edilportale TOUR 2016

Efficienza energetica e comfort abitativo
Tecnologie non invasive e sicurezza
Sostenibilità economica e ambientale

in collaborazione con VELUX, tecnova group Innovative Green Building Solutions, alubel tra la terra e il cielo

**Trento,** 19 aprile 2016

# Retrofit energetico nel restauro dell'edilizia storica

**Niccolò Aste**

# Riferimenti


RESEARCH

## ENERGY RETROFIT OF HISTORICAL BUILDINGS: AN ITALIAN CASE STUDY

N. Aste, R.S. Adhikari,[1] and M. Buzzetti

**ABSTRACT**

*The most suitable intervention for energy rehabilitation of historical buildings has to reach both the goal of the optimization of the energy saving and the preservation of the original characteristics of the building. The present work is related to refurbishment and energy rehabilitation of an historical building dating back to 15th century. The building complex under study is an ancient residential courtyard building located in Northern Italy near Verona. The strategies have been focused on the building envelope and energy supply systems respecting both the regulatory constraints imposed by preservation of historical buildings and, where possible, the current national legislation about the building energy efficiency. This result was achieved only through the identification of best solutions based on mutual compatibility and optimization of the performance of the building envelope and the HVAC systems.*

*In the design phase, the thermal performance of the building for both winter and summer periods have been evaluated by dynamic computer simulations. It has been shown that adequate interventions focused on the building envelope and HVAC systems reduces the energy consumption in a significant way. Further, it has been shown through economical analysis that extra-costs for energy retrofit measures paid back quickly during the life span of the building. Historical buildings are characterized by unique and specific characters that could be preserved, also upgrading them to modern requirements. This study demonstrates how it is possible to intervene effectively (and correctly by the historical and architectural point of view) on the energy performance of ancient buildings. By applying innovative techniques and technologies, in fact, it is possible to achieve high energy efficiency levels, without affecting the original architectural appearance and value. The methodology presented can be an interesting case study for all those building interventions where energy, cultural and historical issues intersect.*

**KEYWORDS**

energy retrofit; historical buildings; case study building; energy performance; economical evaluations

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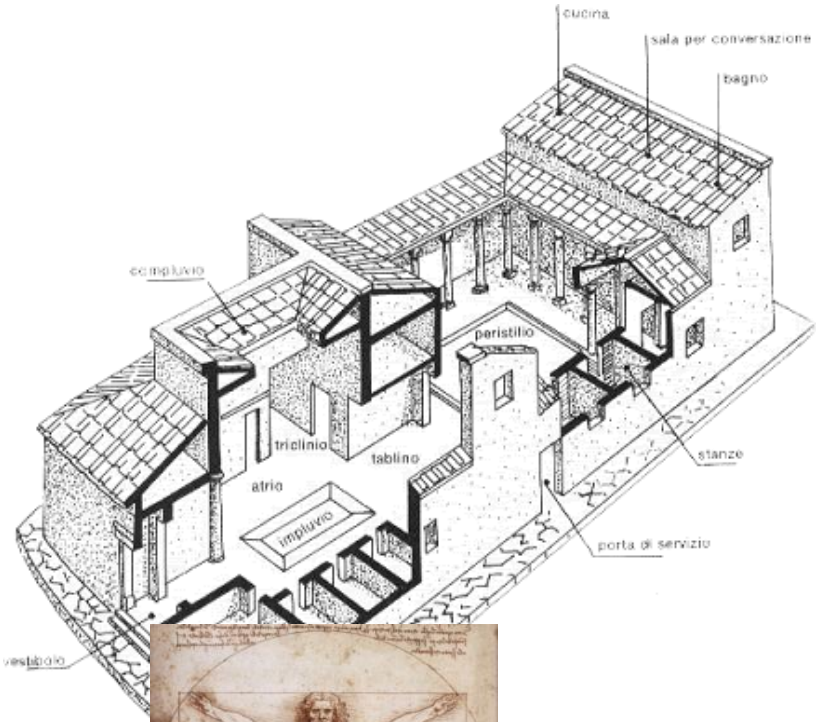
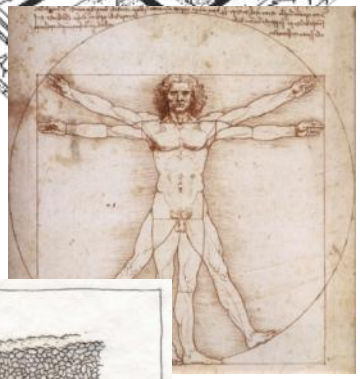
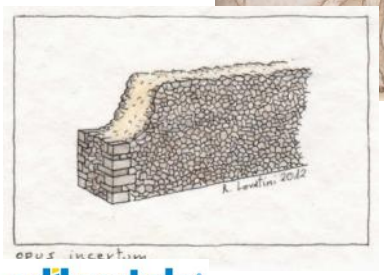
*Aste, N., Adhikari, R.S., Buzzetti, M.*
***Energy retrofit of historical buildings: An Italian case study**, Journal of Green Building, Volume 7, Number 4, pp. 144-165, 2012.*

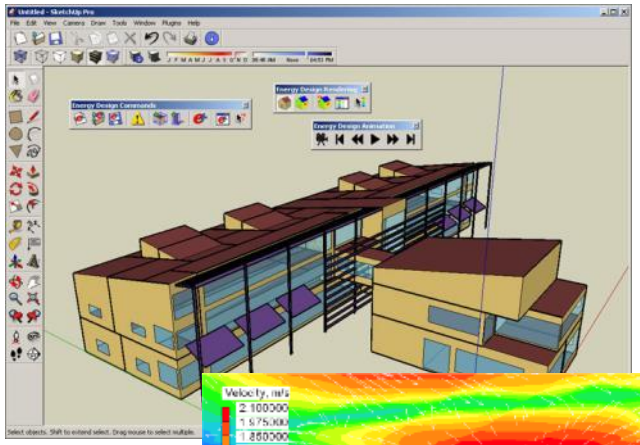
# Metodi a confronto

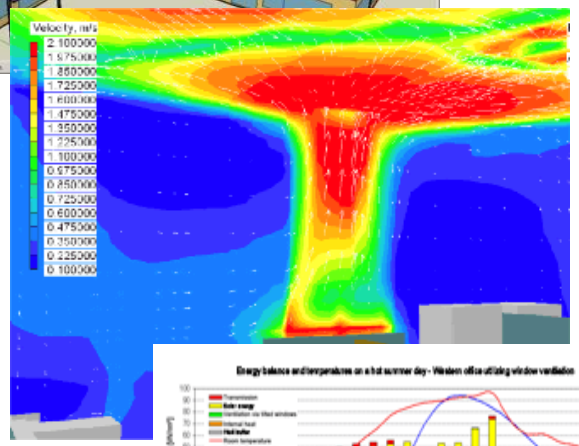


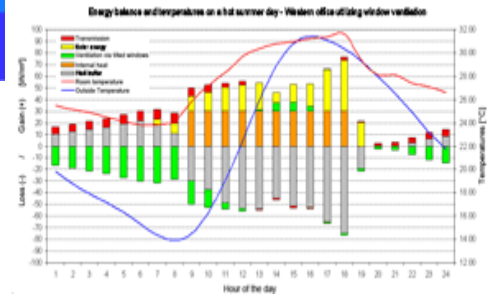










# Prassi consolidata

# Edilizia e consumi energetici

**Settore edilizio italiano**

2% nuovi edifici

20% costruiti prima del 1919

30% edifici con 50 o più anni

64% edifici costruiti prima 1976 (prima legge sull'energia in ambito edilizio)

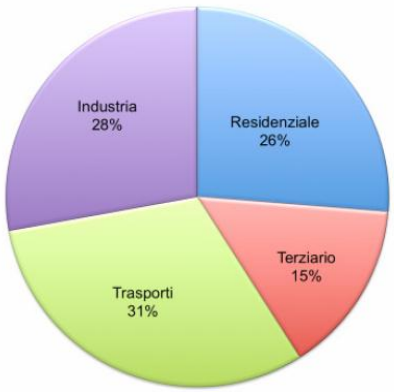
**Consumi di energia annua per riscaldamento**

Europa 150-230 kWh/m$^2$

Italia 120-130 kWh/m$^2$

Nord Italia 170-180 kWh/m$^2$


Europa




Italia

# Italia: edificio “medio”




**Fabbisogno per riscaldamento: 120 kWh/m² anno**
**Fabbisogno per ACS: 30 kWh/m² anno**
**Fabbisogno app. elettriche: 40 kWh/m² anno**
**Fabbisogno per climatizzazione estiva: ?**
**Emissioni $CO_2$: 70 kg/ m² anno**

**Bolletta media italiana**
**Riscaldamento: 1000 €/anno**
**Consumi elettrici: 500 €/anno**

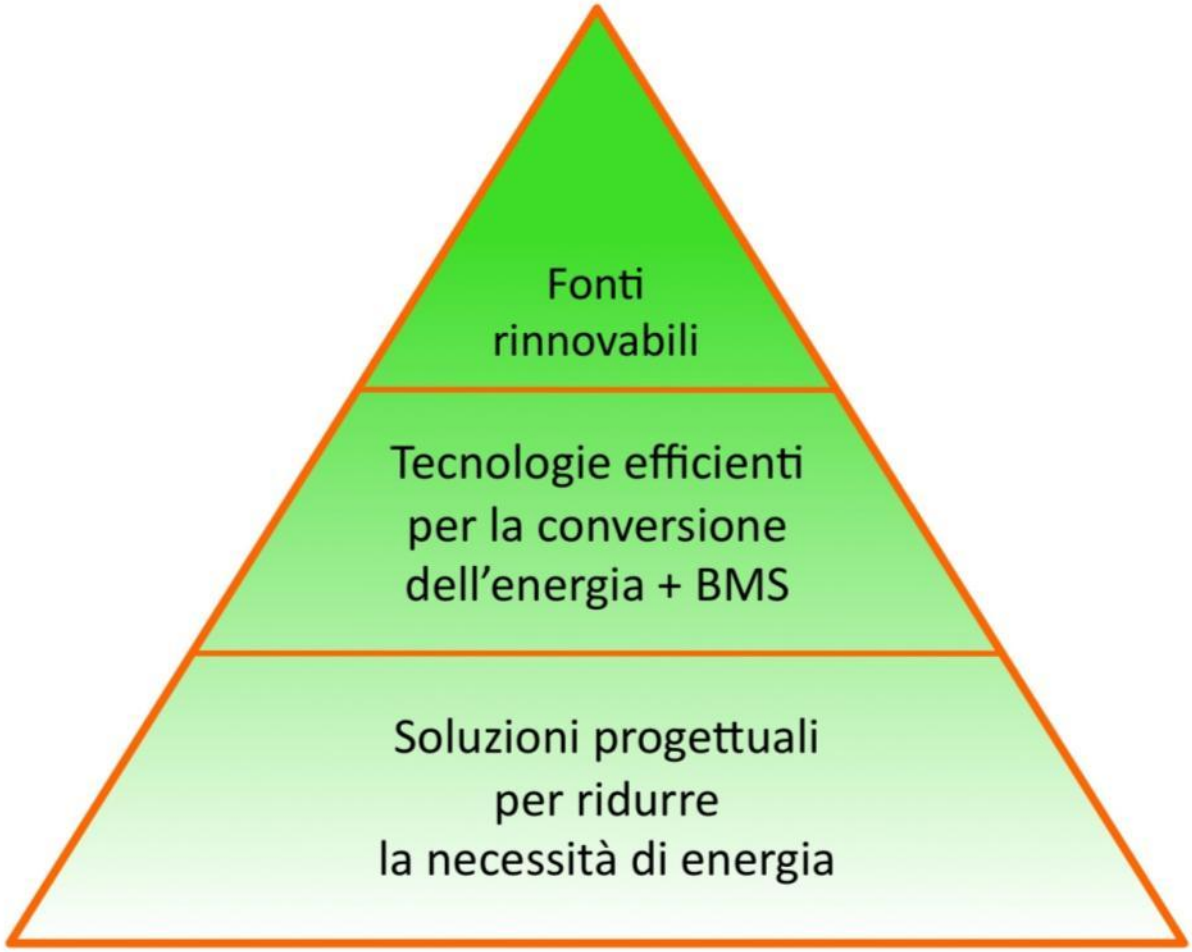
# Italia: edificio “efficiente”


**Fabbisogno per riscaldamento: 25 kWh/m² anno**
**Fabbisogno per ACS: 25 kWh/m² anno**
**Fabbisogno app. elettriche: 20 kWh/m² anno**
**Fabbisogno per climatizzazione estiva: 30 kWh/m² anno**
**Emissioni $CO_2$: 35 kg/ m² anno**

# Corte Montresora, Sona (VR)

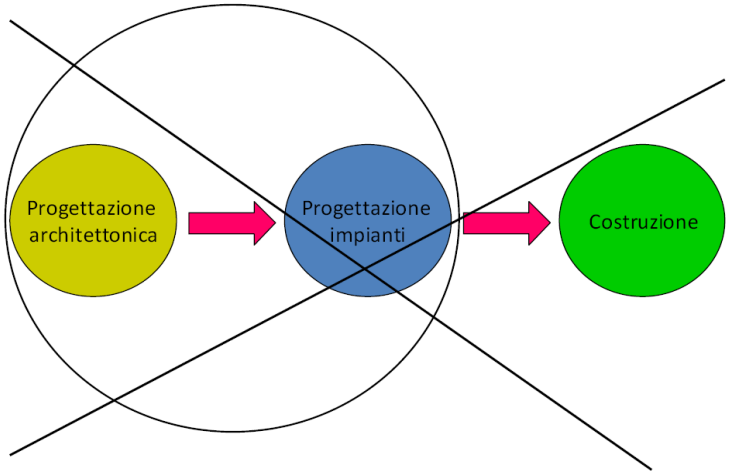
| | |
|---|---|
| Superficie disperdente totale | 3200 $m^2$ |
| Superficie finestrata totale | 188 $m^2$ |
| Area di pavimento lorda | 2200 $m^2$ |
| Area di pavimento netta | 1648 $m^2$ |
| Volume lordo riscaldato | 6687 $m^3$ |
| Volume netto riscaldato | 4796 $m^3$ |
| Rapporto (S/V) | 0.47 |

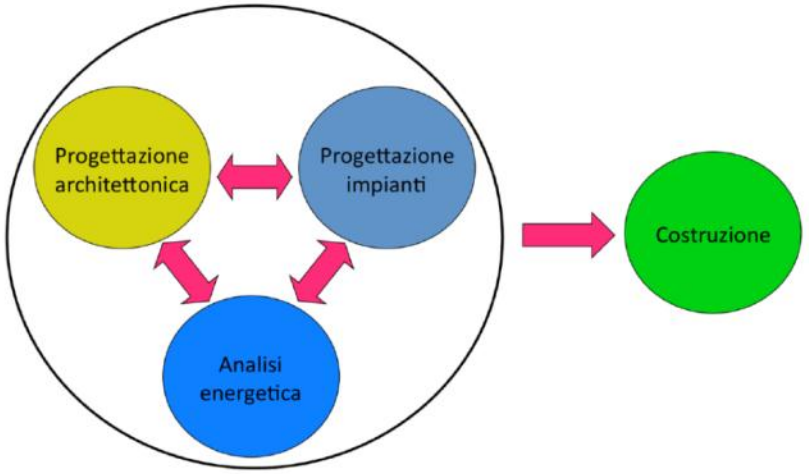
# Approccio metodologico (1)

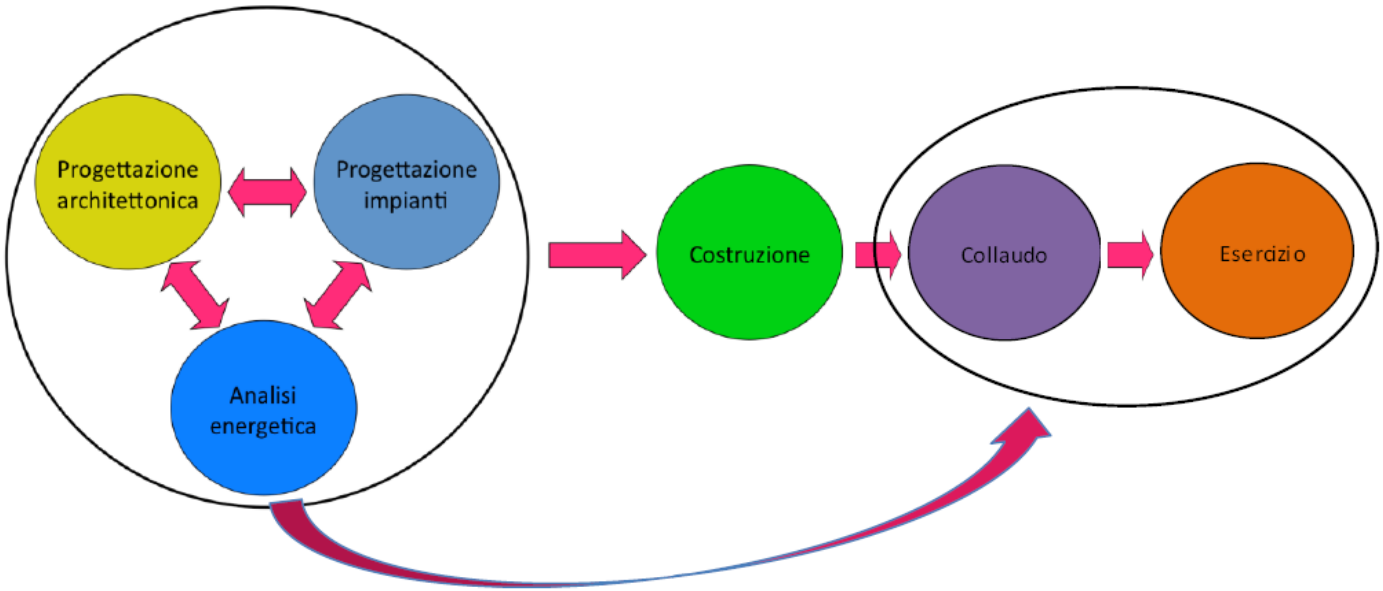


# Approccio metodologico (2)

# Approccio metodologico (3)

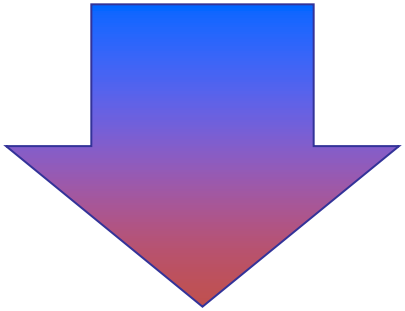


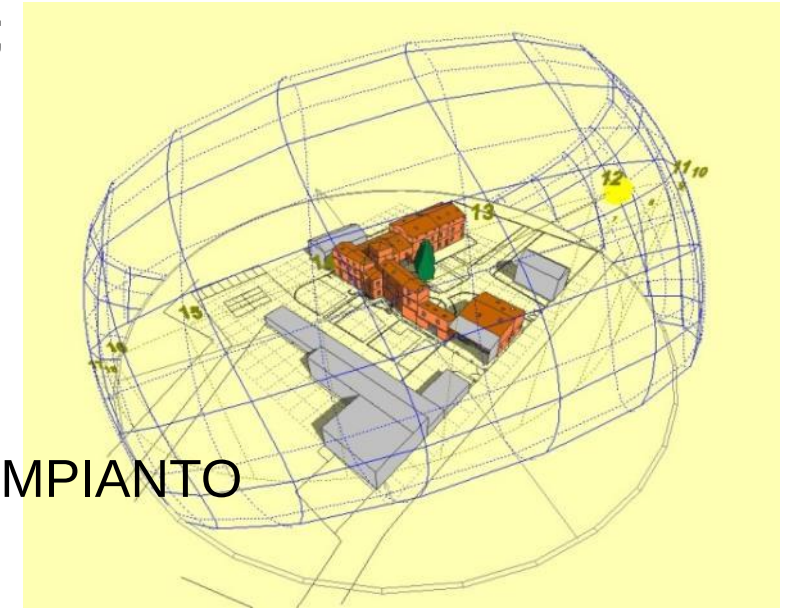



# Analisi energetica

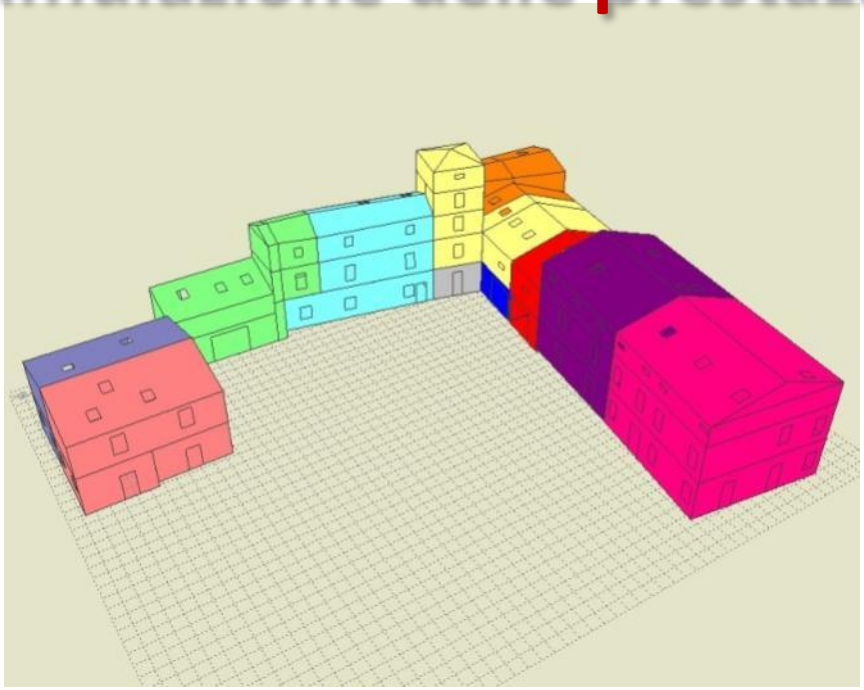
- analisi delle strutture edilizie esistenti e del contesto;
- analisi delle condizioni di comfort richieste;
- analisi e valutazione dei fabbisogni attesi;
- selezione dei possibili interventi sull'involucro dell'edificio;
- selezione dei possibili interventi sul sistema impiantistico;
- elaborazioni ipotesi progettuali alternative;
- simulazione in regime dinamico;
- valutazione delle prestazioni energetiche;
- ottimizzazione tecnico-economica.

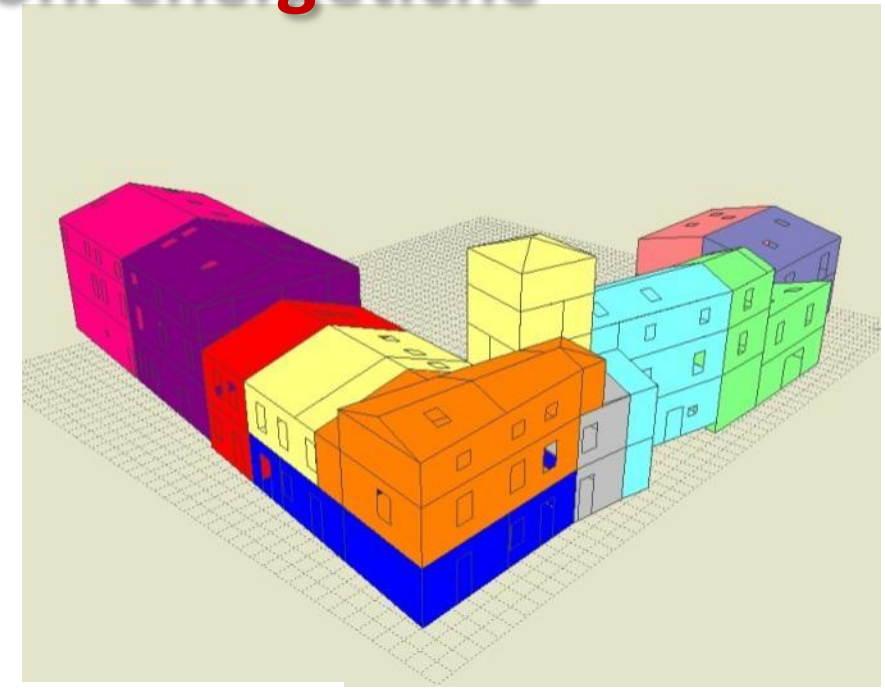


PROGETTAZIONE SISTEMICA EDIFICIO-IMPIANTO

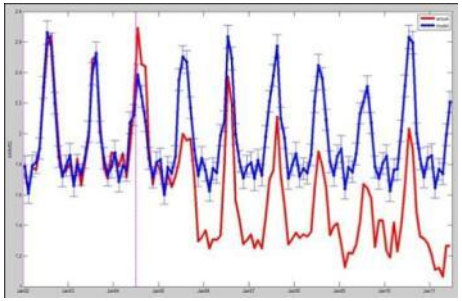


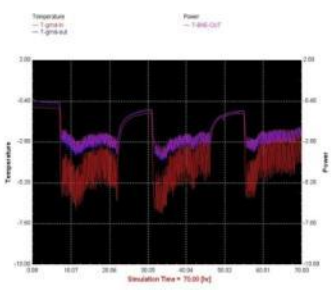
# Simulazione delle prestazioni energetiche

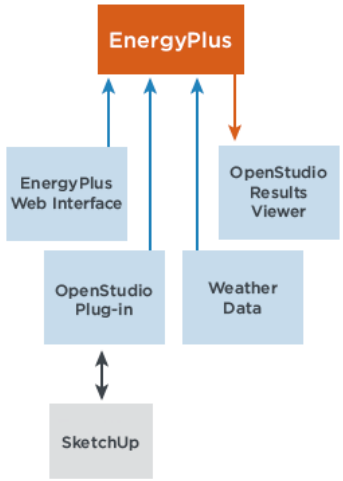


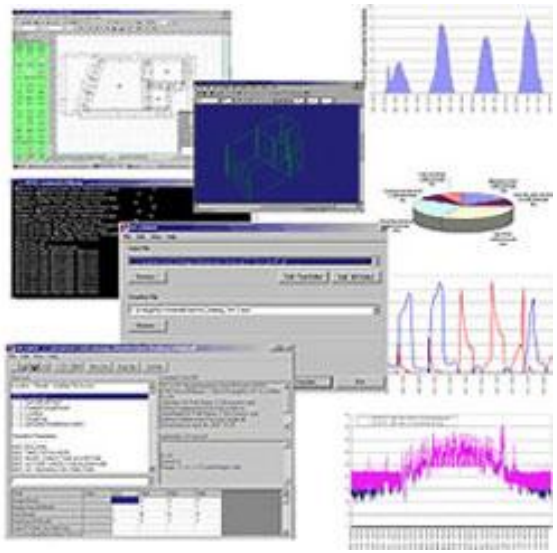


| | | | |
|---|---|---|---|
| | Unità 1 | | Unità 6 |
| | Unità 2 | | Unità 7 |
| | Unità 3 | | Unità 8 |
| | Unità 4 | | Unità 9 |
| | Unità 5 | | Unità 10 |





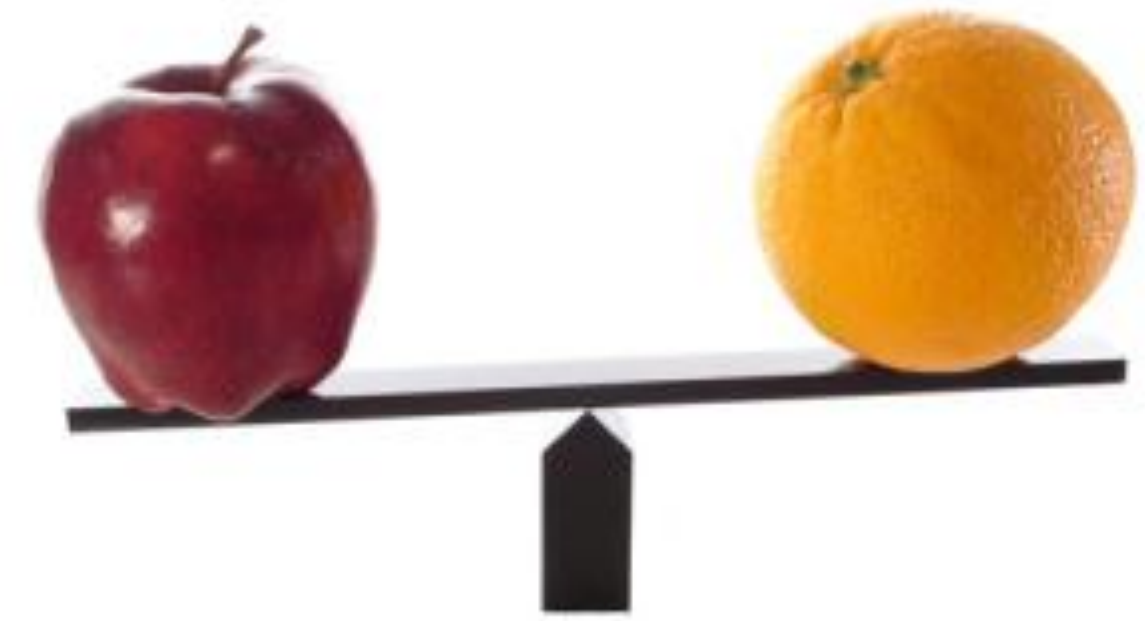


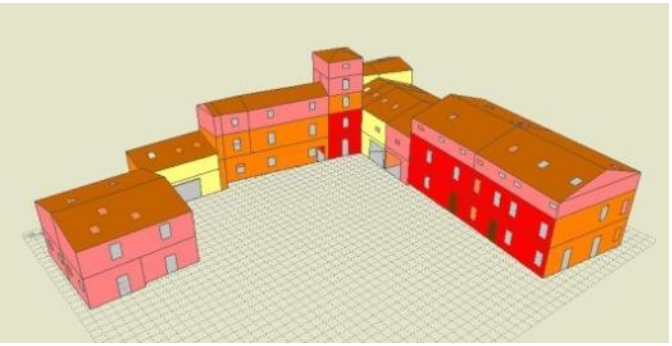
# Analisi prestazionale comparativa

## Scenari per l'analisi energetica

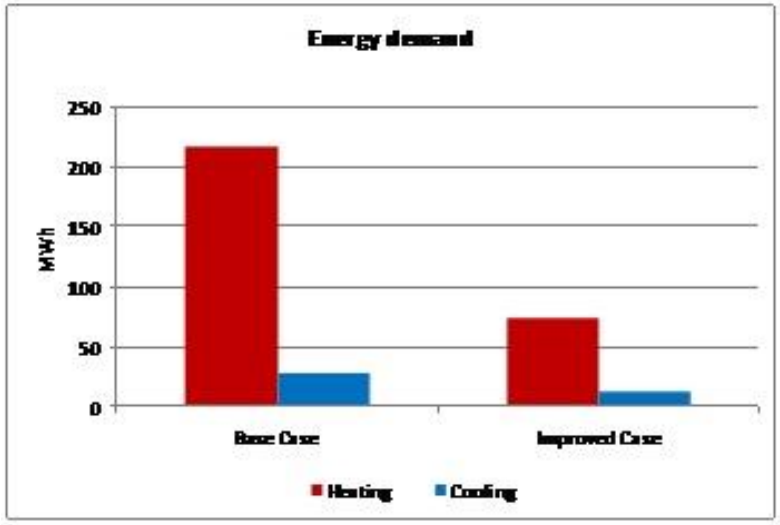
- **Base Case** - progetto di recupero senza retrofit energetico.
- **Improved Case** - progetto di recupero con retrofit energetico.



# Stima dei fabbisogni energetici



| | Caso Base | Caso Migliorato |
|---|---|---|
| Carichi interni | 5 W/m$^2$ | 5 W/m$^2$ |
| Ventilazione e infiltrazione | 0.5 V/h | Inverno-0.5 V/h<br>Estate-0.5 V/h(7:00 alle 22:00)<br>Estate-3.0 V/h(22:00 alle 7:00) |
| Controllo solare | No | Inverno -No<br>Estate - Si |
| Periodo di riscaldamento<br>Set point | 15 ottobre –15 aprile<br>20°C e 50% RH | 15 ottobre – 15 aprile<br>20°C e 50% RH |
| Periodo di raffrescamento<br>Set point | 1 giugno – 31 agosto<br>26°C e 50% RH | 1 giugno – 31 agosto<br>26°C e 50% RH |



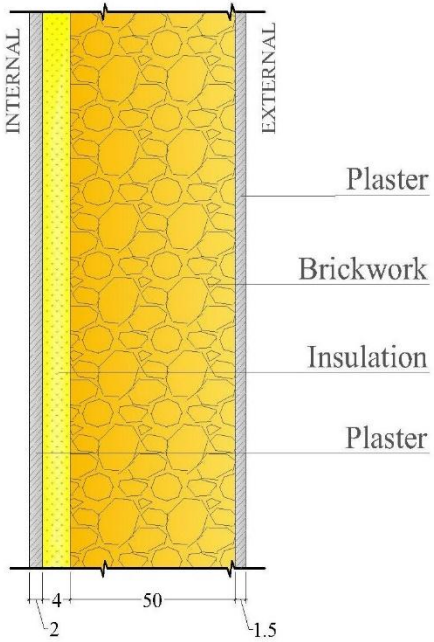

- riduzione del 66% sul fabbisogno utile per riscaldamento
- riduzione del 48% sul fabbisogno utile per raffrescamento

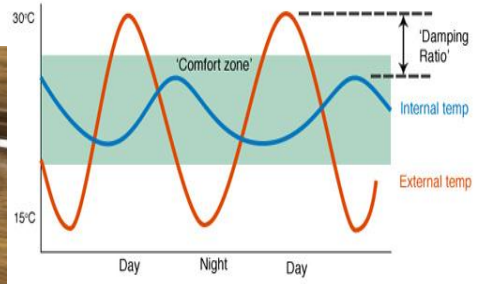
| Potenza di picco | Caso Base | Caso Migliorato |
|---|---|---|
| inverno | 108 kW | 54 kW |
| estate | 58 kW | 41 kW |

# Progetto dell'involucro

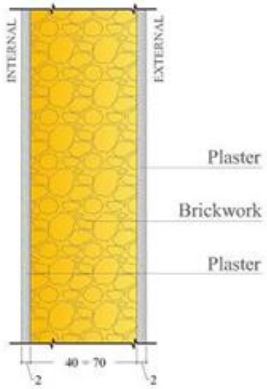
**Priorità**

- aumento della resistenza termica degli elementi d'involucro;
- utilizzo di vetri ad alte prestazioni termiche (doppi o tripli vetri, vetri bassoemissivi);
- integrazione di sistemi d'ombreggiamento per la protezione solare;
- valorizzazione della massa termica dell'involucro esistente.

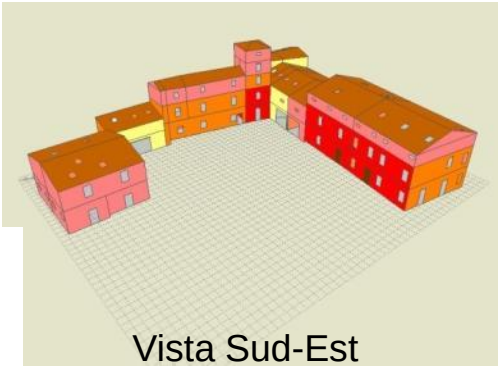


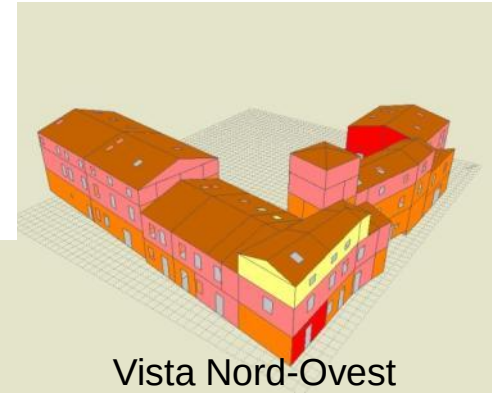



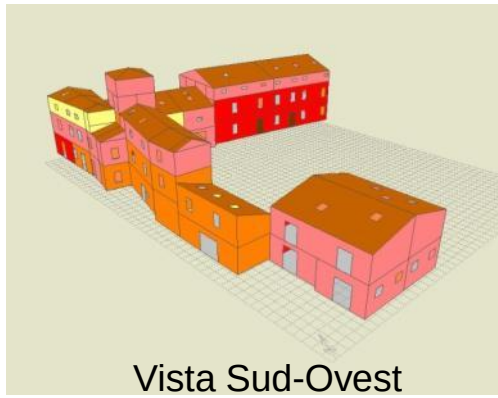

# Murature – Base Case




| | |
|---|---|
| Spessore (cm) | 40 - 70 |
| U ($W/m^2K$) | 2.16 - 1.56 |
| $M_f$ ($kg/m^2$) | 976 - 1666 |
| f (-) | 0.21 - 0.0502 |
| $\phi$ (h) | 10.17 - 16.89 |
| $Y_{ie}$ ($W/m^2K$) | 0.46 - 0.0786 |


Vista Sud-Est

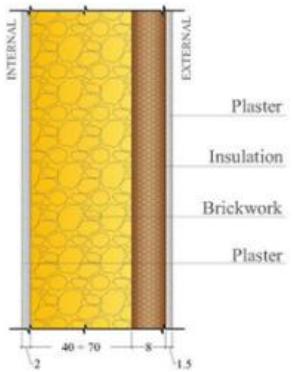

Vista Nord-Ovest


Vista Sud-Ovest

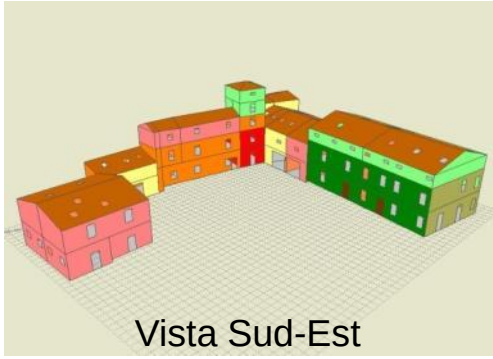
| *Descrizione pacchetti costruttivi* | *Collocazione* | *Stratigrafia (dall'interno)* |
|---|---|---|
| Muro perimetrale (40cm) | | Intonaco (2.cm)<br>Muratura (varia)<br>Intonaco (2.cm) |
| Muro perimetrale (50cm) | | |
| Muro perimetrale (60cm) | | |
| Muro perimetrale (70cm) | | |

# Murature – Improved Case

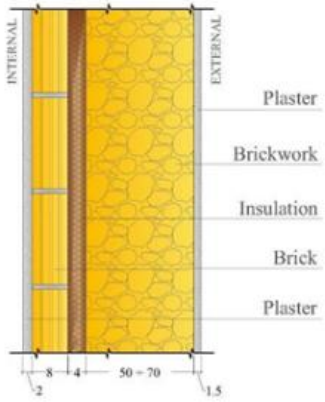




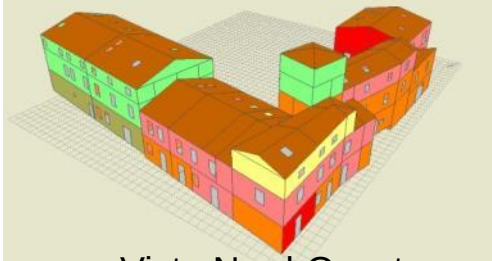

| Spessore parete (cm) | 40 - 70 |
|---|---|
| U ($W/m^2K$) | 0.40 - 0.38 |
| $M_f$ ($kg/m^2$) | 978.6 - 1668.6 |
| f (-) | 0.0657 - 0.0121 |
| $\phi$ (h) | 13.27 - 20.01 |
| $Y_{ie}$ ($W/m^2K$) | 0.0267 - 0.0046 |



Vista Sud-Est

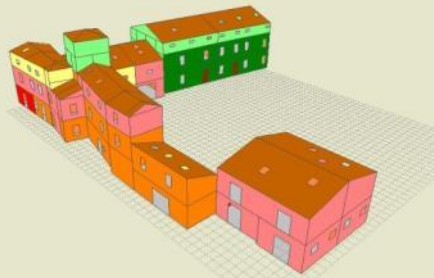



| Spessore parete (cm) | 50 - 70 |
|---|---|
| U ($W/m^2K$) | 0.54 - 0.535 |
| $M_f$ ($kg/m^2$) | 1245 - 1706 |
| f (-) | 0.0514 - 0.017 |
| $\phi$ (h) | 16.62 -21.11 |
| $Y_{ie}$ ($W/m^2K$) | 0.0294 - 0.0091 |



Vista Nord-Ovest

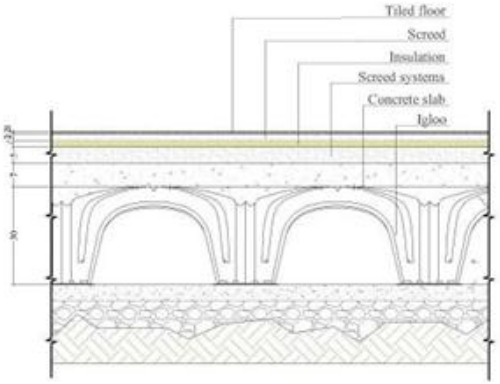
| *Descrizione pacchetti costruttivi* | *Collocazione* | *Stratigrafia (dall'interno)* |
|---|---|---|
| Muro 40 cm | | Intonaco, *In3* (2cm)<br>Muratura, (varia)<br>Isolante, *Is4* (8cm)<br>Intonaco, *In3* (1,5cm) |
| Muro 50 cm | | |
| Muro 60 cm | | |
| Muro 70 cm | | |
| Muro villa 50cm | | Intonaco, *In3* (2cm)<br>Isolante, *Is4* (4cm)<br>Muratura, (varia)<br>Intonaco, *In3* (1,5cm) |
| Muro villa 60cm | | |
| Muro villa 70cm | | |



Vista Sud-Ovest

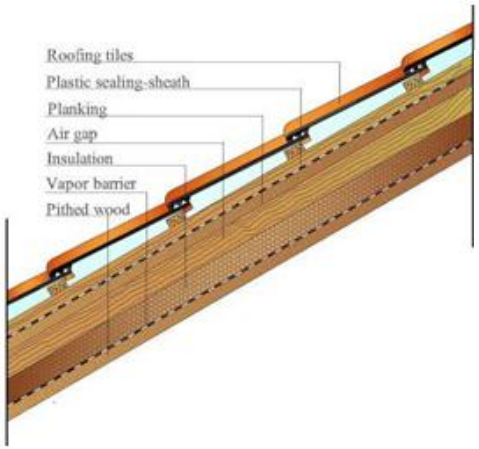
# Solai e coperture

Solaio a terra




| | Base Case | | Improved Case |
|---|---|---|---|
| Spessore (cm) | 57 | Spessore (cm) | 63 |
| U (W/m²K) | 0.65 | U (W/m²K) | 0.391 |
| $M_f$ (kg/m²) | 943.6 | $M_f$ (kg/m²) | 976.8 |
| f (-) | 0.0234 | f (-) | 0.0136 |
| ϕ (h) | 20.0 | ϕ (h) | 21.63 |
| $Y_{ie}$ (W/m²K) | 0.0153 | $Y_{ie}$ (W/m²K) | 0.0053 |

Copertura




| | | | |
|---|---|---|---|
| Spessore (cm) | 20 | Spessore (cm) | 24 |
| U (W/m²K) | 0.5 | U (W/m²K) | 0.33 |
| $M_f$ (kg/m²) | 22.14 | $M_f$ (kg/m²) | 27.9 |
| f (-) | 0.9236 | f (-) | 0.7814 |
| ϕ (h) | 2.57 | ϕ (h) | 4.69 |
| $Y_{ie}$ (W/m²K) | 0.4691 | $Y_{ie}$ (W/m²K) | 0.2586 |

# Serramenti e partizioni interne

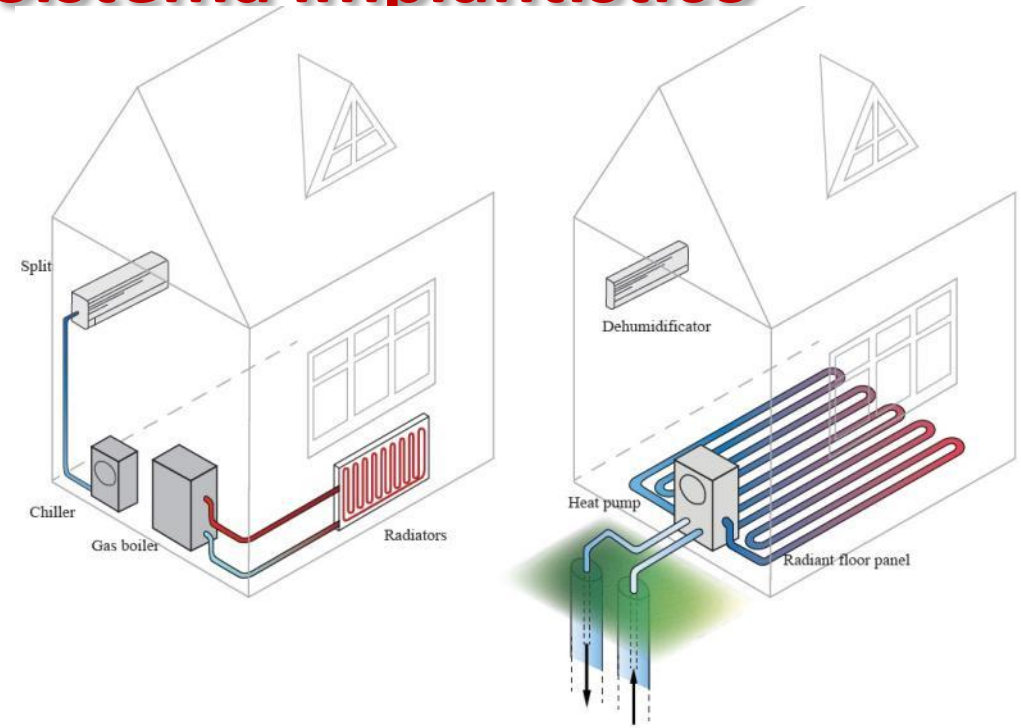
Elementi trasparenti

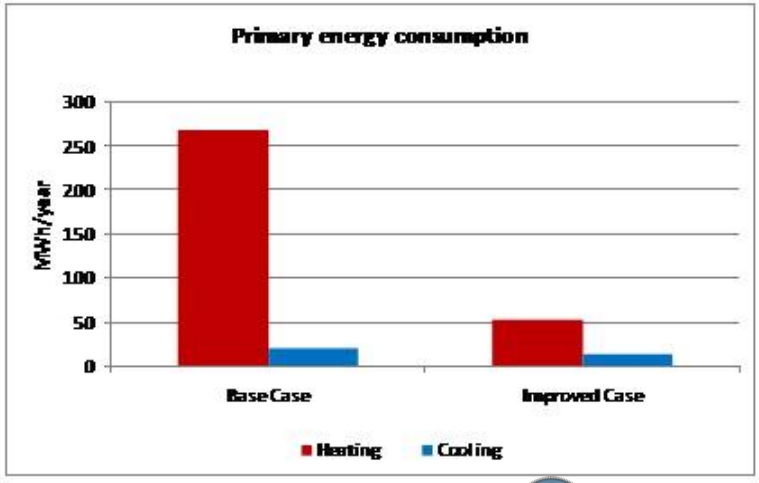
| | | Caso Base | | Caso Migliorato | |
|---|---|---|---|---|---|
| **Elemento** | **Posizione** | **Layers** | **U-value ($W/m^2K$)** | **Layers** | **U-value ($W/m^2K$)** |
| Vetro | Tutto l'edificio | Doppio vetro (g-value = 0.747) | 3.00 | Doppio vetro selettivo (g-value =0.594) | 1.10 |
| Telaio | | Legno | 1.80 | Legno | 1.80 |
| Serramento | | - | 2.50 | - | 1.50 |

Partizioni interne

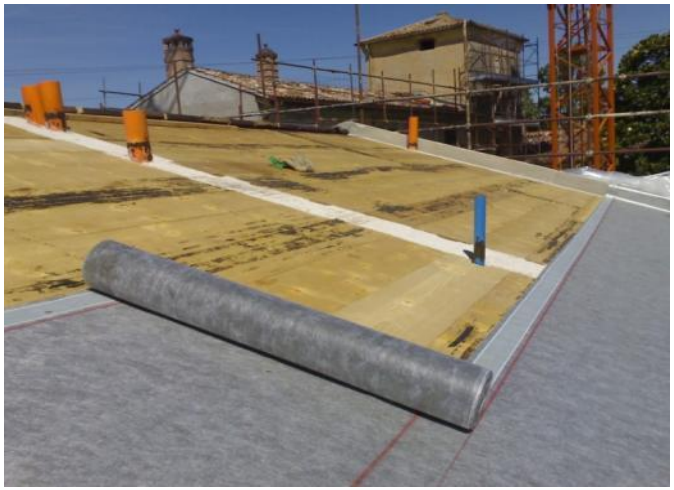
| | | Caso Base | | Caso Migliorato | |
|---|---|---|---|---|---|
| **Elemento** | **Posizione** | **Layers (da int. ad ext.)** | **U-value ($W/m^2K$)** | **Layers (da int. ad ext.)** | **U-value ($W/m^2K$)** |
| Solaio intermendio | All'interno dell'edificio | Piastrelle (1 cm)<br>Massetto (5 cm)<br>Assito in legno (3 cm) | 2.0 | Piastrelle (1 cm)<br>Pavimento radiante (10 cm)<br>Massetto (5 cm)<br>Assito in legno (3 cm) | 0.47 |
| Partizione interna | Partizioni nelle unità abitative | Intonaco (1.5 cm)<br>Muratura (25 cm)<br>Intonaco (1.5 cm) | 1.32 | Intonaco (1.5 cm)<br>Muratura (25 cm)<br>Intonaco (1.5 cm) | 1.32 |
| Parete verticale | Partizioni tra unità abitative | Intonaco (1.5 cm)<br>Muratura (60 cm)<br>Intonaco (1.5 cm) | 1.56 | Intonaco (1.5 cm)<br>Muratura (60 cm)<br>Intonaco (1.5 cm) | 1.56 |

# Sistema impiantistico



# Realizzazione: la copertura



# Realizzazione: murature



# Realizzazione: solai

# Prima e dopo l'intervento