

HUMAN-DRIVEN ENERGY EFFICIENCY IN HISTORIC BUILDINGS

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Genesis of the research

The energy research perspective

Replacement Rate of existing buildings by new ones in EU



The weight of HBs on the **EU building stock**



Historic buildings have a crucial role to reach **EU 2050 GHG emissions' reduction goals (-80-95%)**

Since most HBs host human activities, there is the necessity to **adapt** them to our current lifestyle, e.g. ensuring **health and comfort of occupants**

The preservation sector perspective

In Italy, in 2017, Public Museums revenues from Visitors was **278M€**

In the same year, their annual expenditure for energy-related costs was **250 M€**

In museums, palaces and monuments energy-related costs can represent more than **70% of the annual total balance**



The preservation sector and the energy research seems to pursue mutual exclusive objectives

Preservation

Protection of the building materiality



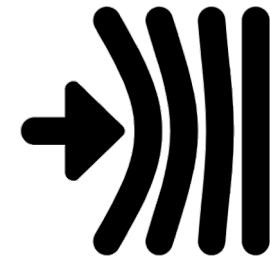
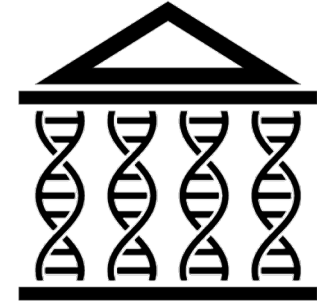
Transmission to the future generation

Adaptation

Intervention on the building materiality

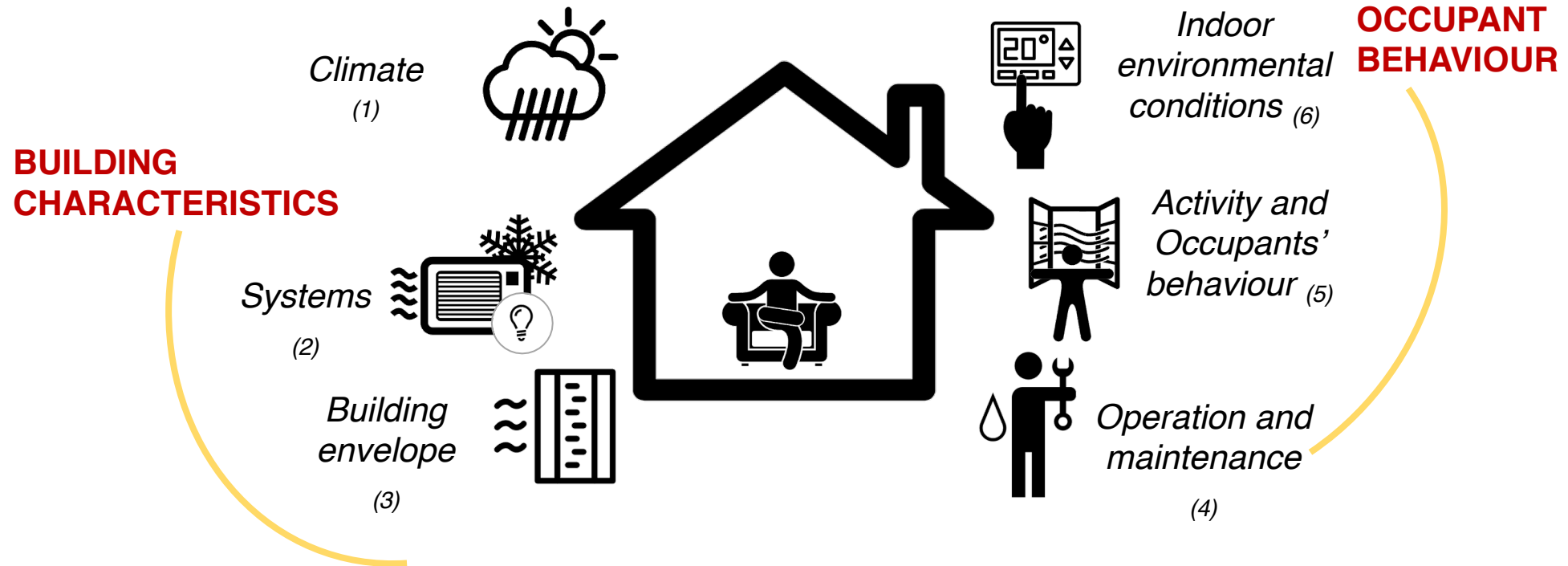


Enhancement of energy performances



Result: most often energy standards exempt HBs from respecting the prescriptions and this building stock is not retrofitted at all

Occupant Behaviour definition and potential



Can acting on Occupant Behaviour (by engaging occupants) be a valuable energy retrofit measure?

Theoretical framework and research question

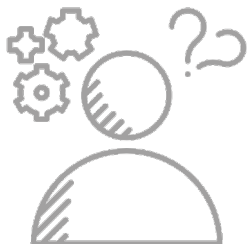
Why conceiving occupant engagement as a potential energy retrofit measure

Theoretical framework

* In the specific context of HBs

- ① Optimize their **occupants' comfort**
- ② Create a pro-active involvement in **reducing energy consumption** and avoid energy waste
- ③ * **Reduce heritage conservation risks** (e.g. artworks and decorations)
- ④ * **Increase social responsibility** towards a conscious preservation of architectural heritage

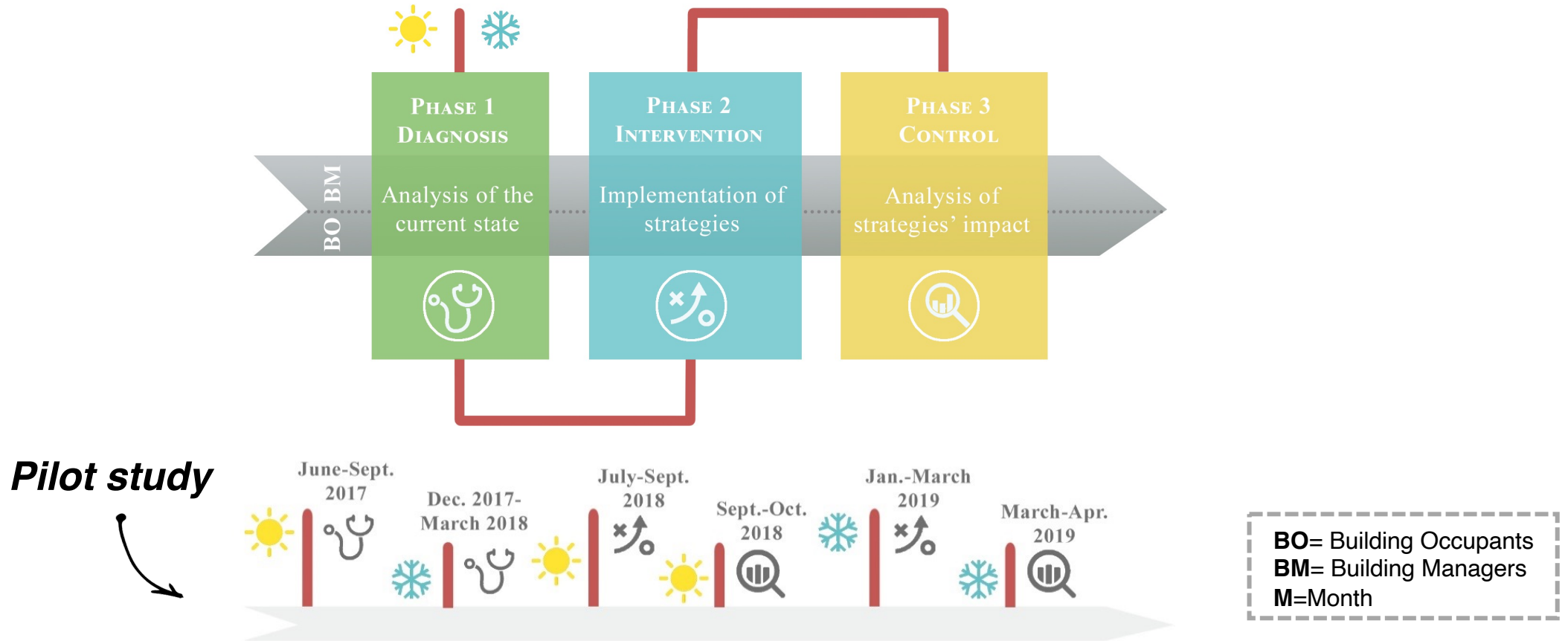
RESEARCH QUESTION



*What are the **potentialities of energy saving and indoor environmental conditions' enhancement** by acting only on the way **non-residential historic buildings are operated** by occupants and operators?*

BIOSFERA METHODOLOGY

BUILDING **I**NTELLIGENT **O**PERATIONAL **S**TRATEGIES **F**OR ENERGY **R**ETROFIT **A**IMS



Phase I - Diagnosis

Hypothesizing the potential



Building managers and technicians



Building occupants

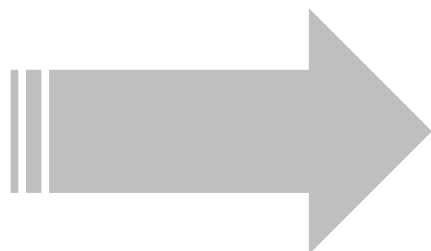
- Semi-structured interviews
- Acquisition and analysis of energy bills;
- Acquisition and analysis of environmental monitoring data.



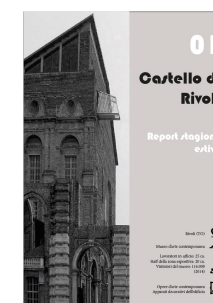
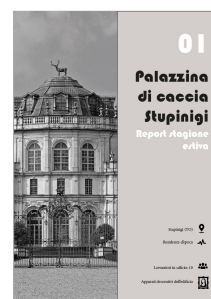
Questionnaire addressed to the various building occupant types:



- office workers (High Level of Control)
- “staff” and classrooms users (Medium L. of C.)
- museum visitors (Low L. of C.)



- **INTERVENTION STRATEGIES**
- **SEASONAL REPORTS**



Phase II - Intervention

Elaborate actions to ameliorate building operation by BMs and Bos



Building managers and technicians

STRATEGIES' OBJECTIVES:

- Lower **energy** consumptions;
- Respond to **occupants'** comfort necessities expressed in the questionnaire;
- Solve critical situation related to **artworks'** conservation.

MEASURES:

- Change of **HVAC** set-points and schedules
- Change of **envelope** elements' management



Building occupants

STRATEGIES' OBJECTIVES:

- **Educate occupants** to take advantage of their control opportunities;
- **Engage occupants** in lowering the building's energy consumption.

MEASURES:

- Newsletters
- HVAC controls' instructions
- Comfort advices
- Reminds



Phase III - Control

Define the potential

Two types of results → **Energy-related**: change in energy consumption and related costs.
→ **Occupant-related**: ameliorating comfort and changing behavior.



Building managers and technicians



Building occupants

- Semi-structured **interviews** about the implementation of strategies;
- Acquisition and analysis of the **new energy bills and environmental monitoring data**.





- **Post-strategies' questionnaire** about environmental comfort, communication/education measures and behavioral change.



Strategies and energy related results

Phase II intervention + Phase III seasonal analyses

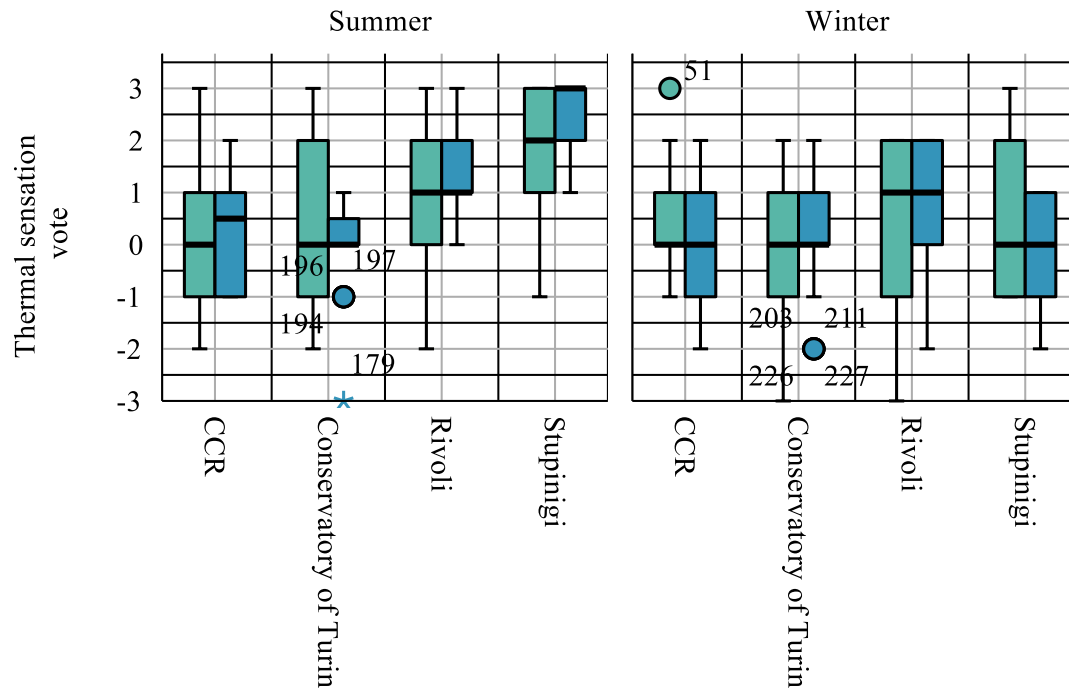
CASE STUDY	PRINCIPAL OPERATIONAL STRATEGIES 	PRINCIPAL EDUCATIONAL STRATEGIES 	EFFECT ON ELECTRIC ENERGY CONSUMPTION (%)		EFFECT ON NATURAL GAS CONSUMPTION (%)*	
Turin Conservatory of music	Change of HVAC and VMC T and UR set-points in classrooms and auditorium	Classrooms: all types of posters Offices: newsletters	-39%	-43%	-20%	+4%
Rivoli Castle	Changes in curtains and windows opening in the exposition area. No HVAC strategies (ESCO)	Offices: comfort, remind posters and newsletters Staff: informative presentation with comfort advices	SUMMER -8%	WINTER -9%	SUMMER -21%	WINTER 12%
Venaria Restoration Center	Change of temperature set-points in all office types (not restoration labs)	Offices and restoration labs: all types of posters (different per functional areas) and newsletter	-9%	-11%	Not available	

*normalized GGE/GGI

Building-occupants-related results

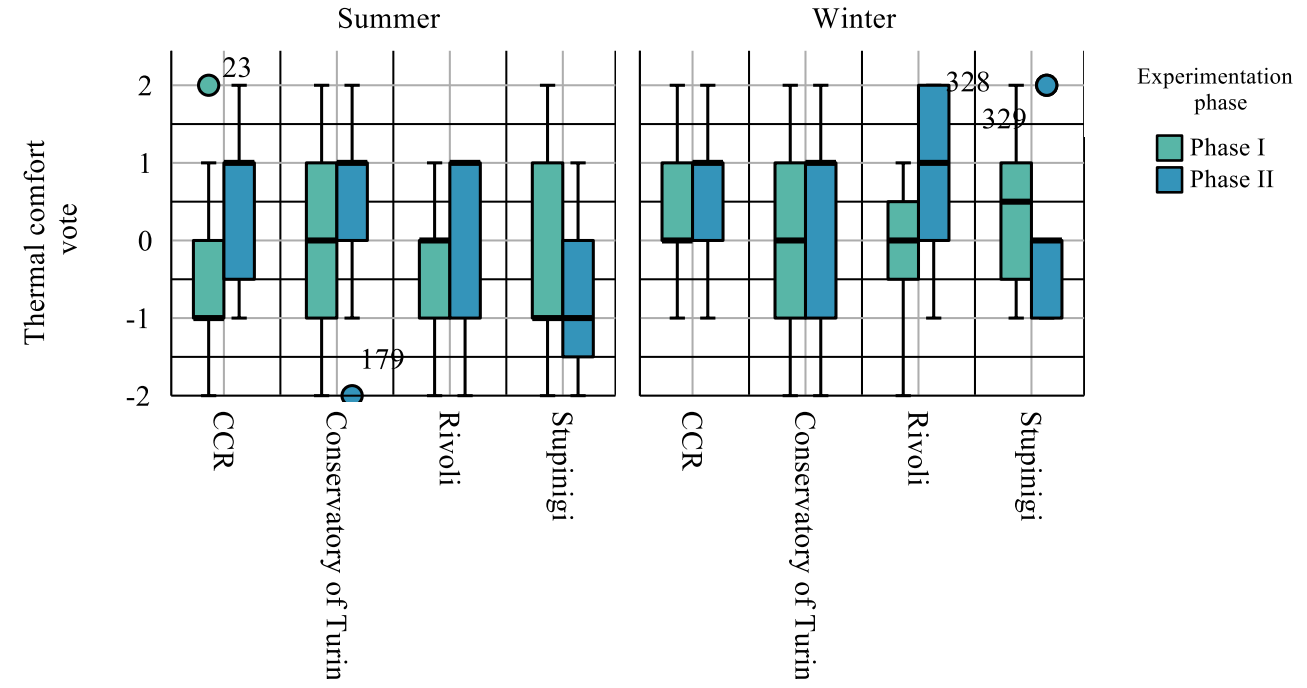
Impact of strategies on occupants' thermal comfort

- In all cases (except one) **Thermal Sensation Votes range** was unaltered or became smaller.
- **Thermal Sensation Votes** are generally between slightly cool and slightly hot (-1, +1).
- Also **Thermal Comfort** votes are generally unaltered or increased. Independent T-test demonstrated that Thermal comfort significantly changed in summer ($p=0.001$, $r=0.26$).



Thermal sensation scale

3=hot; 2=warm; 1=slightly warm; 0=neutral; -1=slightly cool; -2=cool; -3=cold



Thermal comfort scale

2=very comfortable; 1=moder. Comfortable; 0=neutral; -1=moder. Uncomfortable; -2=very uncomfortable

Conclusive summary

The BIOSFERA methodology was adopted as a way to balance the apparently contradictory aims of the energy and preservation sectors.

Conclusive remarks

- Considering the whole impact of the BIOSFERA methodology on **energy consumption** (summer + winter and electricity + natural gas), savings ranged from **10% to 16%**, with a seasonal peak of 36% (in one case study).
- Occupants' **thermal comfort remained unaltered or was enhanced** in the large majority of cases. Moreover, they evaluated positively the adopted engagement measures and **changed behaviour** towards less consuming habits.
- Considering the results and the almost **zero-costly implementation**, the adoption of the BIOSFERA methodology could have a major impact to **reduce energy-related costs** of HBs and could also be implemented to **reduce the risk of rebound effects** in other energy retrofit “material” interventions.

Comparison with other energy retrofit measures applied to HBs* (from 3ENCULT EU project)-*Expected EP savings

Comparable savings: insulation of the roof (~5%), installation of additional windows (~ 10%), mechanical ventilation with heat recovery (~ 8%), increase of plant efficiency (~ 18%)

Higher savings: façade insulation (~ 30%)