bolzano with 2600 HDD, 80 kWh/m² (window) saved
    → energy payback 2.5 years
Technologies, systems and tools for retrofitting historic buildings

• STUDY in Sachsen / Germany
Technologies, systems and tools for retrofitting historic buildings

A  Energy Management
B  Airtightness
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# Technologies, systems and tools for retrofitting historic buildings

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- A1 Implement energy management procedures for Energy Efficiency with Monitoring & Targetting protocols
- A2 Install energy monitoring and management system
- A3 **Education** program related to energy saving actions for occupants
Technologies, systems and tools for retrofitting historic buildings

A  Energy Management
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- B1 Proprietary airtightness system of seals to all openings and **joints**
- B2 - Airtightness of **windows**
- B3 **Chimney** dampers and closers
- B4 Instal draught lobby at external **doors**
- B5 Airtightness membrane to underside **roof** insulation
Technologies, systems and tools for retrofitting historic buildings

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• C1 Provide natural ventilation of the whole building
• C2 Install mechanical ventilation systems on the whole building with heat recovery
  • Central
  • Decentral
  • Volume flow balancing
• C3 Instal Air Biofilter
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Active overflow system

Fresh air into corridors → from their via doors or wall to room and back → ducts only to bring used air back to heat recovery unit.

Much less ducting! No suspended ceilings in corridors!
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• D1 Increase daylight use
• D1.1 Glazing with high light transmittance
• E1.2 Narrow window frames
• E1.3 Light pipes
• E1.4 Shading systems with integrated daylight redirection
• E1.5 Redirecting window shutters
• D2 Increase light efficiency of the room
• D3 Optimise G-value of the window to suit building and climate
• D3.1 Glazing with low g-value
• D3.2 Install energy efficient window films
• D4 Install shading devices
• D4.1 Install external shading devices
• D4.1 Install internal shading devices
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- **F1 Optimise thermal insulation of external envelope**
- **F2 Reduce thermal bridging wherever possible**
- **F3 Install high performance window and glazing systems**
- **F4 Install radiator reflector**
Technologies, systems and tools for retrofitting historic buildings

**3ENCULT window development**

Using thin glass

→ 2mm!

- 2+8+2+8+2
  = 22 mm
- 4+12+4
  = 20 mm
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3ENCULT window development
Technologies, systems and tools for retrofitting historic buildings

3ENCULT window development

113 mm
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• F1 Optimise thermal insulation of external envelope
• F2 Reduce thermal bridging wherever possible
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• F4 Install radiator reflector
Technologies, systems and tools for retrofitting historic buildings

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- F1 Optimise thermal insulation of external envelope
  - F1.1 Exterior insulation
    - F1.1.1 Exterior insulation with a composite system
    - F1.1.2 Exterior insulation with ventilated cavity
    - F1.1.3 Exterior insulation with insulation plaster
  - F1.2 Interior insulation
    - F1.2.1 Diffusion closed interior insulation
    - F1.2.2 Diffusion-open, capillary-active interior insulation systems
  - F1.3 Insulation of an existing cavity
- F2 Reduce thermal bridging wherever possible
- F3 Instal high performance window and glazing systems
- F4 Install radiator reflector
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Building Physics – exterior versus interior insulation

**exterior insulation**

**interior insulation**

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**Technologies for energetic improvements in historic districts**

Bau 2015, Munich, 24/01/2015
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Two principles for interior insulation

Operation of diffusion-tight interior insulation:
- No moisture accumulation, no condensation, hardly steam flow, low drying potential.

Operation of diffusion open and capillary-active interior insulation:
- Moisture accumulation:
  - Steam flow
  - Water transport
- High drying potential

Course of Temperature and Vapor pressure
## Technologies, systems and tools for retrofitting historic buildings

### Capillary active interior insulation

<table>
<thead>
<tr>
<th></th>
<th>Potsdam</th>
<th>Dresden</th>
<th>Freiberg</th>
<th>Görlitz</th>
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<tbody>
<tr>
<td><strong>Name</strong></td>
<td>loam cork</td>
<td>IQ-Therm</td>
<td>Tec-Tem</td>
<td>Calcuimsilicate</td>
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<td><strong>Appearance</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Insulation effect</strong></td>
<td>$\lambda = 0.08 \text{ W/mK}$</td>
<td>$\lambda = 0.031 \text{ W/mK}$</td>
<td>$\lambda = 0.045 \text{ W/mK}$</td>
<td>$\lambda = 0.065 \text{ W/mK}$</td>
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<tr>
<td><strong>Material and form</strong></td>
<td>frame, plaster</td>
<td>board, plaster</td>
<td>board, plaster</td>
<td>board, plaster</td>
</tr>
<tr>
<td><strong>Capillary active</strong></td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Moisture regulation</strong></td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Natural material</strong></td>
<td>++</td>
<td>- -</td>
<td>+/-</td>
<td>+/-</td>
</tr>
<tr>
<td><strong>Fire protection</strong></td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Soundproofing</strong></td>
<td>++</td>
<td>-</td>
<td>++</td>
<td>++</td>
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<tr>
<td><strong>Sustainable</strong></td>
<td>++</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Workmanship</strong></td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td>100 €/m²</td>
<td>45 €/m²</td>
<td>45 €/m²</td>
<td>75 €/m²</td>
</tr>
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</table>
Technologies, systems and tools for retrofitting historic buildings

Mind the details!

\[ \Psi_a = 0.355 \text{ W/(mK)} \]

\[ \vartheta_{\text{min}} = 11.5 \degree \text{C} \]

Unacceptable with \( \vartheta_{\text{min}} < 12.6 \degree \text{C} \)
in the corner → risk of mould growth
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Mind the details!

Unacceptable with \( \vartheta_{\text{min}} < 12.6 \, ^\circ\text{C} \)
in the corner \( \rightarrow \) risk of mould growth

Interior insulation with accompanying insulation (wedge)

\[ \Psi_a = 0.355 \, \text{W/(mK)} \]
\[ \vartheta_{\text{min}} = 11.5 \, ^\circ\text{C} \]

\[ \Psi_a = 0.25 \, \text{W/(mK)} \]
\[ \vartheta_{\text{min}} = 14.6 \, ^\circ\text{C} \]

\( d = 20 \, \text{mm}, \) length 200 mm

Acceptable \( \vartheta_{\text{min}} > 12.6 \, ^\circ\text{C} \)

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Mind the details!

Metal sheet as a passive heat collector in the corner

Unacceptable with $\theta_{\text{min}} < 12.6 ^\circ \text{C}$ in the corner $\rightarrow$ risk of mould growth

$\Psi_a = 0.355 \text{ W/(mK)}$

$\theta_{\text{min}} = 11.5 ^\circ \text{C}$

$\Psi_a = 0.423 \text{ W/(mK)}$

$\theta_{\text{min}} = 13.8 ^\circ \text{C}$
Technologies, systems and tools for retrofitting historic buildings

Development aim

• Look at the whole building
• Chose the right solution
• Mind the details
Technologies, systems and tools for retrofitting historic buildings

Main results from 3½ years research summarised and elaborated for architects

- How to communicate across disciplines?
- How to select the best fitting solution?
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