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Energy and Environmental analysis for Historical Buildings: Insights from MOLAB by E-RIHS

Filippo Calcerano

CNR Institute of Heritage Science

INTERNATIONAL WORKSHOP
DIGITAL INTEGRATED STRATEGIES TO SAFEGUARD HERITAGE CONSTRUCTION TECHNOLOGIES
September 30 - October 5, 2024 | Poggioreale, Trapani

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UIH Lab Urban Innovation & Heritage Laboratory

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BUILT HERITAGE AND CLIMATE CHANGE

ENERGY AND ENVIRONMENTAL IMPROVEMENT OF BUILT HERITAGE

SIMULATION-BASED DESIGN AND HBIM

THE ROLE OF E-RIHS

ENICBCMED BEEP PROJECT - THE CASE STUDY OF PALAZZO MAFFEI BORGHESE IN ROME

BUILT HERITAGE AND CLIMATE CHANGE

Built heritage and climate change

Cultural heritage plays a key role in many of the 17 objectives of the Sustainable Development Goal agenda, so much so as to lead some to consider the cultural dimension as the fourth dimension of sustainable development (with the economic, environmental and social ones).

Built heritage and climate change

Energy consumption and climate change are an issue also for the built heritage sector

Built heritage and climate change

An issue in terms of aggressive environments towards buildings, risk assessment from the macroscopic impacts of climate change, and a risk in terms of reduced usage of buildings, which is the most important factor to enhance the conservation of any historical building.

Built heritage and climate change

Historical buildings and fabrics are not the most numerous nor energy-intensive part of the building stock and they generally behave more efficiently than buildings constructed between the World War II and the 1980s thanks to their passive behaviour, optimised for the reference climate.

Built heritage and climate change

Climate change is weakening this assumption, by undermining the natural functioning of historical buildings, with significant consequences for their conservation as well.

John Robert Cozens (1752-1797), Peasant's hut between Naples and Portici,

Built heritage and climate change

Home

The New York Times | CLIMATE

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Originally published in 2018

How Much Hotter Is Your Hometown Than When You Were Born?

As the world warms because of human-induced climate change, most of us can expect to see more days when temperatures hit 32 degrees Celsius (90 degrees Fahrenheit) or higher. See how your hometown has changed so far and how much hotter it may get.

Your hometown | Birth year

Please enter your information to continue.

350

Built heritage and climate change

Furthermore, the increase in comfort standards has made no longer acceptable thermohygrometric conditions that once were

Energy and Buildings 116 (2016) 218–231

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Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Sustainable church heating: The Basilica di Collemaggio case-study

CrossMark

Niccolò Aste, Stefano Della Torre, Rajendra S. Adhikari, Michela Buzzetti, Claudio Del Pero*, Fabrizio Leonforte, Massimiliano Manfren

Built heritage and climate change

From the conservation point of view, it will be necessary to develop increasingly advanced methods of adaptation to climate change in order to enhance the resilience of historical buildings (i.e. the ability to cope with change while maintaining an equilibrium).

View of ancient buildings in a sandstorm in Lanzhou city, northwest Chinas Gansu province, 24 April 2014 (Imaginechina/Corbis)

Put the focus also on mitigation

In addition to vulnerability to climate change, the issue of energy consumption, now and in the future, needs to be also addressed both from a conservation/valorisation perspective (avoid fuel poverty and thus building abandonment) and from a sustainable development perspective (reduce consumption and emissions, help mitigate the causes of climate change in the long run).

ENERGY AND ENVIRONMENTAL IMPROVEMENT OF BUILT HERITAGE

A change in sensitivity

Despite the EU being an early mover on the climate change adaptation and mitigation policies, and having strongly committed on energy efficiency of the construction sector, a coordinated action on the built heritage is still lacking.

A change in sensitivity

It is no coincidence that the Climate Heritage Network, to date the most important network of actors of cultural heritage from an environmental point of view, released its European Heritage Green Paper to assess the role that heritage has or should have in relation to the European Green Deal (not very sensitive to the potential synergies between cultural heritage and the fight against climate change)

Climate Heritage NETWORK

A change in sensitivity

Energy and environmental improvement of built heritage

The Italian debate, in the wake of what has happened in the structural field, today uses the concept of "improvement" for the energy and environmental interventions on built heritage as a enhancement and protection strategy, however subordinate to their conservation, thus without losing the general objective of interventions on cultural heritage which is their conservation for future generations, which is also linked to the principle of integrated conservation introduced by the Amsterdam Declaration

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Energy and Buildings

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Energy efficiency as a protection tool

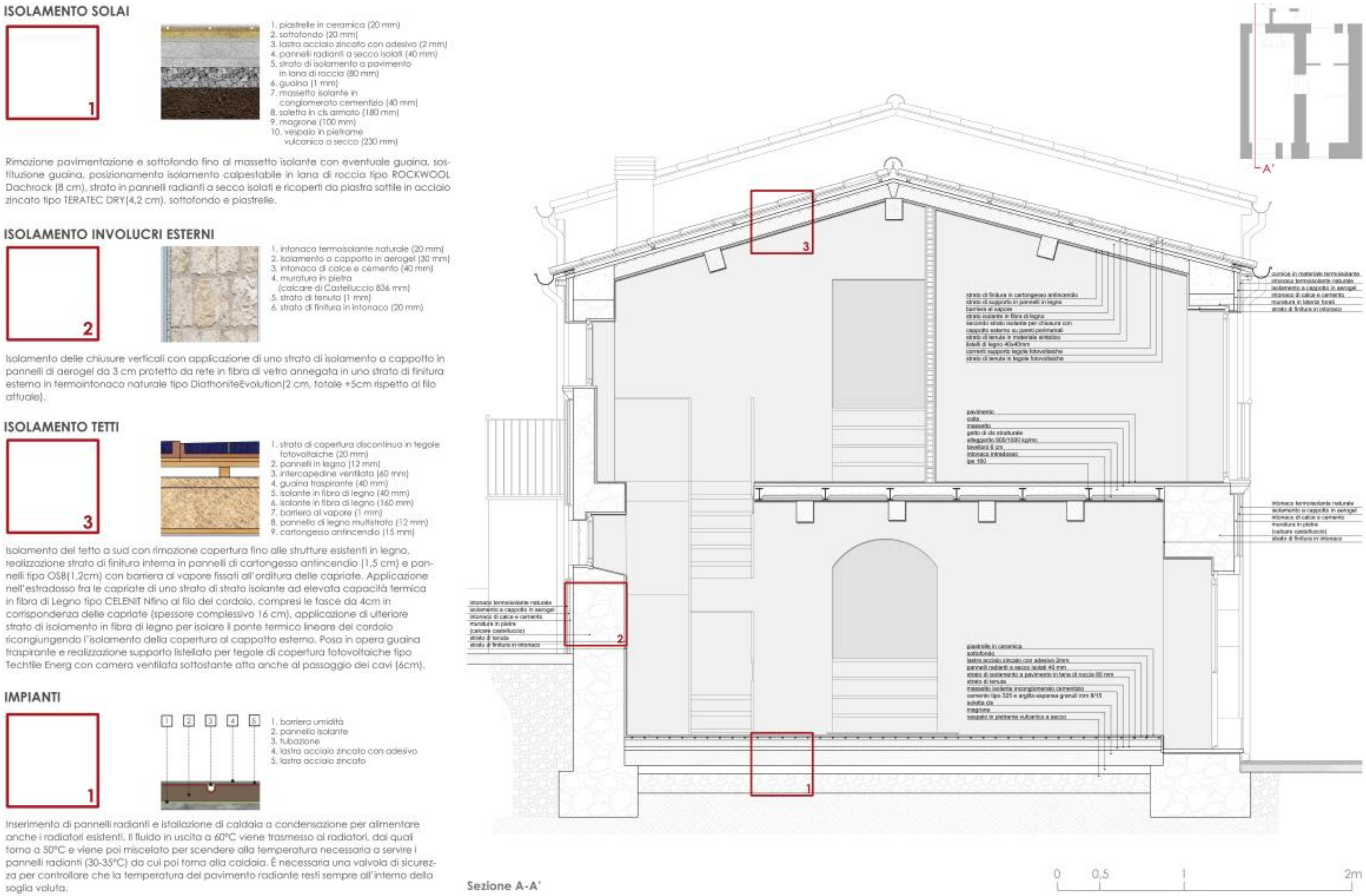
Giovanni Carbonara*

University of Roma "La Sapienza", Dipartimento di STORIA, DISEGNO E RESTAURO DELL'ARCHITETTURA, Piazzale A.Moro, 5, Roma, Italy

Energy and environmental improvement of built heritage

The approach involves compliance with the guiding principles of the international restoration charters:

- minimum intervention;
- reversibility;
- distinguishability;
- physical-chemical and figurative compatibility;
- respect for the material and figurative authenticity of the asset.



Energy and environmental improvement of built heritage

The study of built heritage from an environmental design perspective also guarantees at least four fundamental advantages:

- disciplinary cross fertilization;
- added value of knowledge;
- beacon for the sector;
- technological stress test.

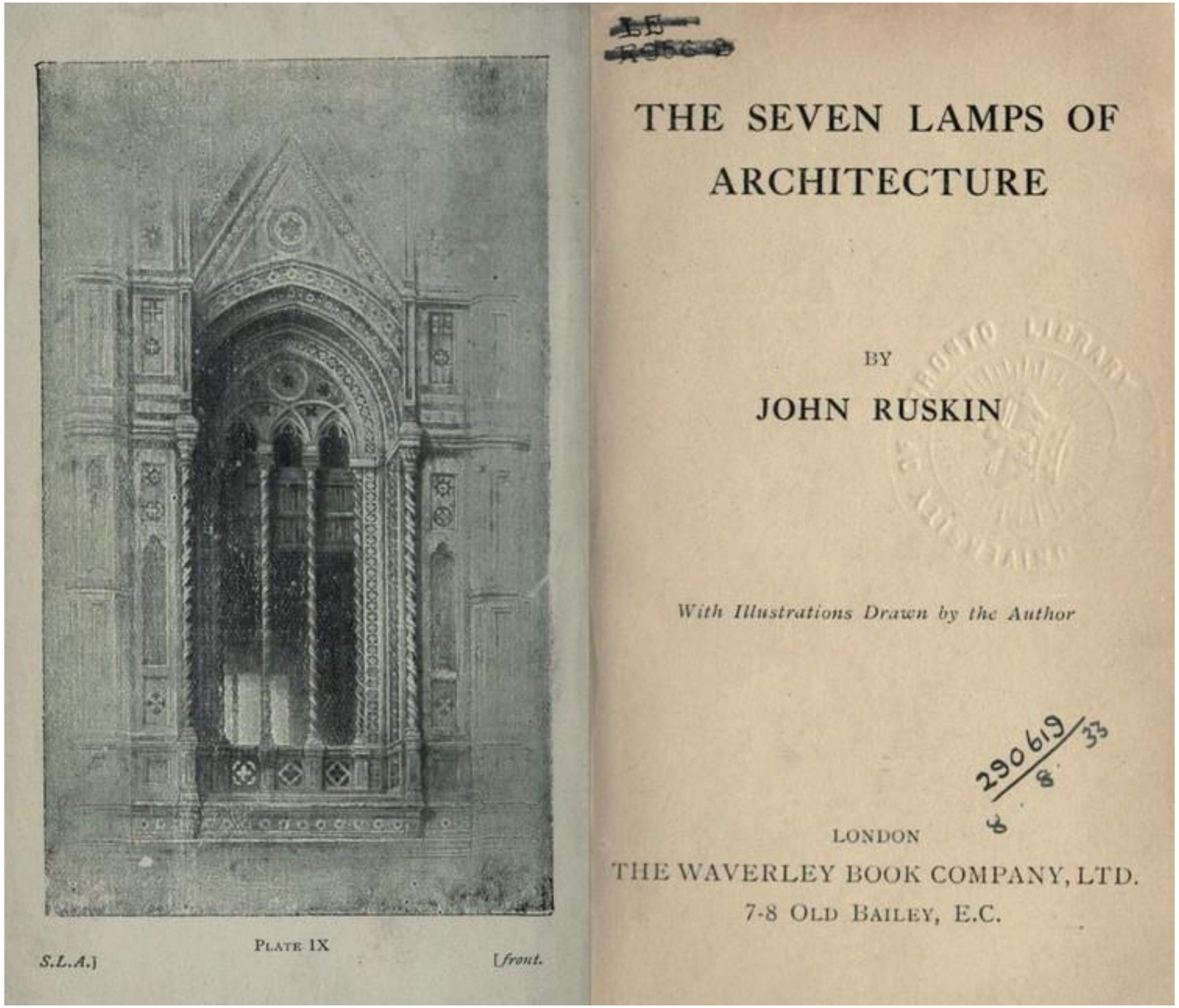
Chuandixia Village, China

Energy and environmental improvement of built heritage

The connection between cultural heritage and the environment, anticipated, in the interpretation of Di Stefano of John Ruskin (1982), was however already present in the UNESCO convention of 1972, and became clearer with the 1994 Aalborg charter.

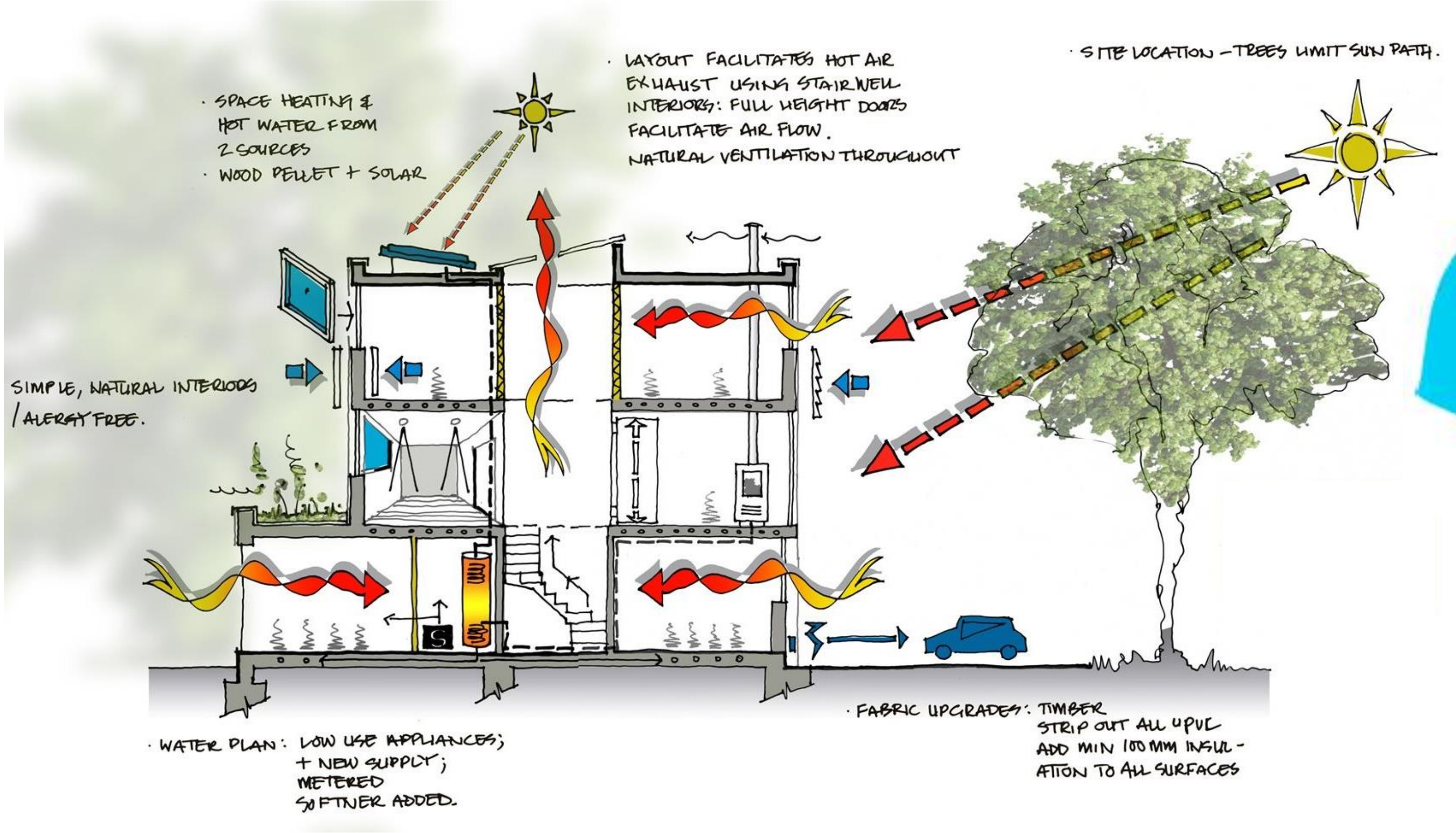
UNESCO
United Nations
Educational, Scientific and
Cultural Organization

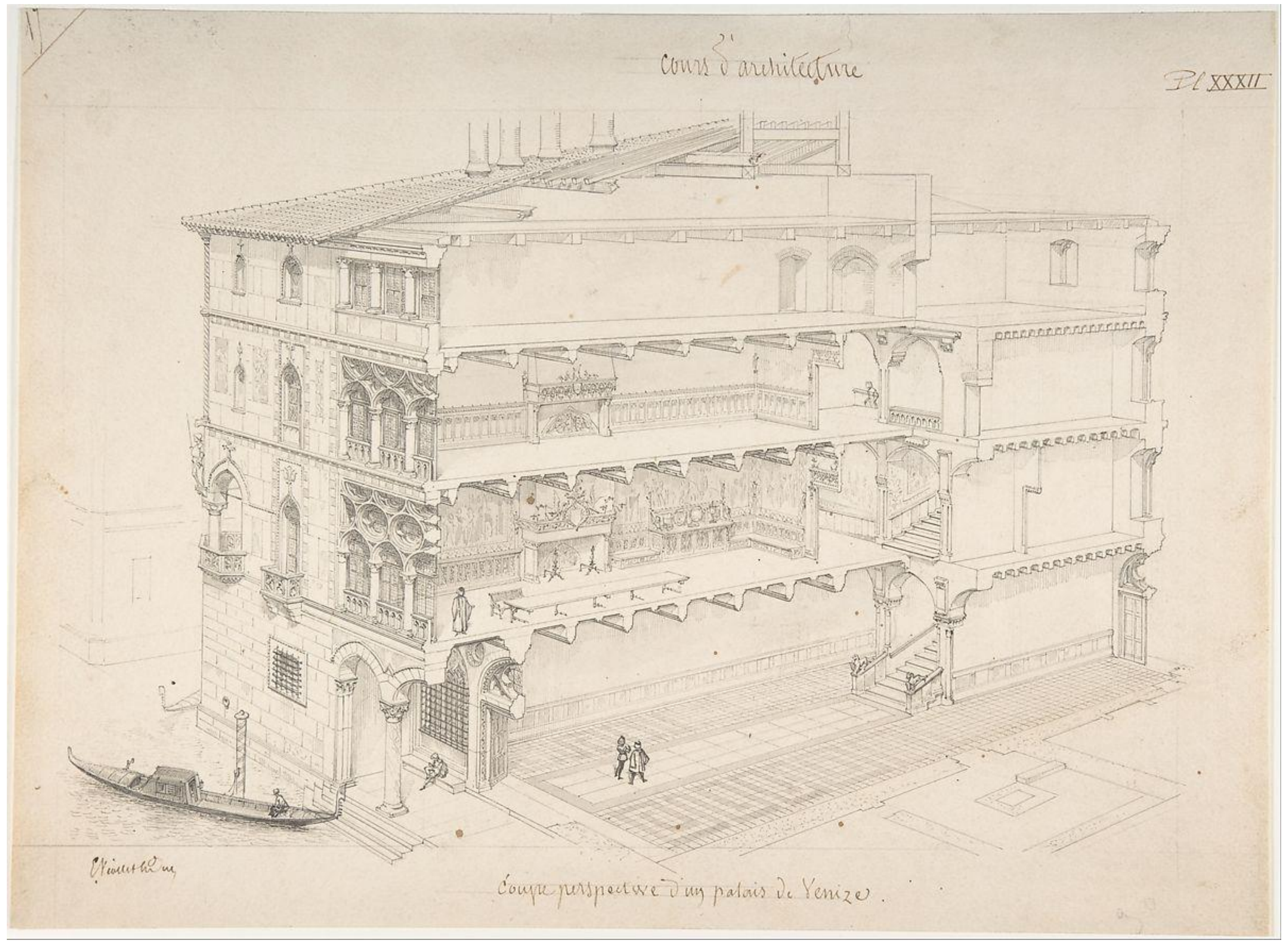
World
Heritage
Convention



Energy and environmental improvement of built heritage

Environmental design and conservation have always had many methodological aspects in common, from the transgenerational temporal perspective, to the need to deal with strongly interdisciplinary, holistic and multiscalar approaches, to the need to move in a space of uncertainty on the border between hard sciences and humanities, which provides us with the most interesting insight.





Energy and environmental improvement of built heritage

where scholars argue that the division between cultural and technical aspects does not exist and that the building must be studied as a complex system that cannot be analysed by parts, thus allowing to have a compass for the introduction of innovative technologies and methodologies on historic buildings.

Gustavo Giovannoni, inspirer of the Athens charter of 1931, Liliana Grassi, Roberto Pane.

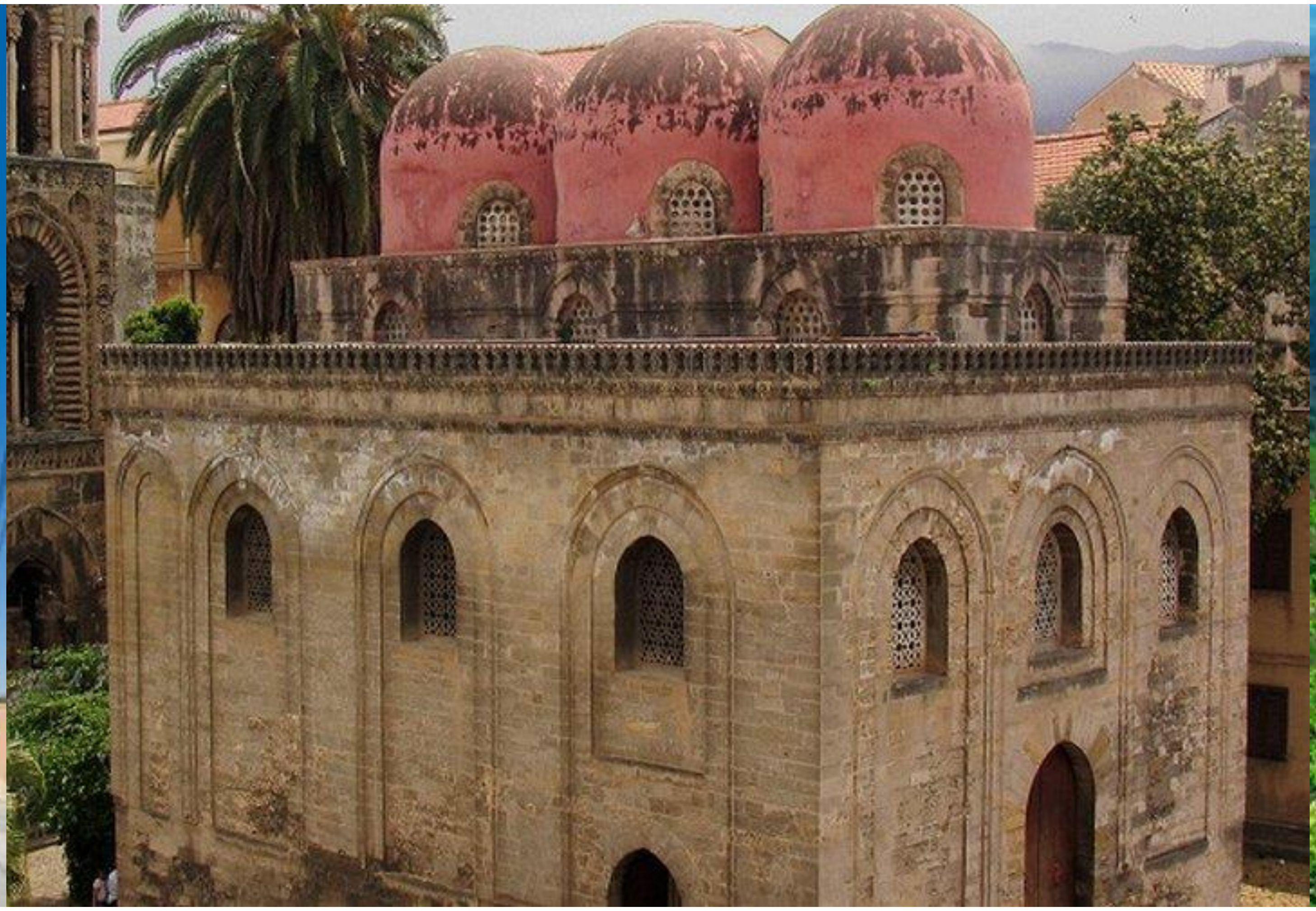
Energy and environmental improvement of built heritage

As using deterministic approaches on heterogeneous buildings with high levels of uncertainties should nevertheless be included in the science's reasoning process to pursue the best possible rational formulation of a problem on the basis of data, hypothesis and interpretation.

La scuola di Atene, Raffaello 1510

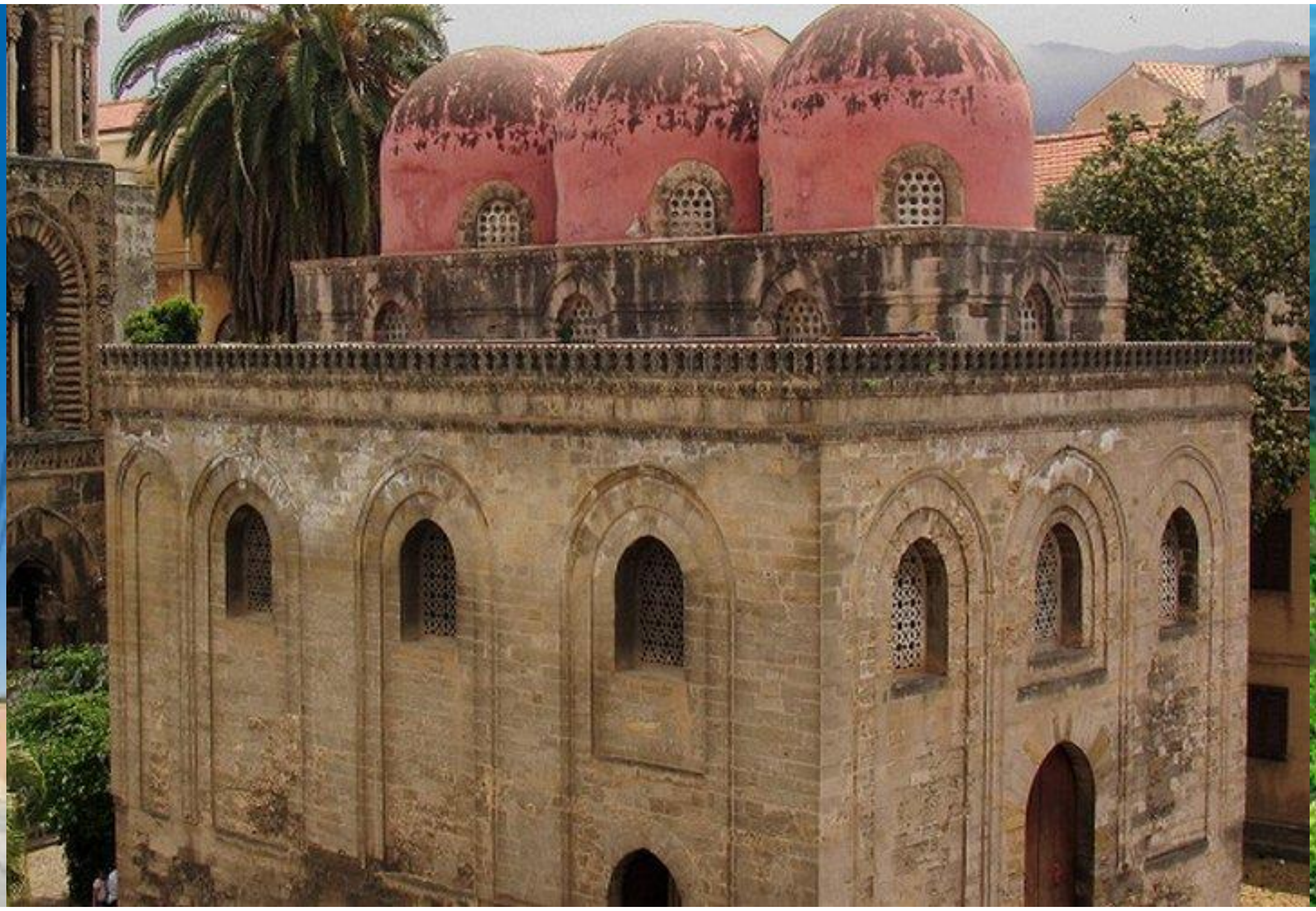
Energy and environmental improvement of built heritage

Another aspect concerns the nature of historical buildings, that being **optimised for their climate** are an inexhaustible source of ideas for environmentally and energetically conscious buildings.



Energy and environmental improvement of built heritage

Not to mention that the study of the bioclimatic behaviour of historical fabrics provides an added value of knowledge thanks to the possibility of reconstructing their natural functioning processes while enhancing their distinctive characteristics and identities linked to local microclimate (to be used both for their energy efficiency that for conservation, as sun and wind strongly affects also decay processes).



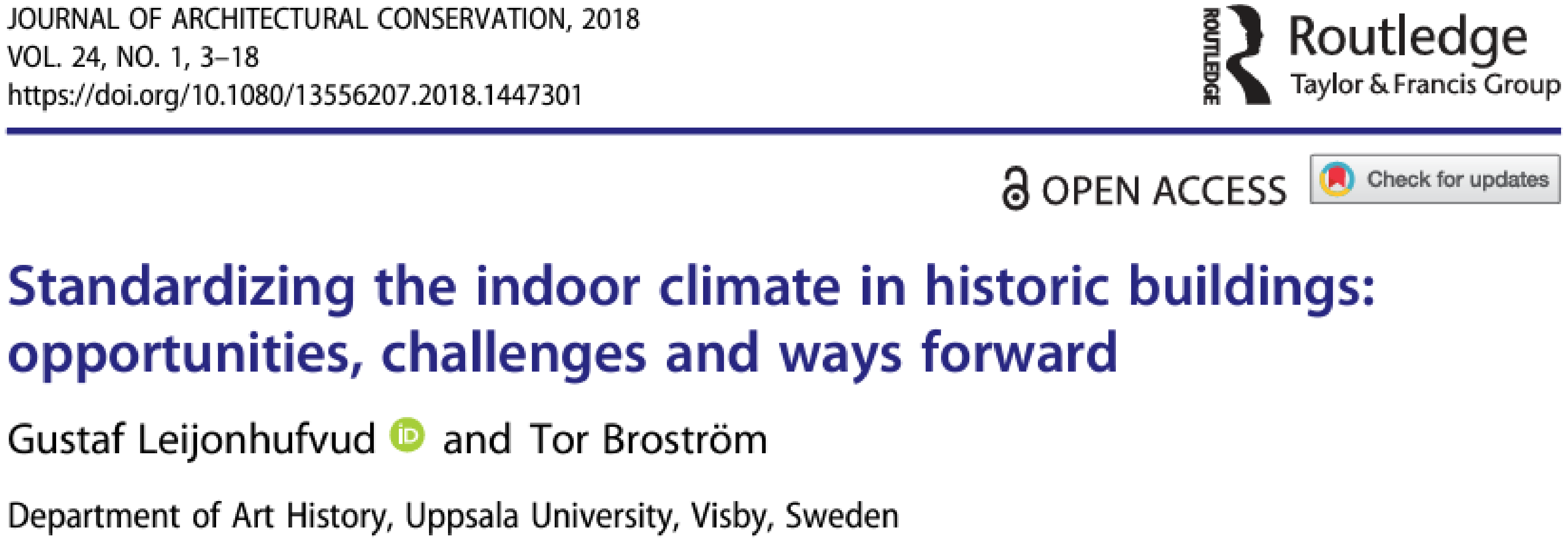
The third aspect concerns the European Directive 2010/31 which emphasizes the role of Public Administrations as an example in the energy efficiency of the construction sector; historical buildings as symbols of European cities if not of Europe itself (beacon) reinforce this role, as also underlined by European research projects on the subject (SECHURBA or BEEP project).

Energy and environmental improvement of built heritage

Finally, the complexities related to those interventions (uncertainty in the measurements of the thermophysical characteristics of the building, the geometric irregularity, the heterogeneity in the construction systems and their conservation conditions), makes historic buildings the most demanding experimental laboratory ever to test new technologies, approaches and their scalability (stress test).

Energy and environmental improvement of built heritage

During the last years, guidelines and standards in the conservation field have moved away from universal recommendations to **process-oriented standards** which aim to support the decision process in each individual case.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https://doi.org/10.1080/13556207.2018.1447301

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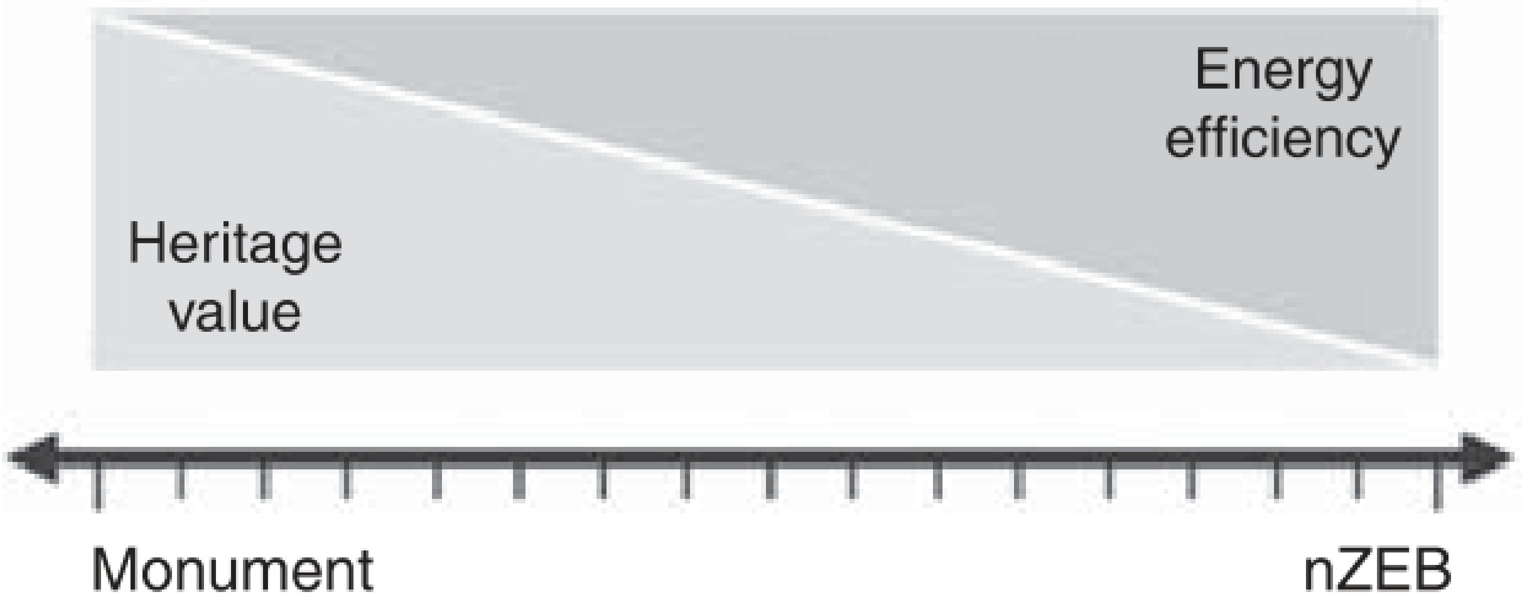
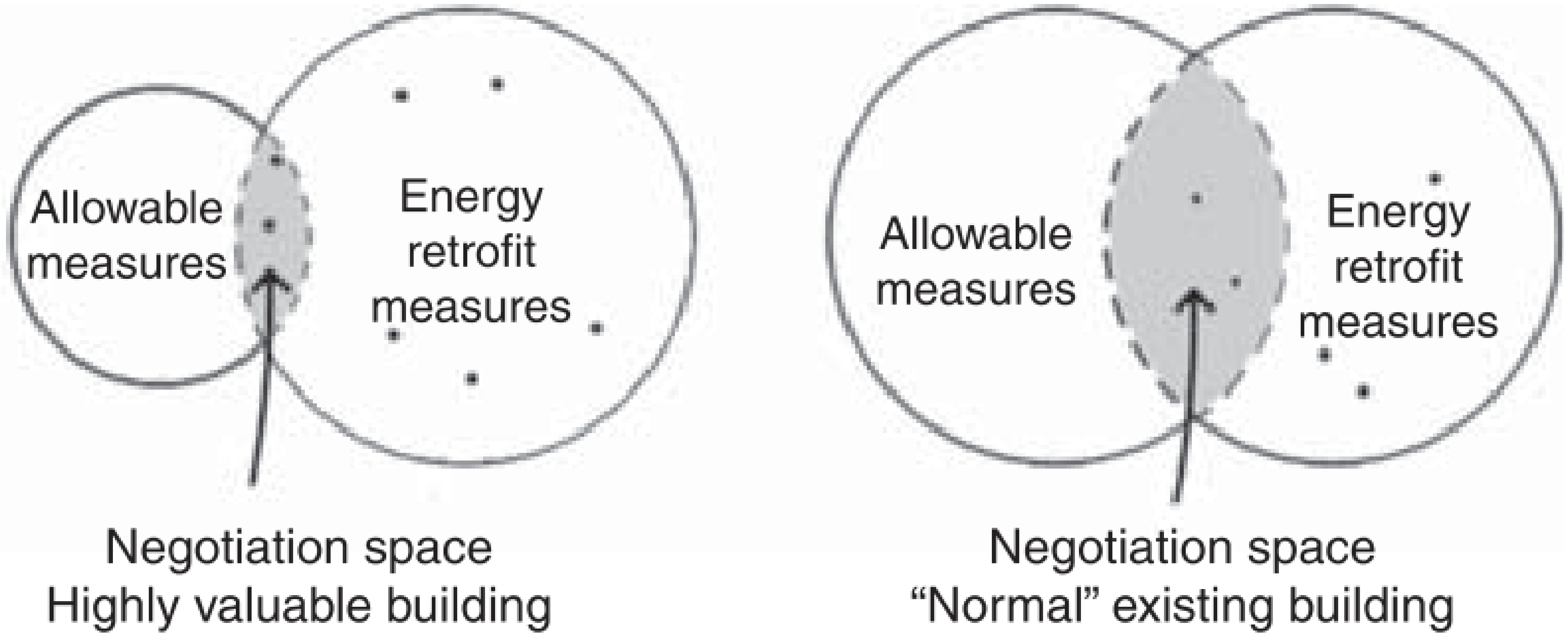
Standardizing the indoor climate in historic buildings: opportunities, challenges and ways forward

Gustaf Leijonhufvud and Tor Broström

Department of Art History, Uppsala University, Visby, Sweden

(Herrera-Avellanosa et al., 2019)





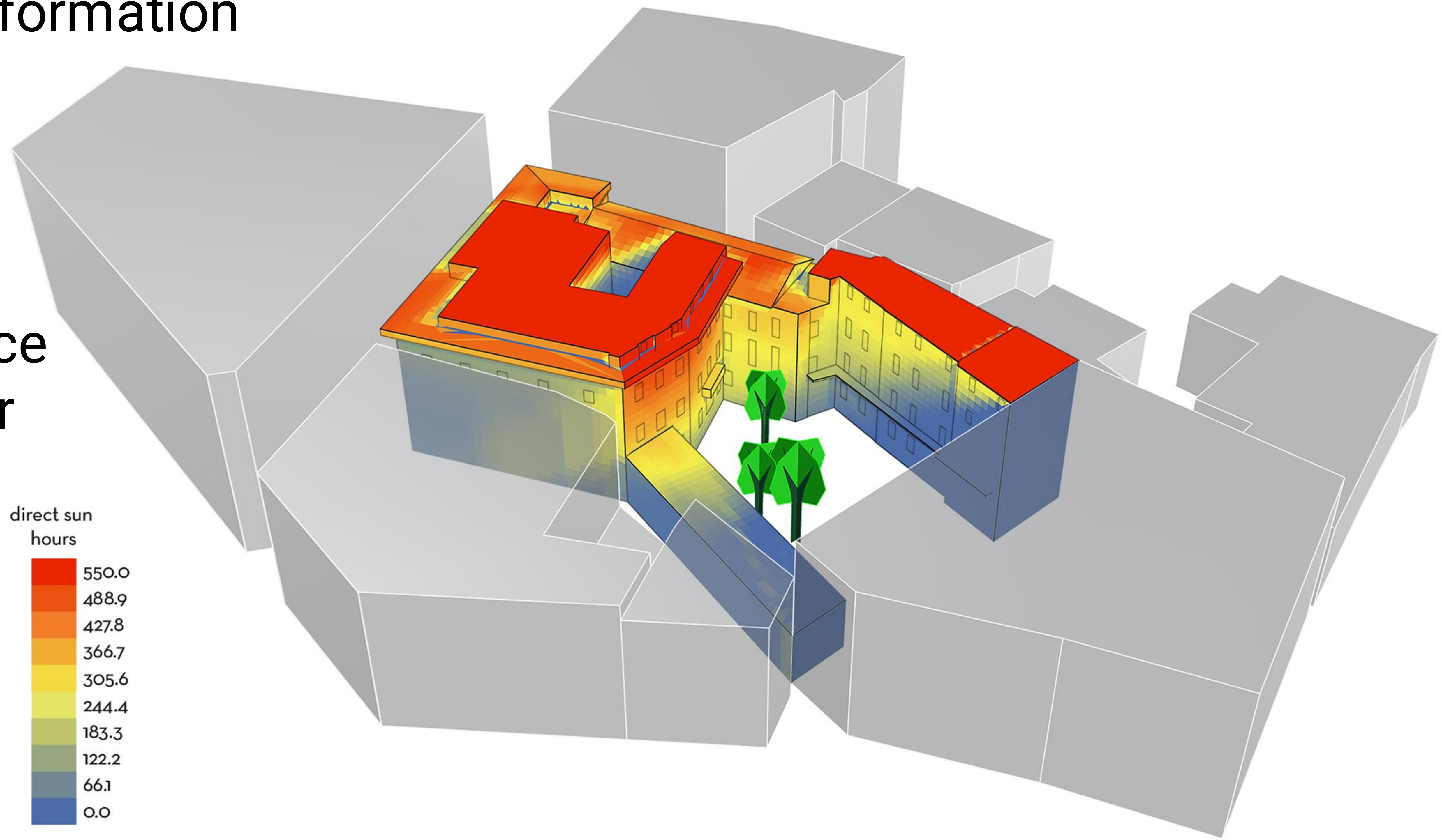
SIMULATION-BASED DESIGN AND HBIM

Simulation-based design and HBIM

Heritage Building Information Modelling (HBIM)

Building Performance Simulation (BPS) for built heritage

HBIM and BPS interoperability

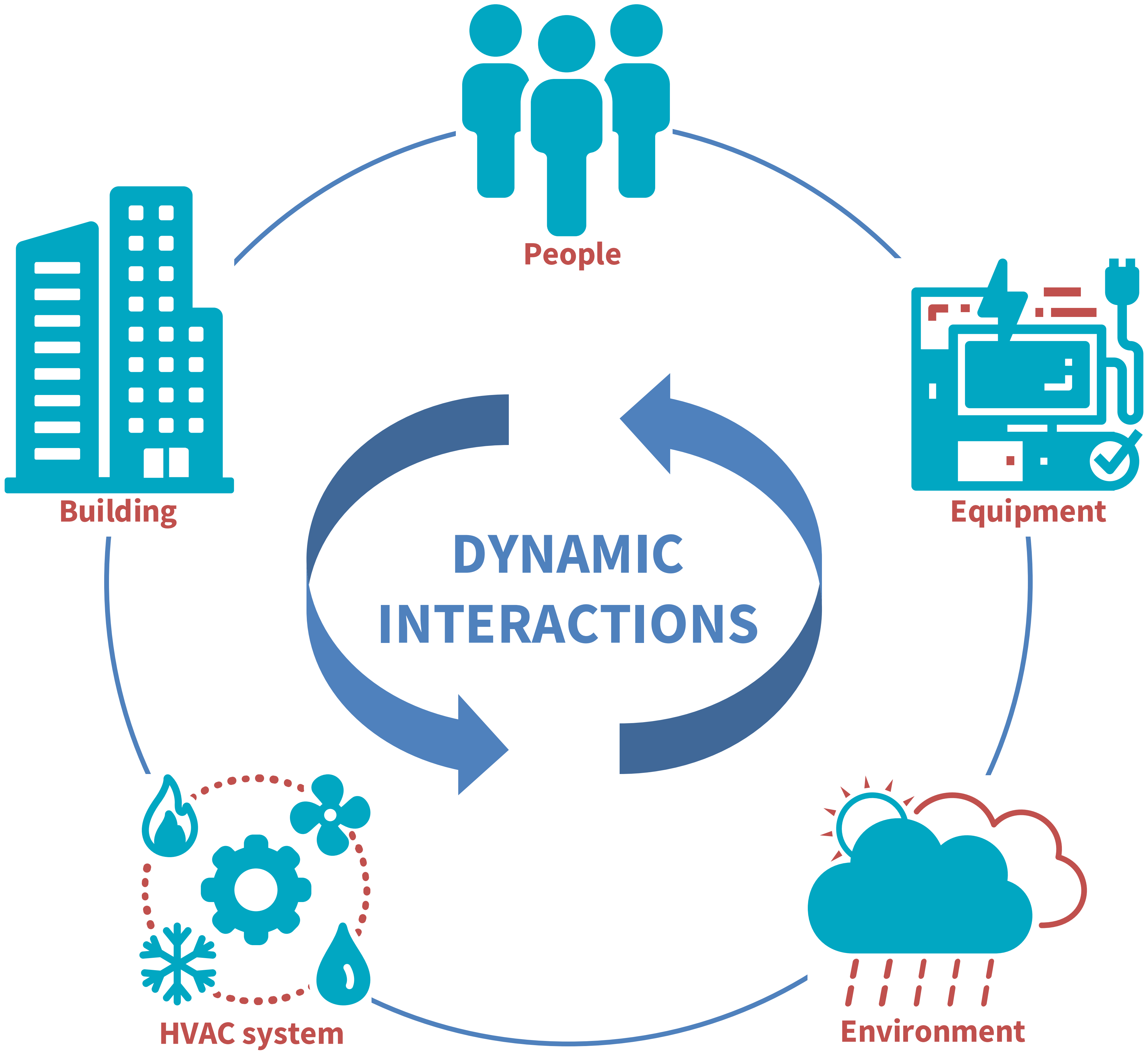


Building Performance Simulation

Building Performance Simulation (BPS) is based on a "behavioural" model of a building or an urban context at a given stage of its development, reducing the physical entities of the real world and the phenomena related to them to a certain level of abstraction.

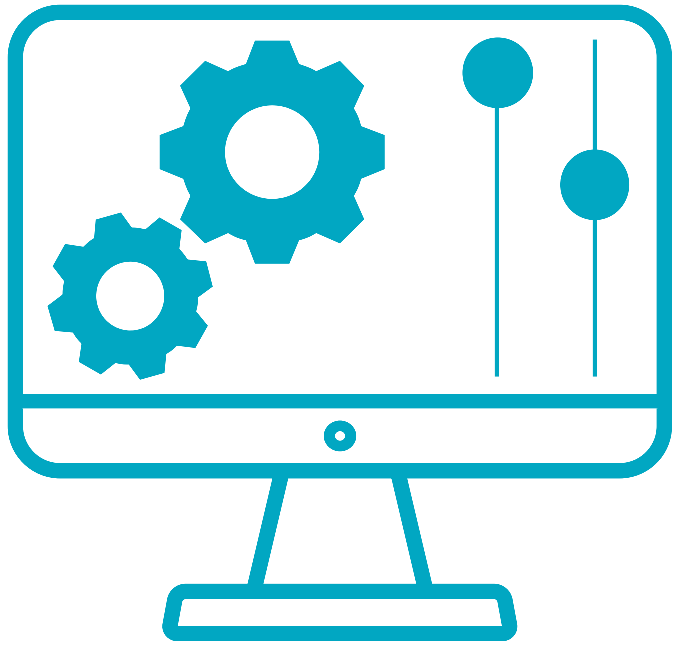
Simulations are an extremely promising tool to be applied on built heritage, as they allow to:

- understand and analyse complex phenomena;
- enhance innovative applications in the restoration process and in pre-diagnostic and diagnostic non-destructive analyses;
- ensure feedback on the energy and environmental implications of design choices, e.g. in relation to decay phenomena.



Building Performance Simulation

Despite the potential offered by these tools, the use of BPS is still not widespread both in the early stages of the project and in application to historic buildings with a concentration of studies in Italy.



Building and Environment 258 (2024) 111621

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Current practices and open issues on the whole-building dynamic simulation of historical buildings: A review of the literature case studies

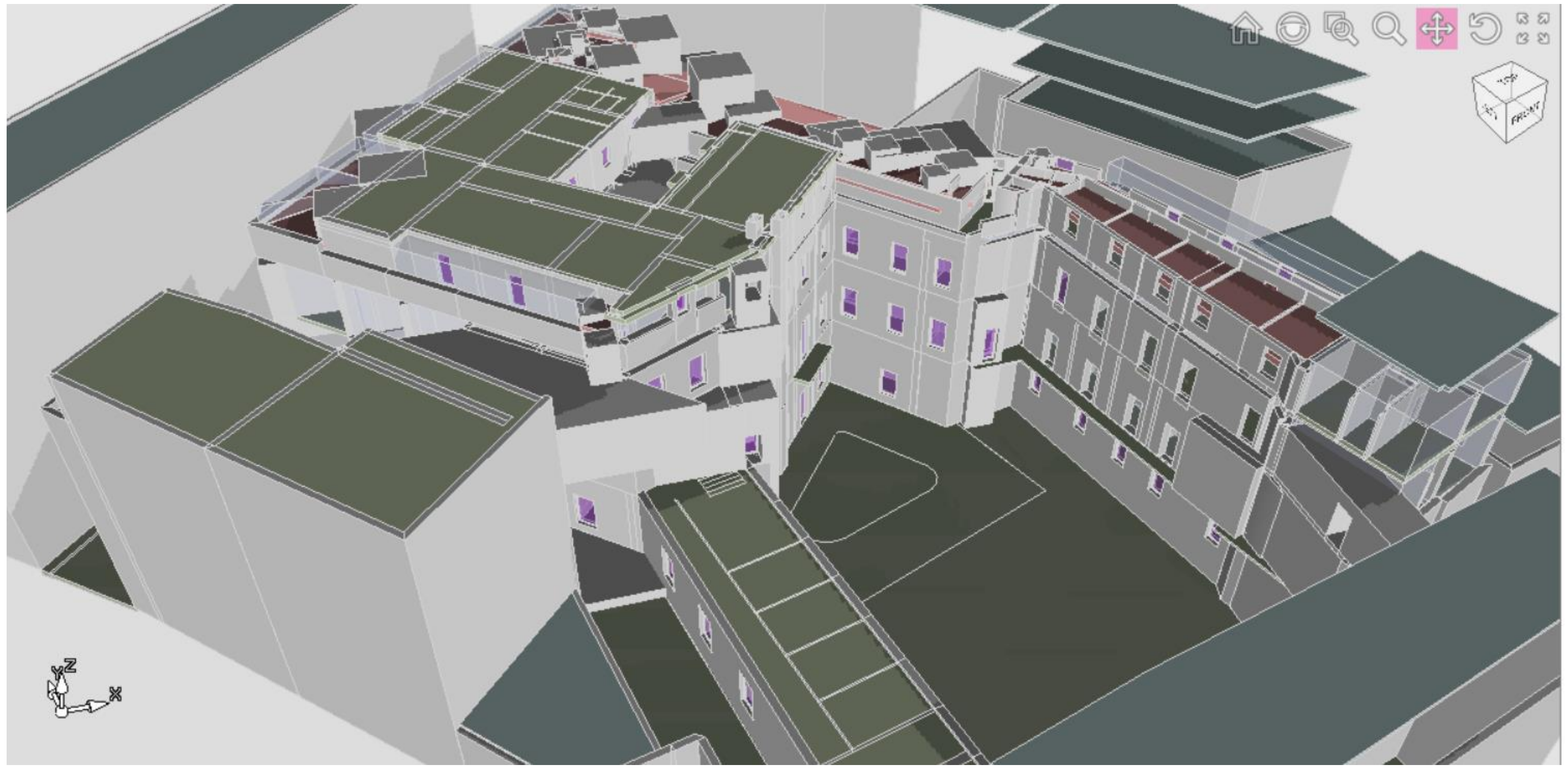
Elena Verticchio *, Letizia Martinelli, Elena Gigliarelli, Filippo Calcerano

ISPC Institute of Heritage Science, National Research Council, Italy

Building Performance Simulation

The reason is mainly related to the complexities of historical buildings:

- complex geometries involved, as opposed to energy models still characterized by simplified forms that struggle to correctly represent the relationships between surfaces;



Palazzo Maffei-Borghese (Italy), HBIM and BPS model, BHiLab

Building Performance Simulation

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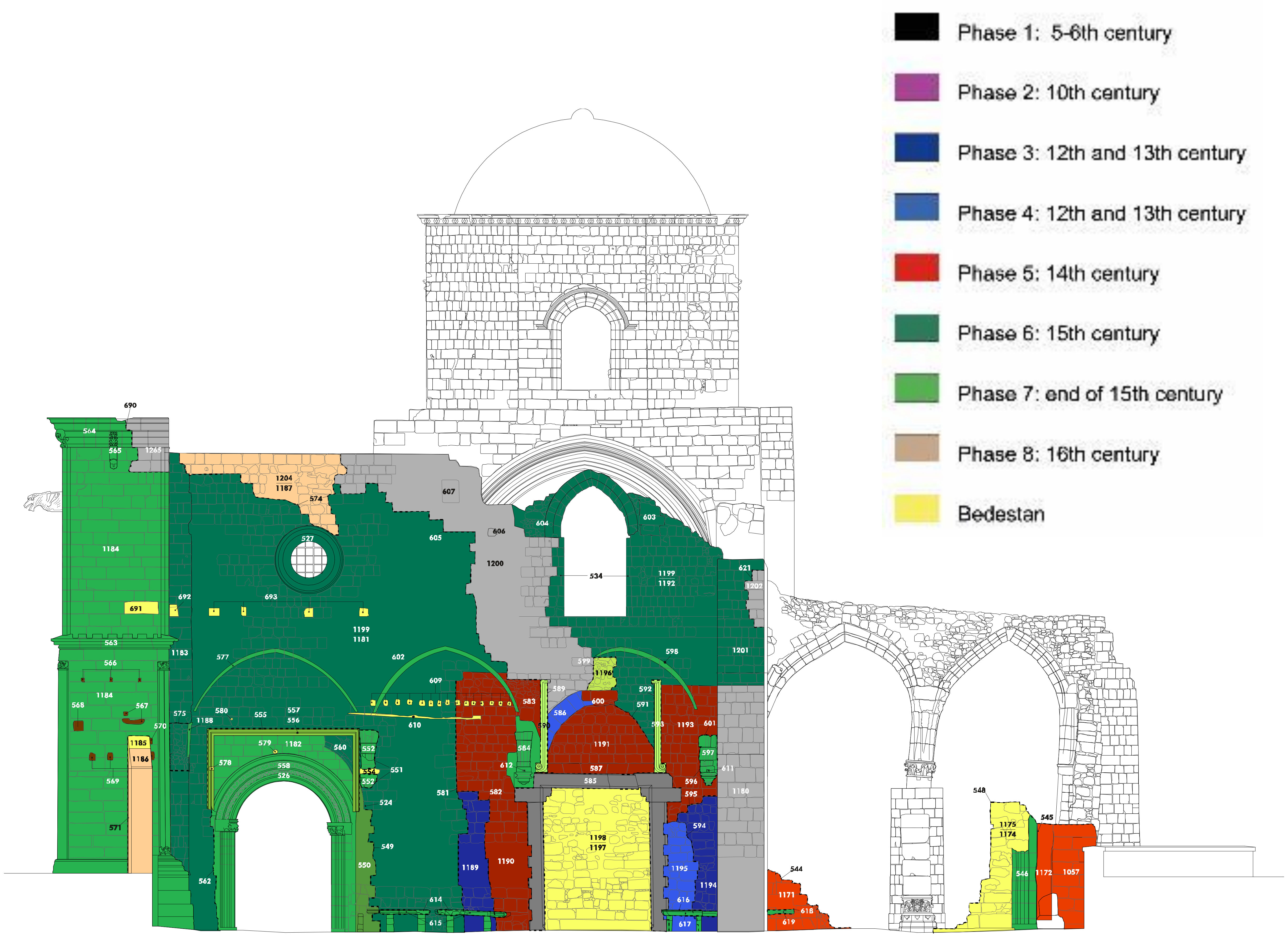


Palazzo Maffei-Borghese (Italy), HBIM and BPS model, BHiLab

Building Performance Simulation

The reason is mainly related to the complexities of historic buildings:

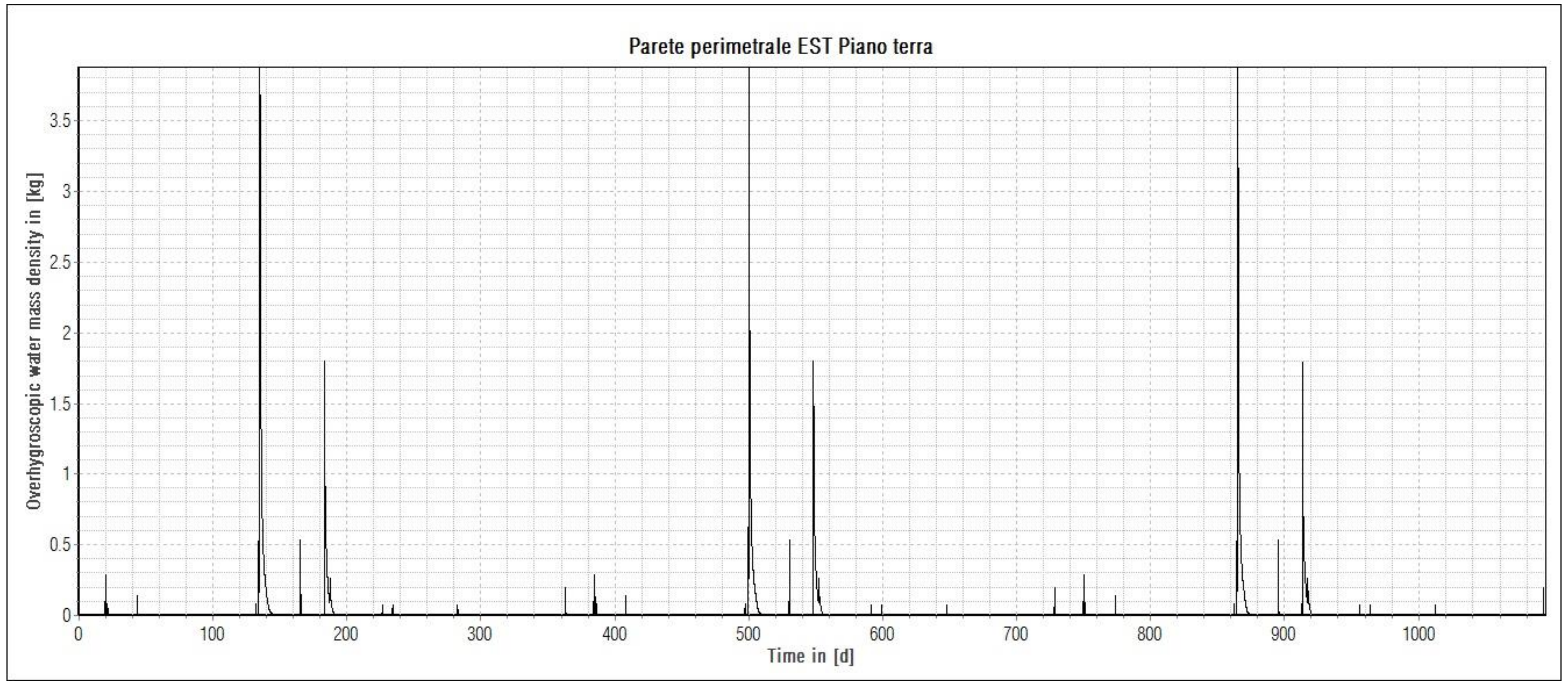
- complex geometries involved;
- lack of standardized elements in heterogeneous constructive systems;
- massive behaviour of the building (beyond a certain thickness, the current limitations of simulation software require specific countermeasures and attention);

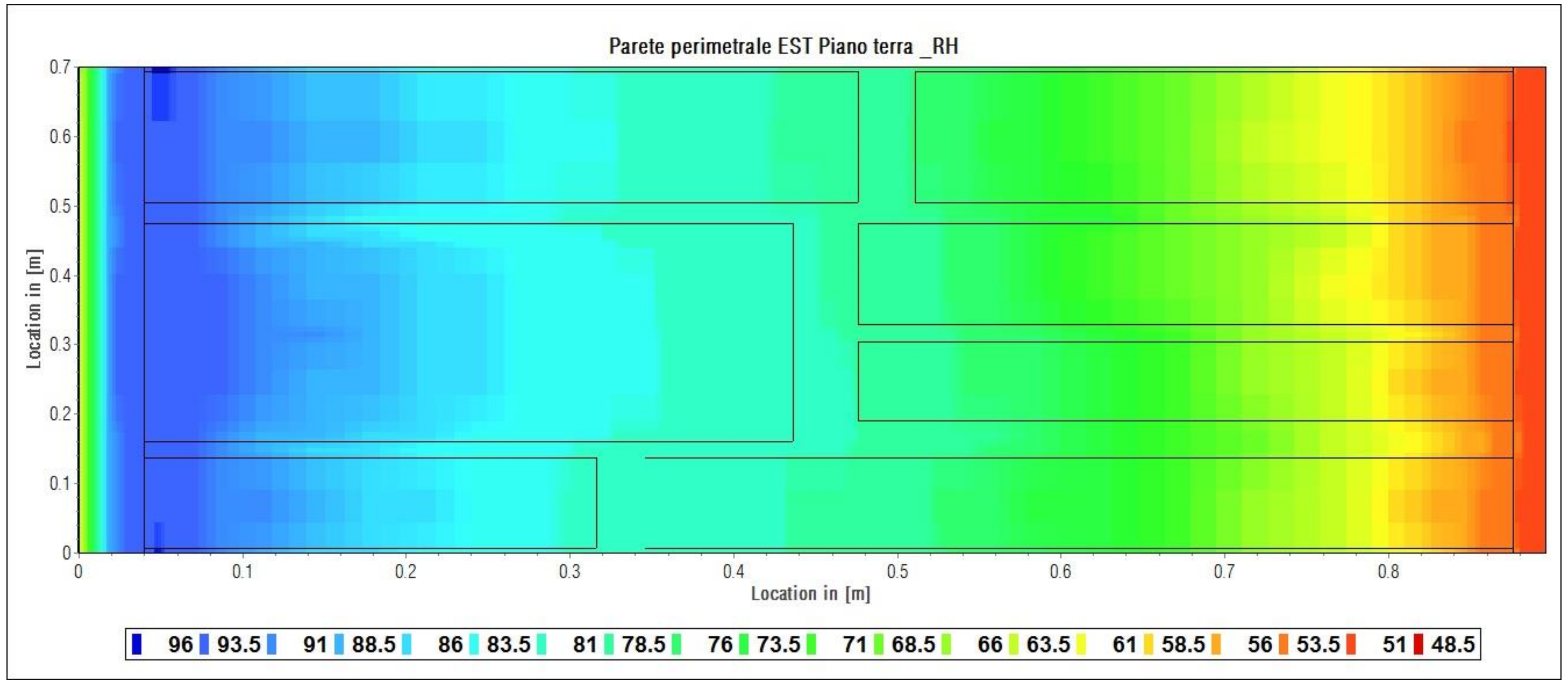
Fujian Toulou, China

Building Performance Simulation

The reason is mainly related to the complexities of historical buildings:

- complex geometries involved;
- lack of standardized elements in heterogeneous constructive systems;
- massive behavior of the building;
- importance of moisture transport (the HAMT point of view of the problem);



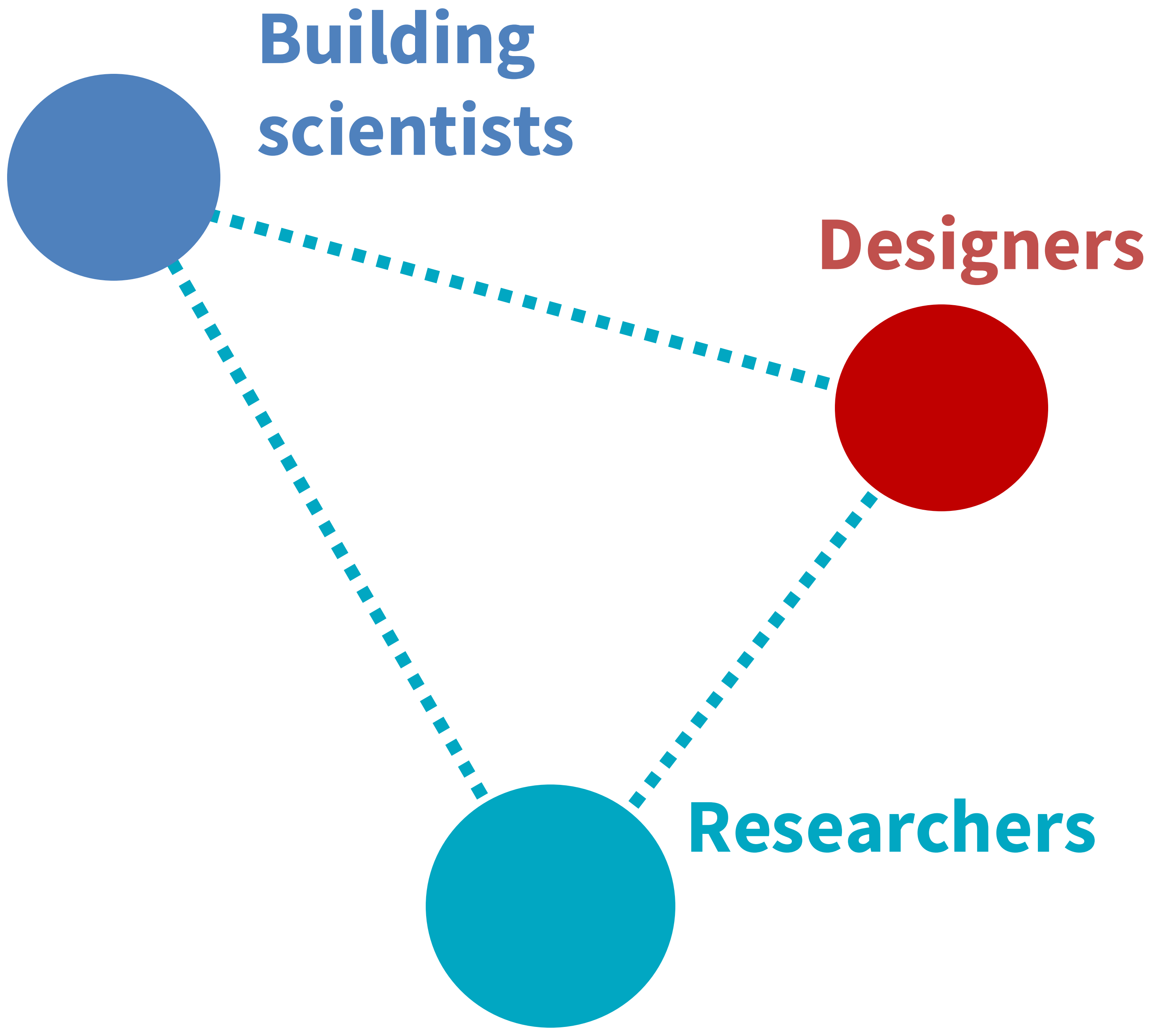


Metrics project (Italy), Heat Air and Moisture Transport modeling, BHiLAb

Building Performance Simulation

The reason is mainly related to the complexities of historical buildings:

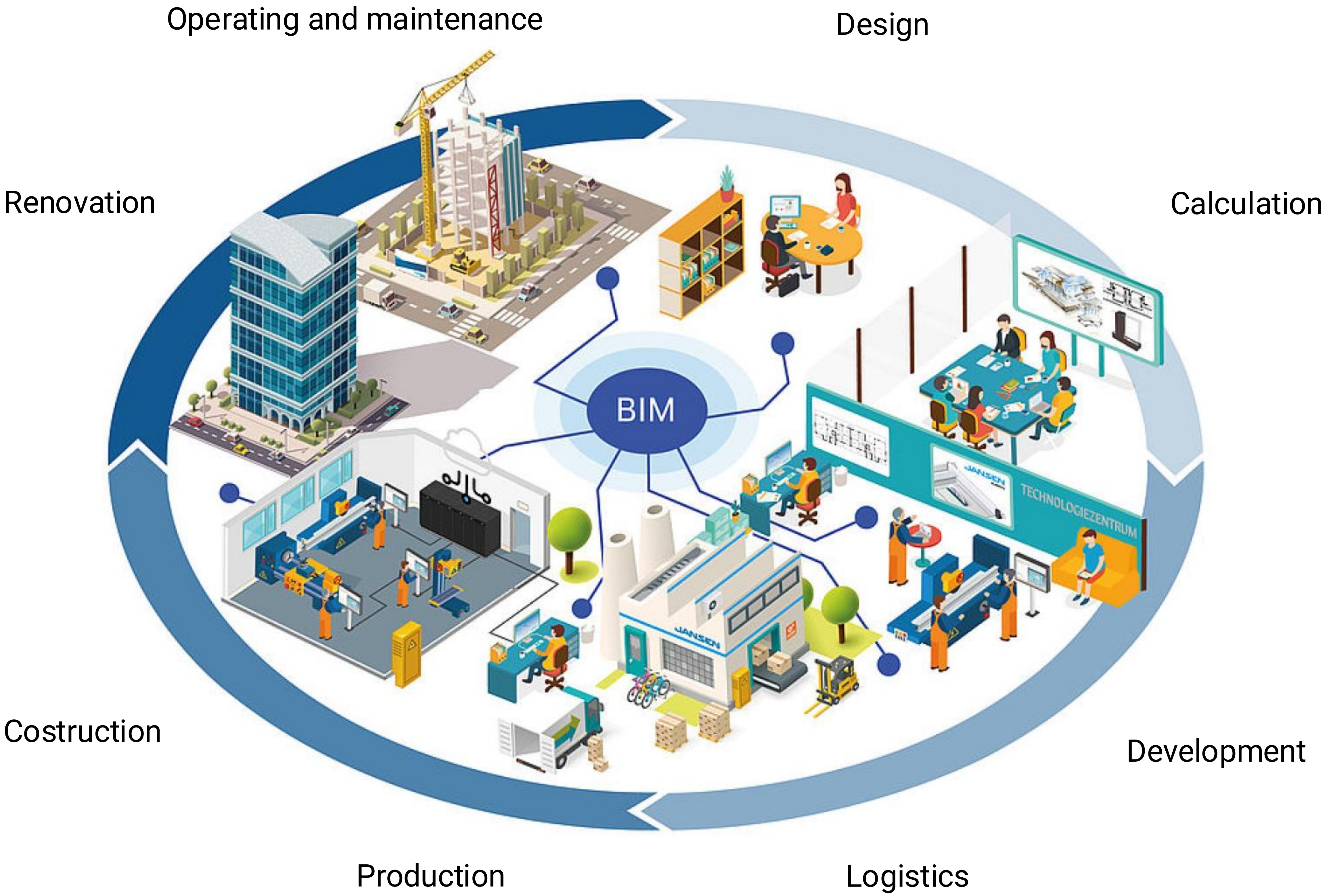
- complex geometries involved;
- lack of standardized elements in heterogeneous constructive systems;
- massive behavior of the building;
- importance of moisture transport (the HAMT point of view of the problem);
- scarce diffusion of these tools in the architectural professional practice and difficulties in building a common knowledge framework among experts.



Heritage BIM

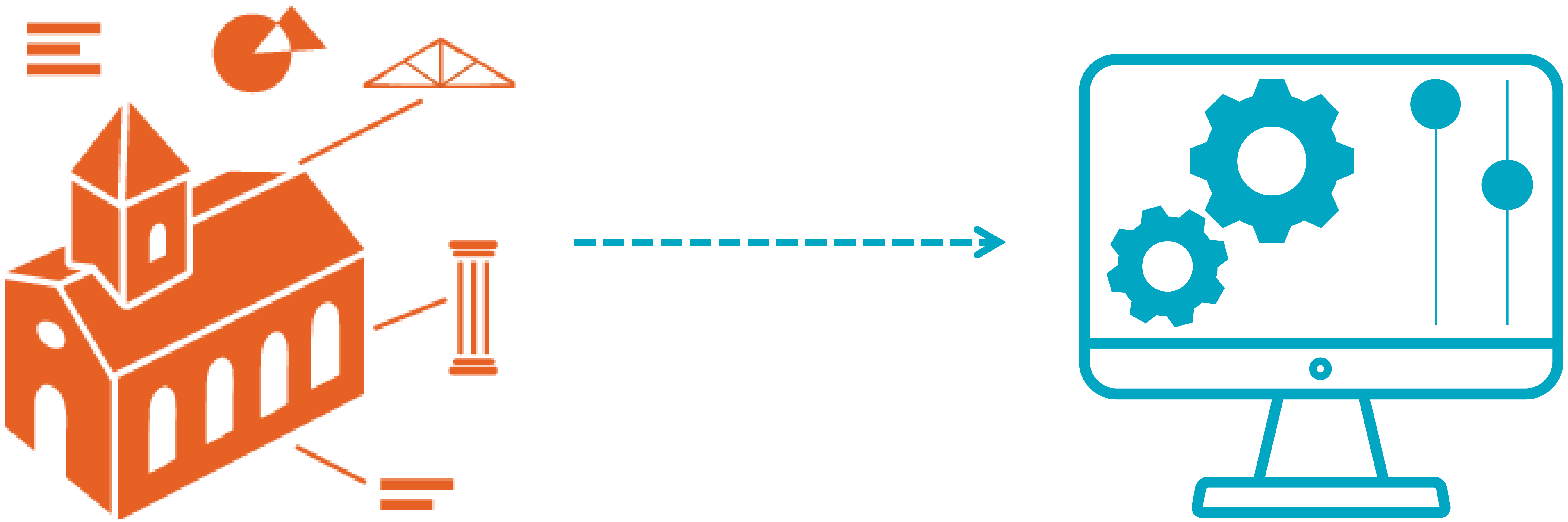
Another very promising technology is Building Information Model (BIM) - “digital representation of the physical and functional characteristics of a built asset” (NIBS).

It is based on the creation and updating of an information system, combining geometric and semantic information, associating the 3D representation of building elements with a dynamic and implementable database.



HBIM to simulation interoperability

Given that the HBIM model can be designed to contain a large amount of data required for numerical simulation, interoperability among the two environments can save time while reducing the risk of errors.



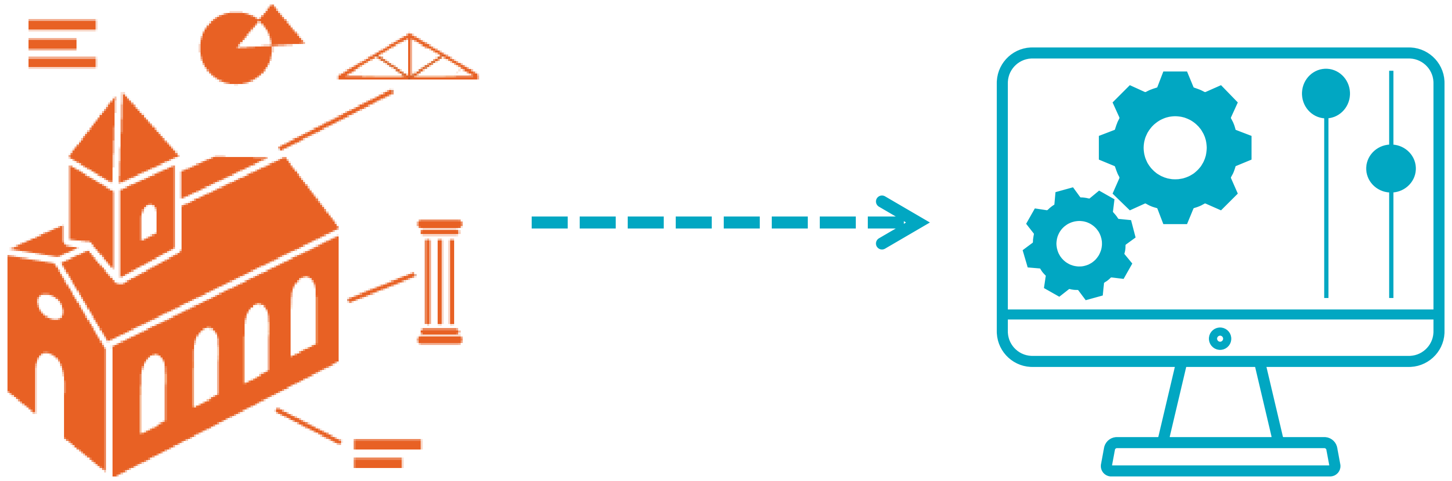
HBIM to simulation interoperability

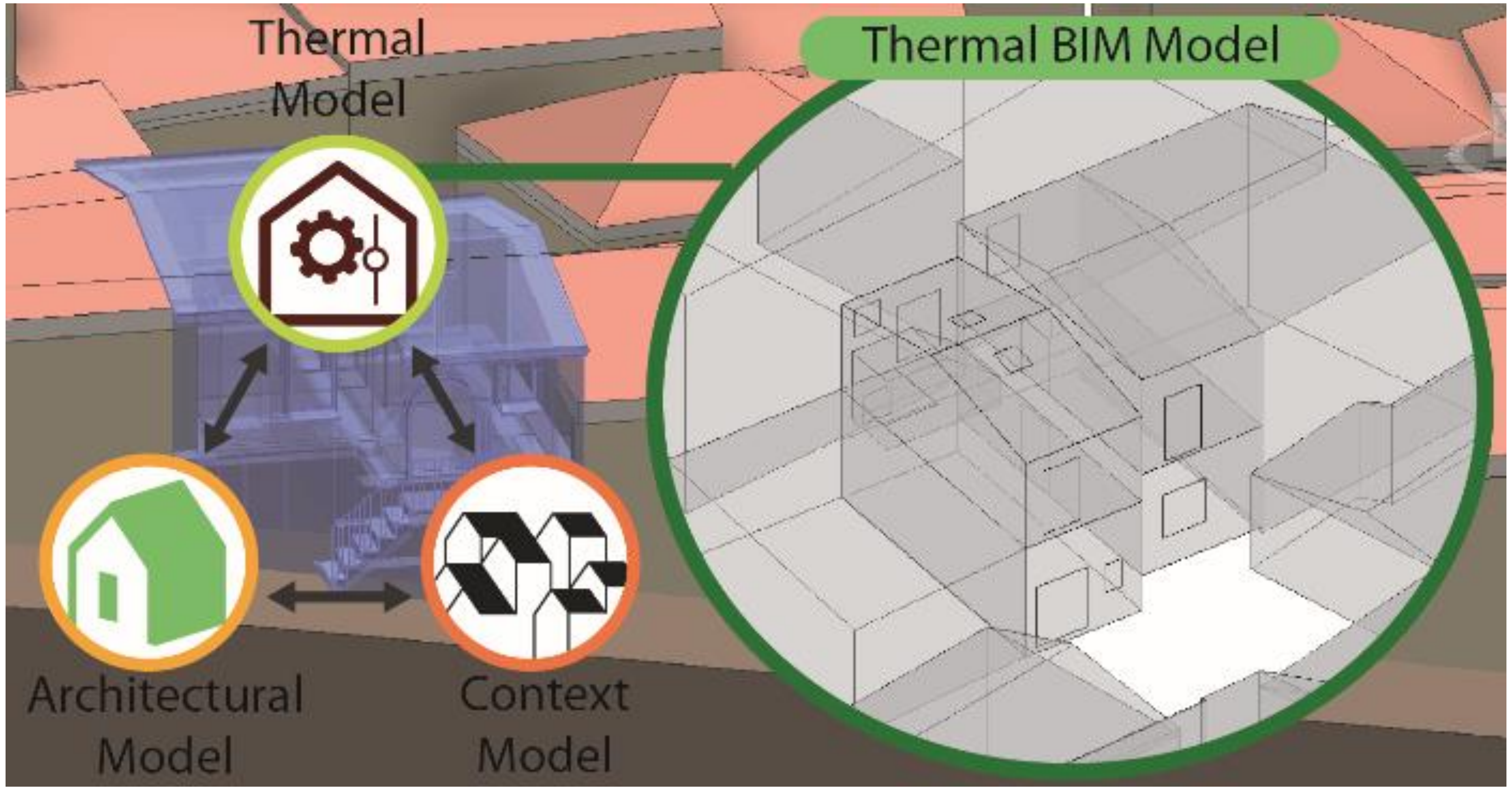
Unfortunately, the integration between the BIM environment and simulations is still complex and under development.

- Interoperability is based mainly on two open file schemes: IFC and gbXML, which still do not allow to efficiently transfer the data required for the simulation (both geometric and informative).
- Therefore, often the BIM-based model for simulation ends up being so modified by the simulation purpose as to result in a sort of parallel modeling.

HBIM to simulation interoperability

The limits in seamless BIM to BPS data-flow derives from the simplification and the assumptions needed by energy modelling, the different logic with which the two software environments evolved, and the related need to go beyond a simple data exchange among software through a data conversions. Also simulation usually needs data jointly from different BIM disciplines like the architectural and structural one while data on HVAC is usually modelled in BIM very differently from how simulations needs it.

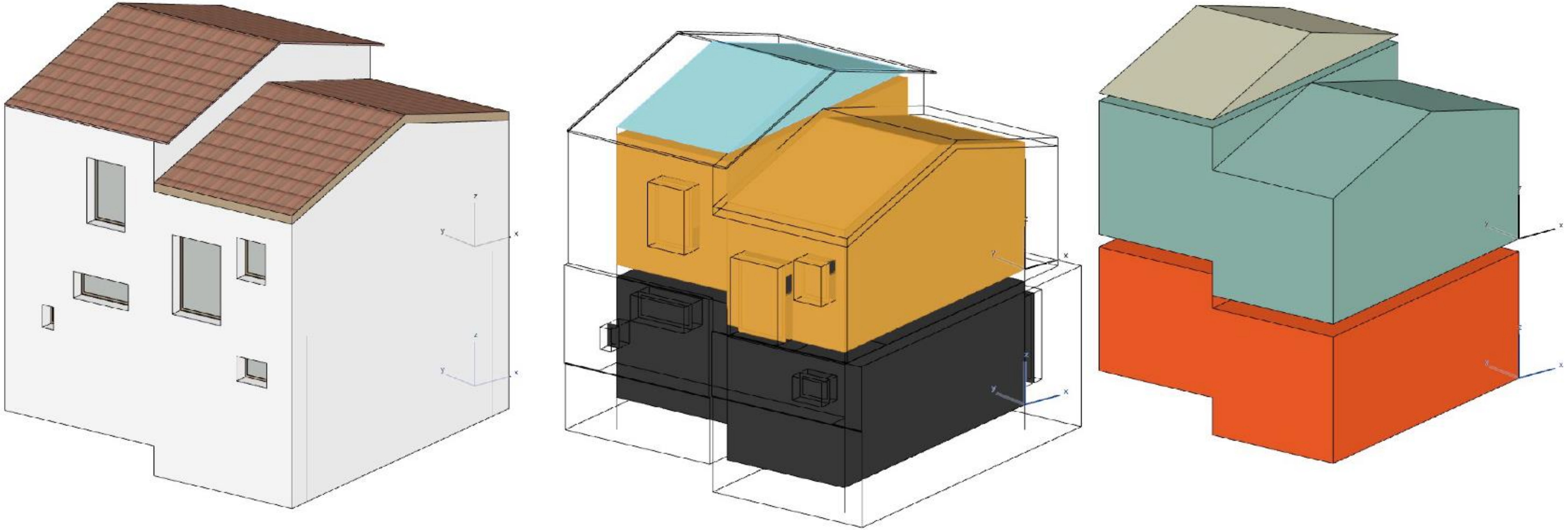




HBIM to simulation interoperability

Interoperability issues reported in literature concerns:

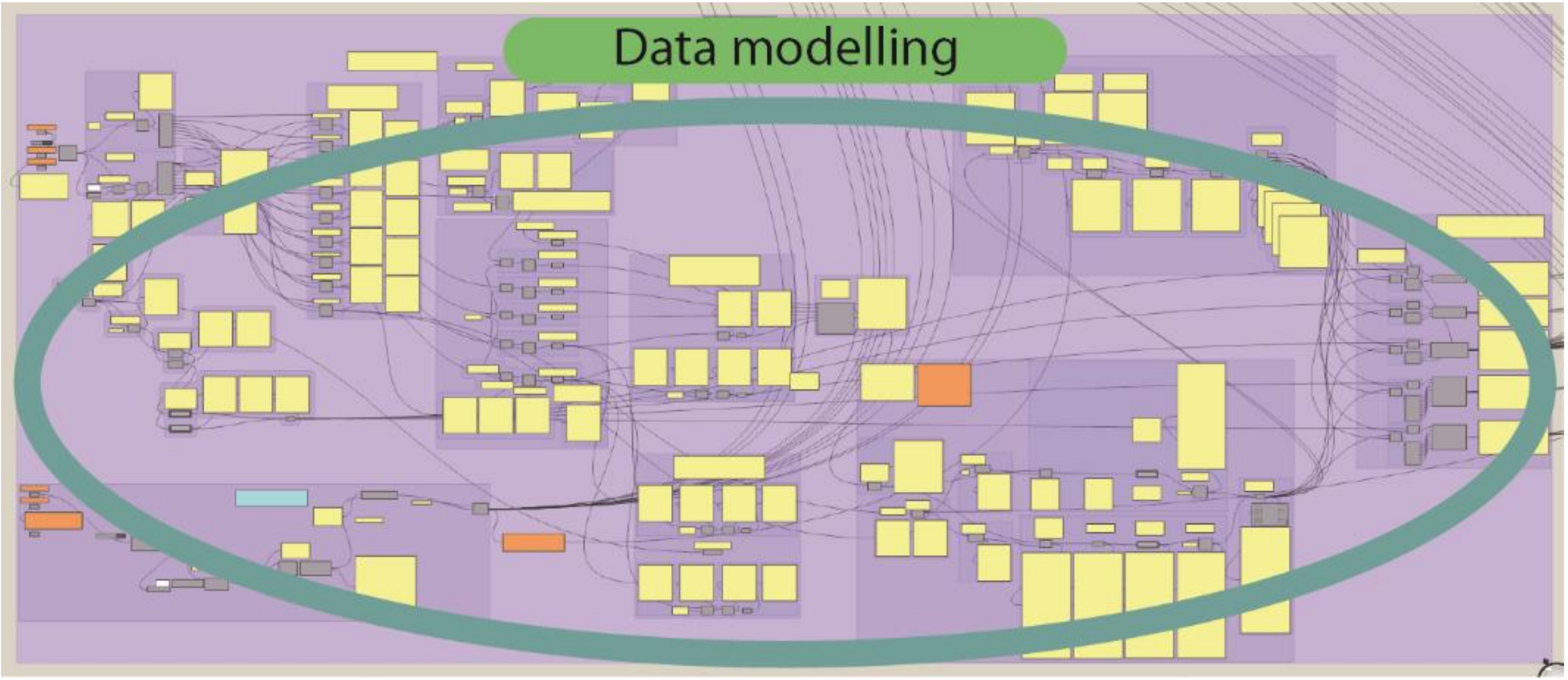
- geometric issues (definition of space boundaries, incorrect geometry representations, spatial hierarchies and nested elements, surface normals errors, non closed zones and specific building elements complexities on windows and roofs;



HBIM to simulation interoperability

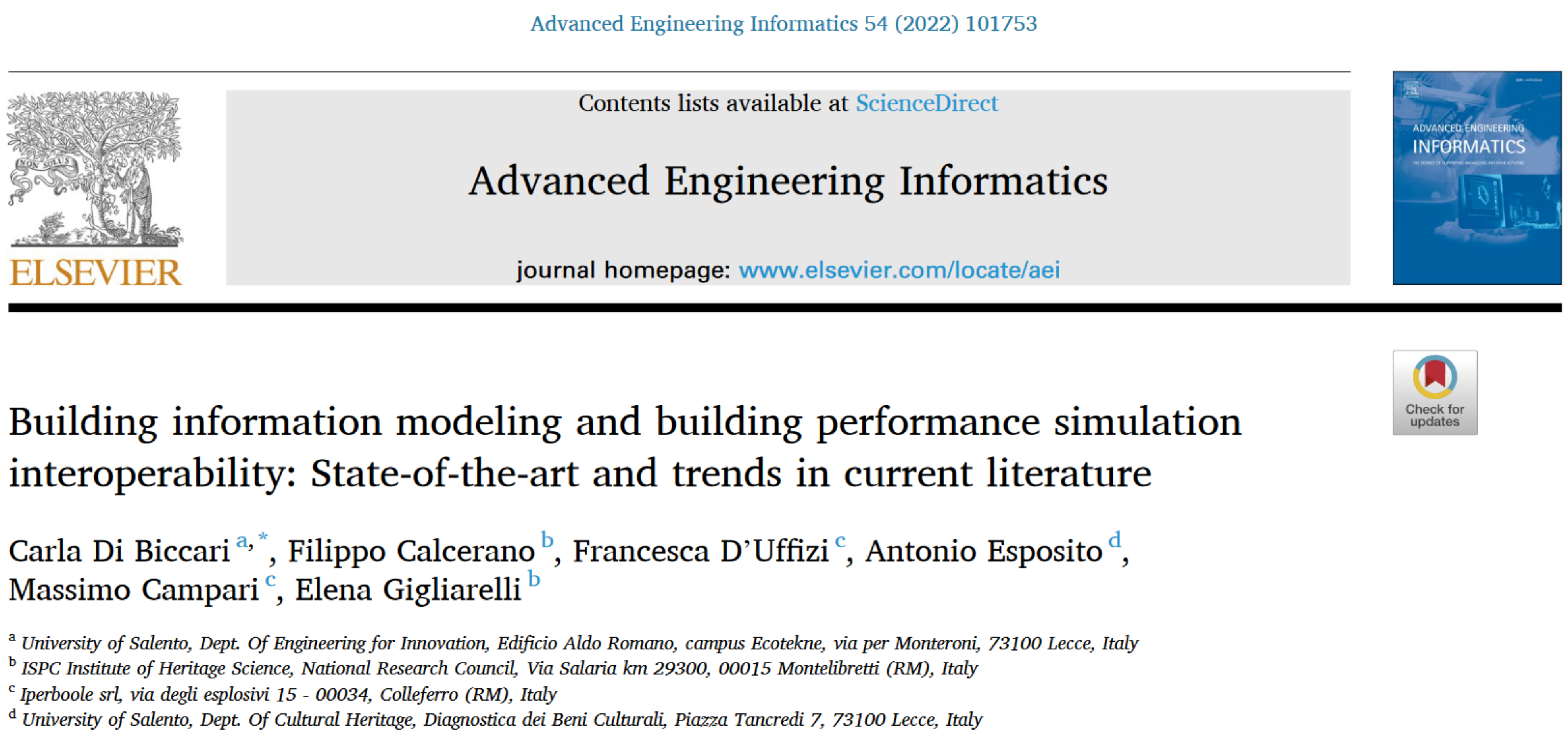
Interoperability issues reported in literature concerns:

- alphanumeric issues (mainly on the construction materials);
    - Missing fields on the exchange files to define specific simulation inputs especially on systems



HBIM to simulation interoperability

This calls for semi-automated to manual approaches of data re-input and file checking that, thanks to the possibility of human intervention, are more reliable than fully automated ones in the case of historical buildings.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Building information modeling and building performance simulation interoperability: State-of-the-art and trends in current literature

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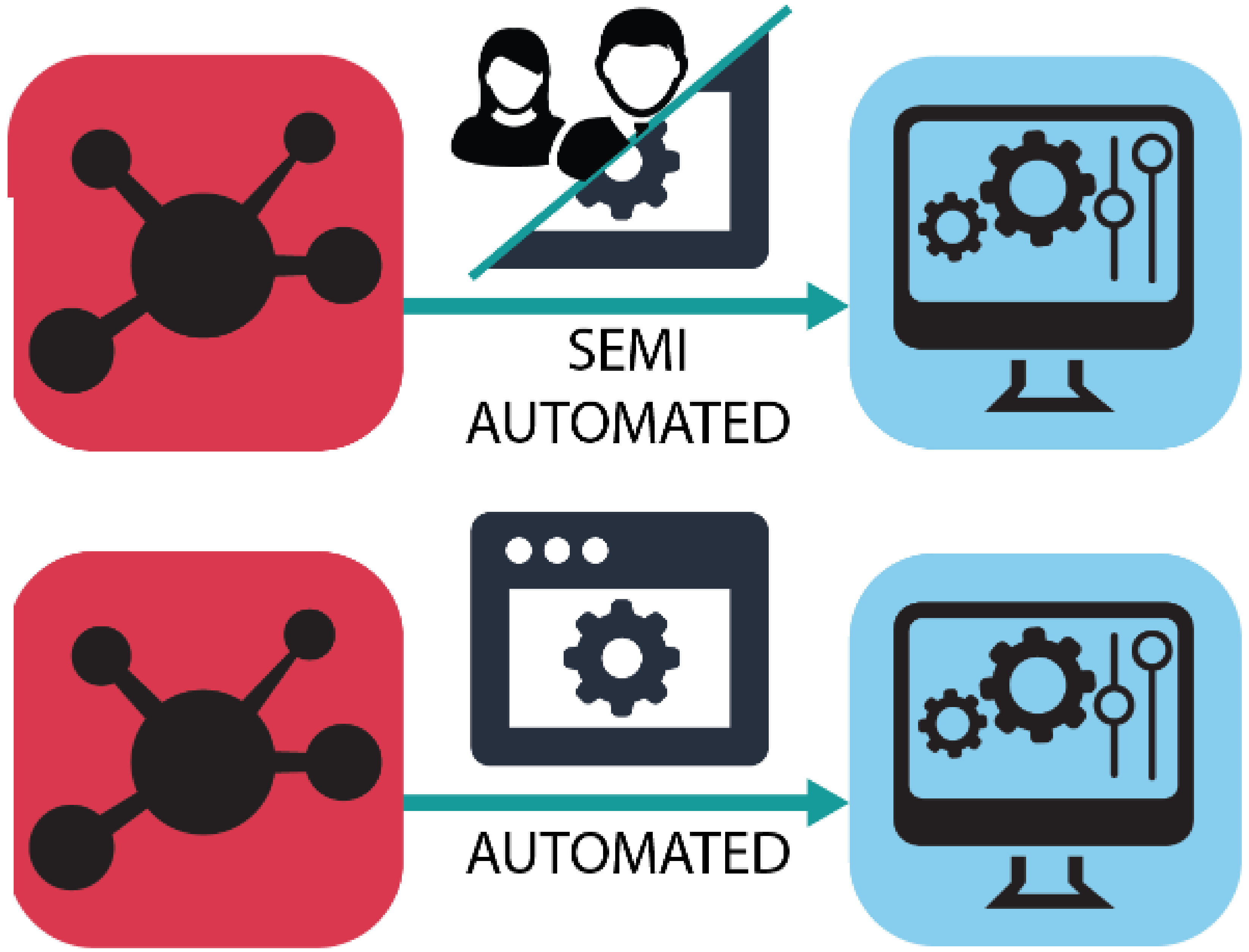
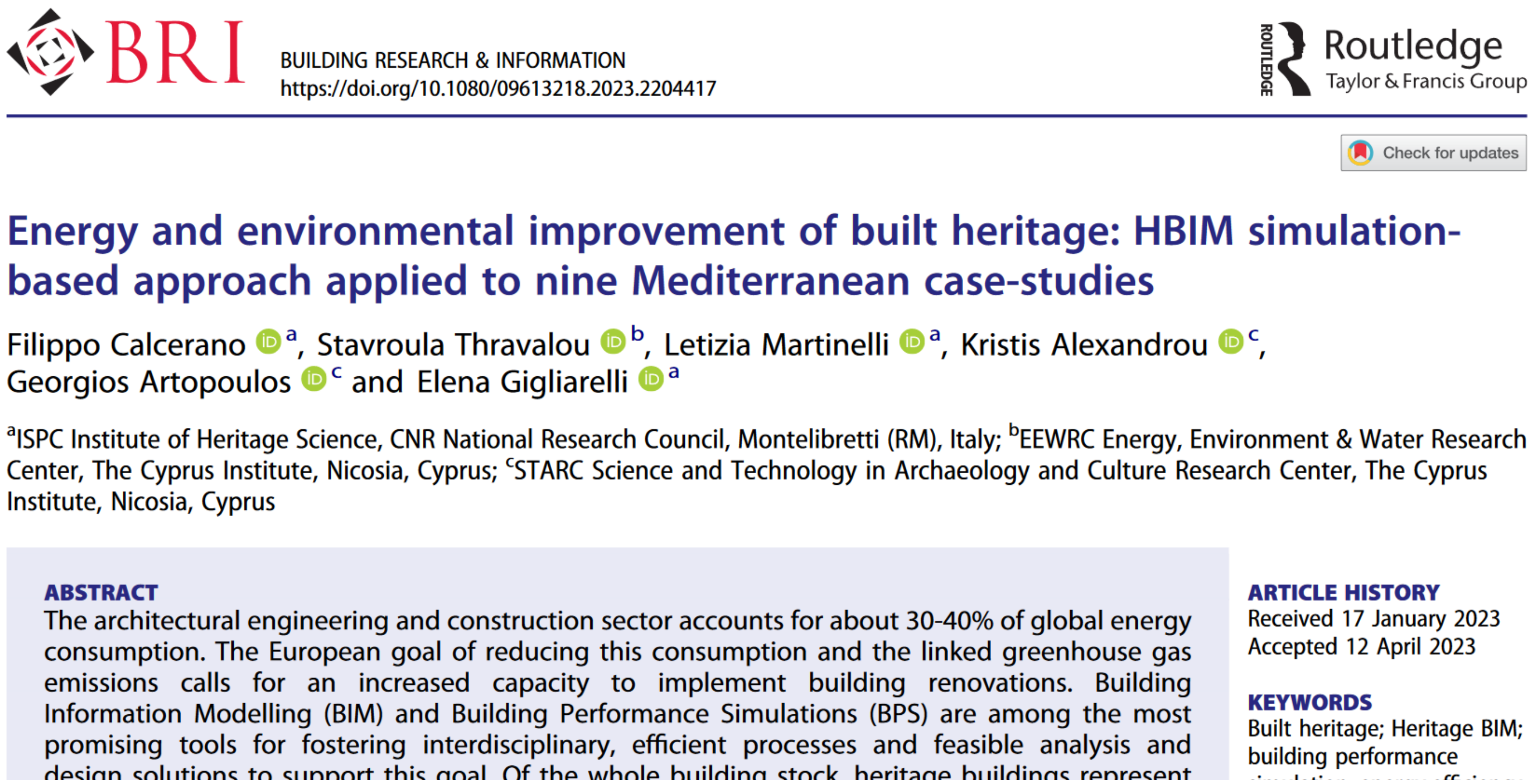


HBIM to simulation interoperability

Another key features is to keep each expert in its comfort zone, to create a process that is simple, flexible and scalable to the market.

Simulation-based design and HBIM

The workflow integrates analyses, HBIM, simulations and design solutions. The different analyses produce geometric and/or alphanumeric data. They are funneled into two fundamental phases within the simulation process: the model calibration on the current state of the building and then the design solutions' evaluation.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Routledge Taylor & Francis Group
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Energy and environmental improvement of built heritage: HBIM simulation-based approach applied to nine Mediterranean case-studies

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ABSTRACT
The architectural engineering and construction sector accounts for about 30-40% of global energy consumption. The European goal of reducing this consumption and the linked greenhouse gas emissions calls for an increased capacity to implement building renovations. Building Information Modelling (BIM) and Building Performance Simulations (BPS) are among the most promising tools for fostering interdisciplinary, efficient processes and feasible analysis and design solutions to support this goal. Of the whole building stock, heritage buildings represent

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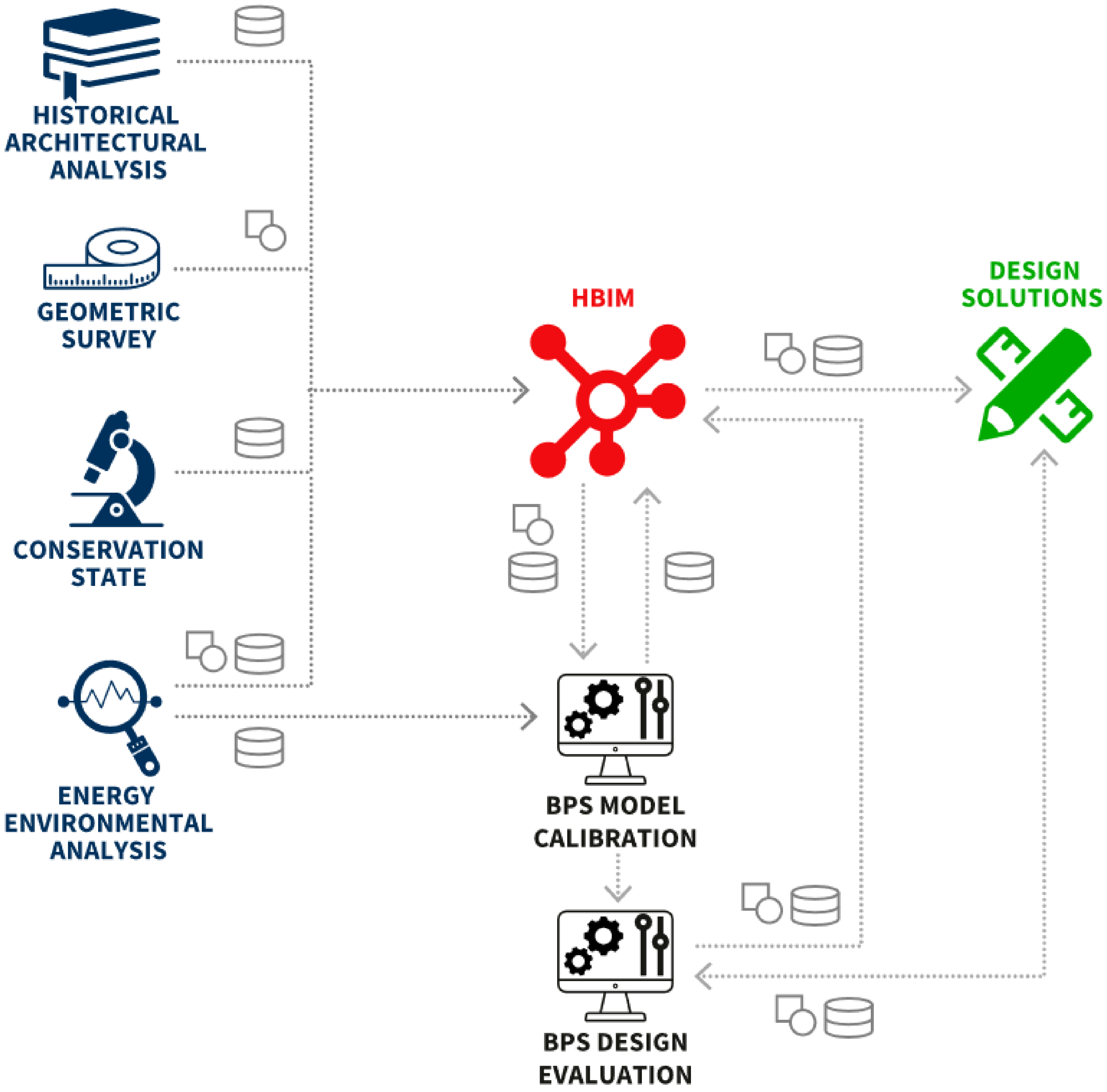
KEYWORDS
Built heritage; Heritage BIM; building performance

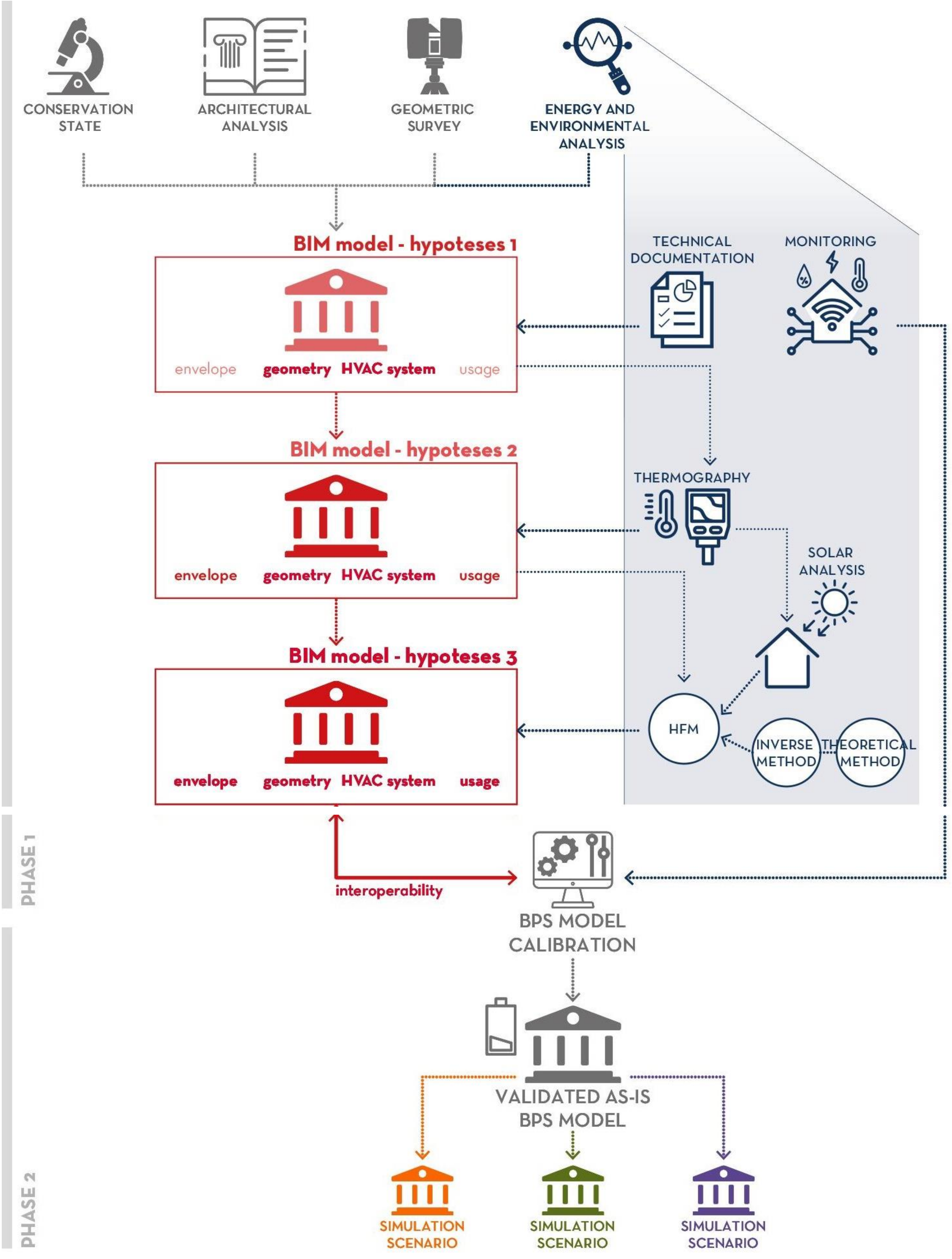


Simulation-based design and HBIM

and if we consider that the analyses can generally start at the same time but each one has different completion times (especially energy and environmental analyses that can easily span over on year of monitoring,

we also understand how the HBIM helps the interdisciplinary team to keep track of the development of the study by iteratively updating the models and the Common Data Environment, tuning the initial hypotheses as the data is acquired and new hypotheses are consolidated.

With the interoperability phase ideally marking the milestone of our knowledge on the building, as we are now ready to go into the last step of the analysys phase that is also the first step of the design phase, the model calibration



Cornaro, Cristina, Gianluigi Bovesecchi, Filippo Calcerano, Letizia Martinelli, and Elena Gigliarelli. 2023. “An HBIM Integrated Approach Using Non-Destructive Techniques (NDT) to Support Energy and Environmental Improvement of Built Heritage: The Case Study of Palazzo Maffei Borghese in Rome.” *Sustainability* 15 (14): 11389. https://doi.org/10.3390/su151411389.

THE ROLE OF E-RIHS

What is a research infrastructure?

Research Infrastructures provide broader access to services (instruments, facilities, data, tools, laboratories and expertise) supporting communities of researchers in scientific discovery and collaboration across disciplinary and geographical boundaries.

HS Research infrastructures can act as key innovation enabler to enhance the understanding, care and sustainability of historic buildings.

ESFRI European Strategy Forum on Research Infrastructures

E-RIHS EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE

DARIAH-EU Digital Research Infrastructure for the Arts and Humanities

What is E-RIHS?

The mission of the European Research Infrastructure for Heritage Science (E-RIHS) is to deliver integrated access to interdisciplinary expertise, data and cutting-edge technologies and equipment.

Among E-RIHS pillars to promote excellence and innovation, it will foster innovation, interdisciplinarity, interoperability, and co-creation principles.

ESFRI European Strategy Forum on Research Infrastructures

E-RIHS EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE

What is E-RIHS?

E-RIHS pathway

HORIZON 2020

Preparatory Phase (2017-2020)

→ To address governance, financial aspects, legal documents and logistics

HORIZON EUROPE

Implementation Phase (2022-2024)

→ To establish the European Research Infrastructure Consortium (ERIC)

E-RIHS platforms

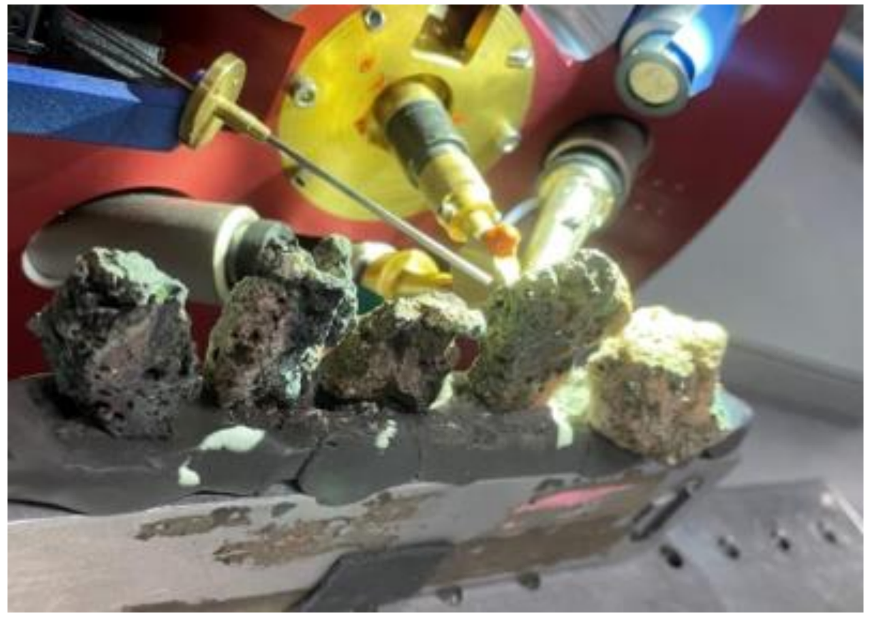
To support frontier HS research, E-RIHS offers access to expertise, data and technologies through a standardized approach organized in platforms.

The platforms provide:

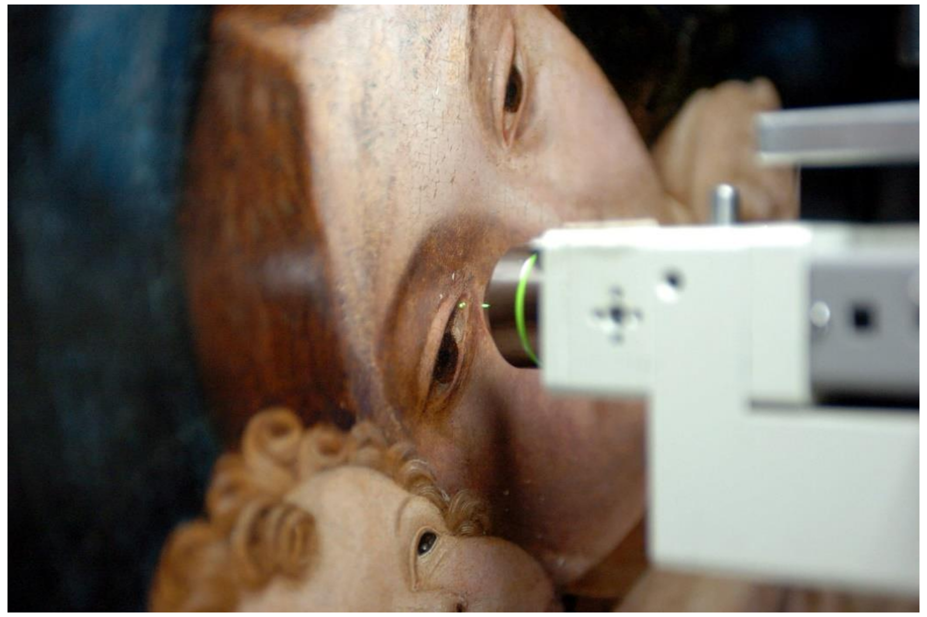
- major scientific equipment (or sets of instruments),
- knowledge-based resources (such as collections, archives and scientific data),
- e-infrastructures, computing systems and communication networks.

E-RIHS platforms

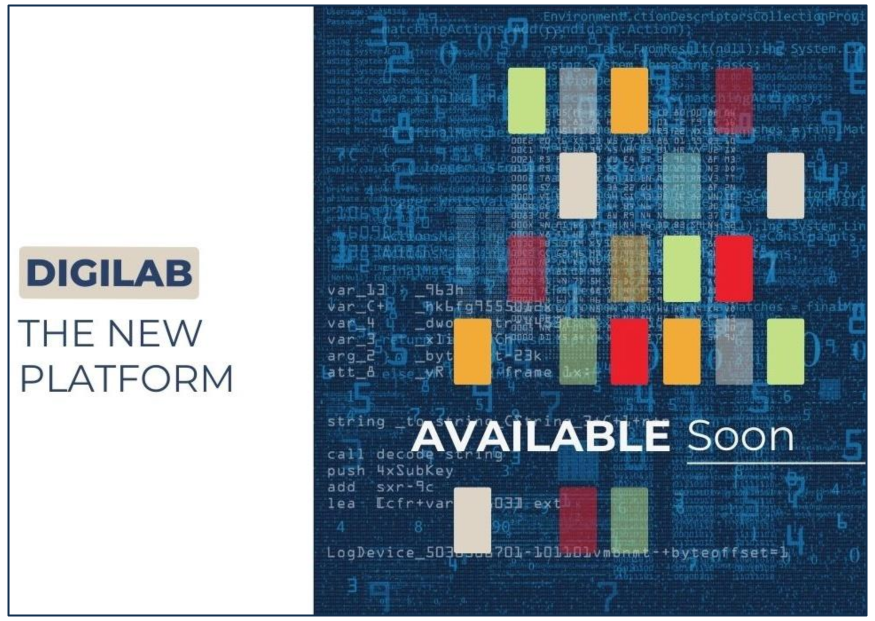
ARCHLAB
Access to specialised knowledge and organise scientific information in datasets largely unpublished from archives of prestigious museums, galleries and research institutions



FIXLAB
Access to large-scale and medium-scale facilities particle accelerators and synchrotrons, neutron sources; non-transportable analytical instruments

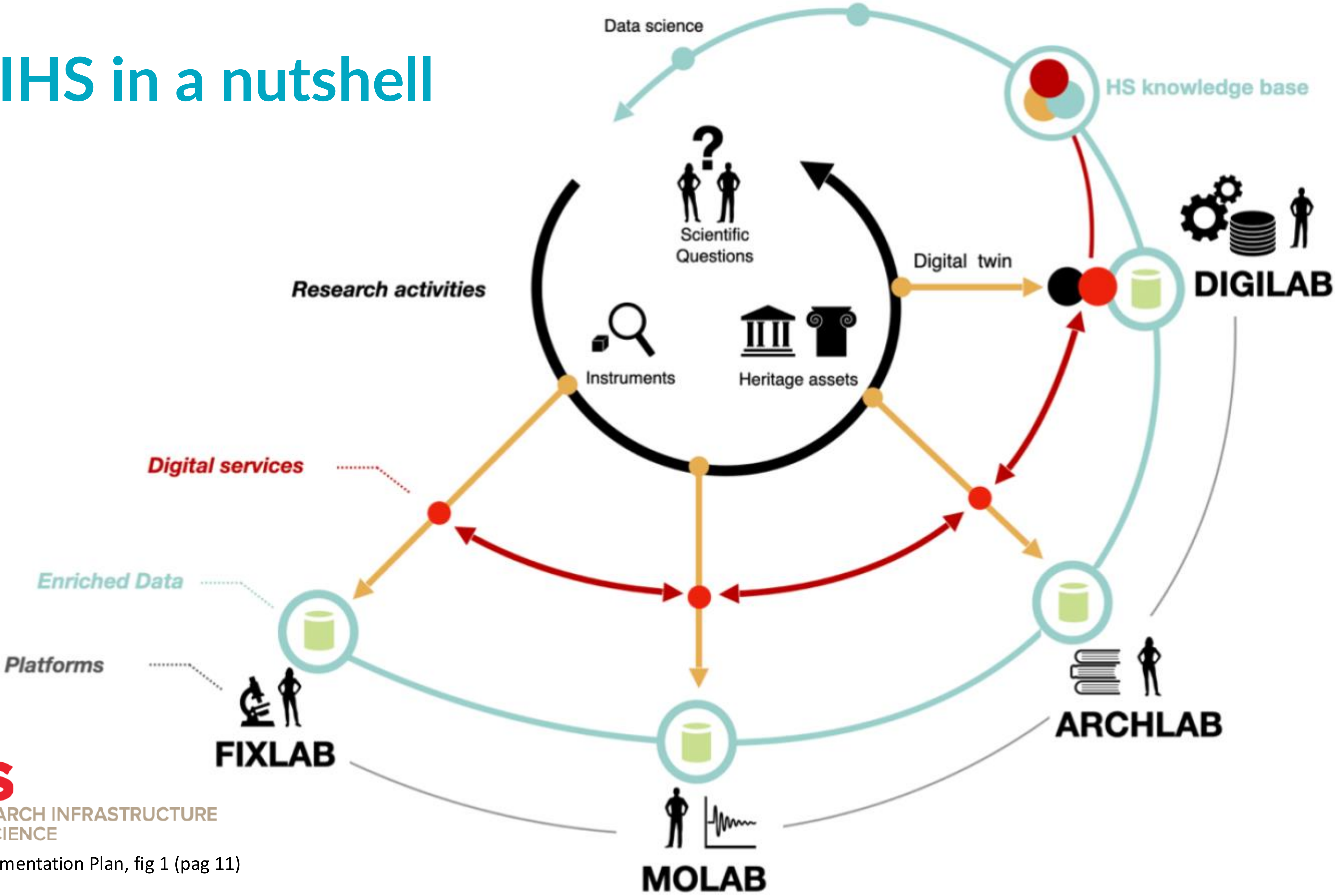


MOLAB
Access to an impressive array of advanced mobile analytical instrumentations for non-invasive measurements on valuable or immovable objects, archaeological sites and historical monuments.



DIGILAB
Virtual access to scientific data concerning tangible heritage, making them FAIR. It includes searchable registries of multidimensional images, analytical data and documentation

E-RIHS in a nutshell



E-RIHS
EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE

E-RIHS IP - D5.1 DIGILAB Implementation Plan, fig 1 (pag 11)

E-RIHS MOLAB Energy and Environmental analysis facility

Spot Analyses

- Bioluminescence
- Contact Sponge Method
- Drilling Resistance Measurement (DRMS)
- Eddy Current conductivity measurement
- Evanescent Field Dielectrometry (EFID)
- External reflection near-FTIR
- External reflection mid-FTIR
- Low Energy XRF
- Micro Raman (532 & 785 nm)

Imaging/Mapping techniques

- High resolution digital microscopy
- IR Thermography
- Macro XRF/VIS NIR Hyperspectral mapping
- Macro XRF rotational mapping
- Microprofilometry
- Micro XRF mapping
- Optical Coherence Tomography
- Scanning multispectral VIS-NIR reflectography
- Terahertz time-domain imaging spectroscopy
- UV/IR imaging

2D/3D digitization and survey techniques

- 2D digitization using RTI techniques
- 2D digitization using planetary scanner and large format scanner
- 3D Laser Scanning technique
- 360° photo shooting and video recording
- Global Navigation Satellite System (GNSS)
- Laser scanner Faro Focus
- Medium or small-scale 3D digitization with active instrumentation

Remote Sensing & Geophysics analyses

- Fluxgate gradiometry
- Georesistivity meters
- GPR structure scan
- Global Navigation Satellite System (GNSS)
- Ground Penetrating Radar
- Magnetic gradiometer
- GPR multi-antenna
- Multi-depth electromagnetic conductivity meters

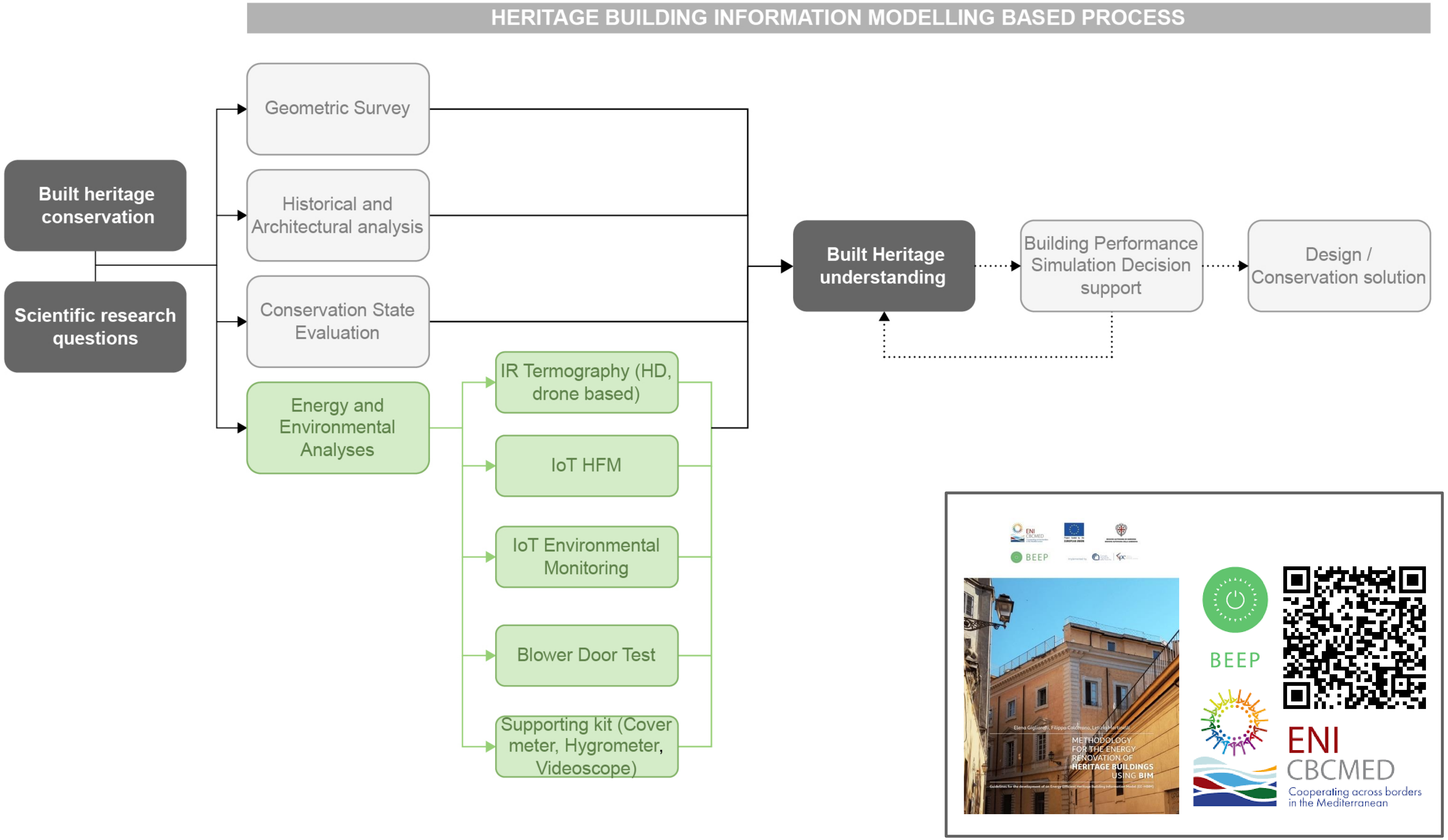
Energy and Environmental Analyses

- IR thermography (HD, drone)
- IoT Heat Flux Measuring system
- IoT Indoor Environmental Monitoring system
- Blower door test
- Supporting kit (Cover meter, Hygrometer, Videoscope)

The Role of E-RIHS

Here is what currently E-RIHS can support of the procedures you have seen before. Within an HBIM managed workflow that aims to built heritage understanding also but not necessarily with simulations the energy and environmental analysis facility of E-RIHS provides support to the energy and environmental analysis part according to the same procedure that we developed and tested during BEEP project that we will see in the following slides.

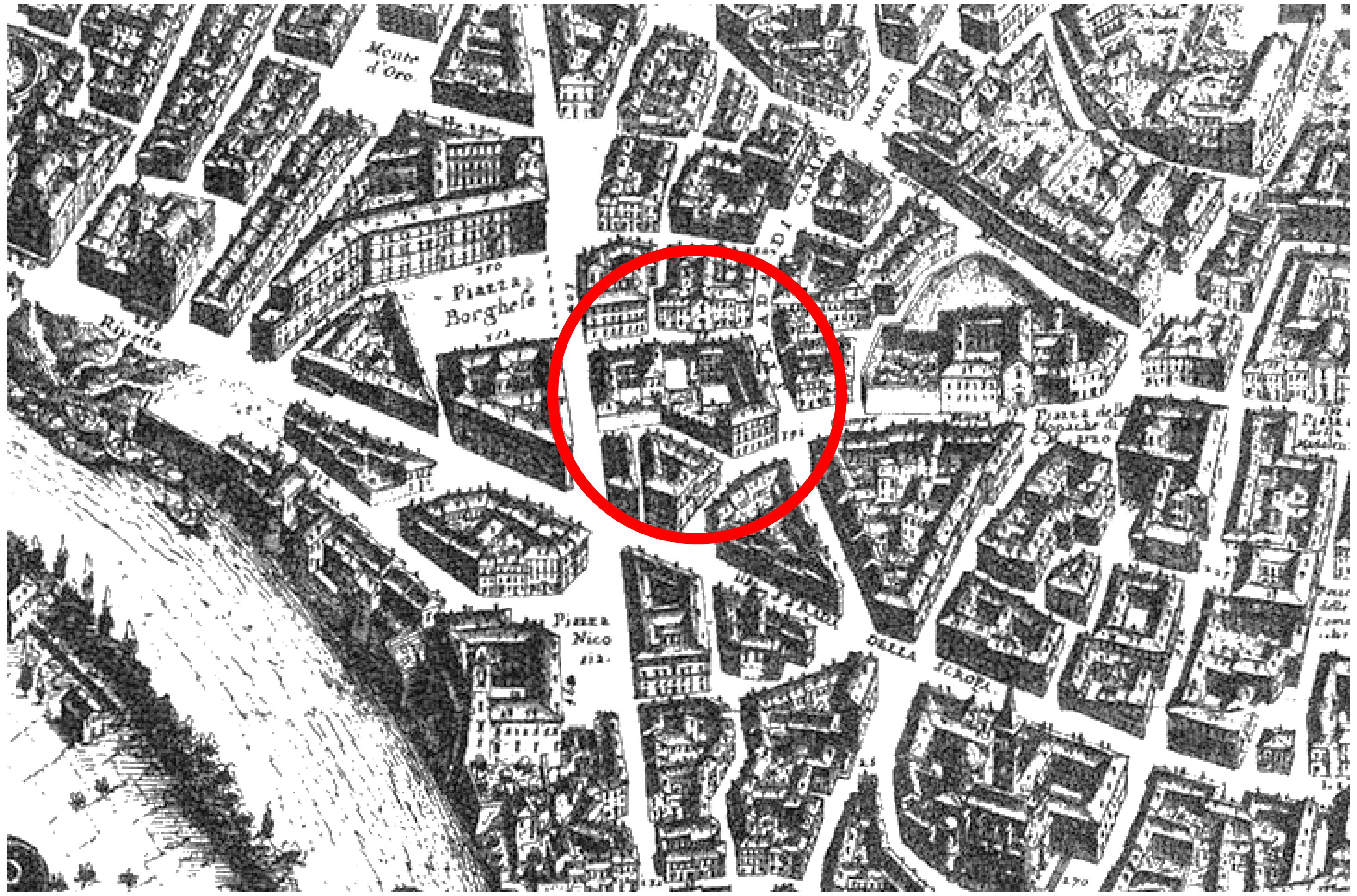
E-RIHS
EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE



ENICBCMED BEEP PROJECT - THE CASE STUDY OF PALAZZO MAFFEI BORGHESE IN ROME

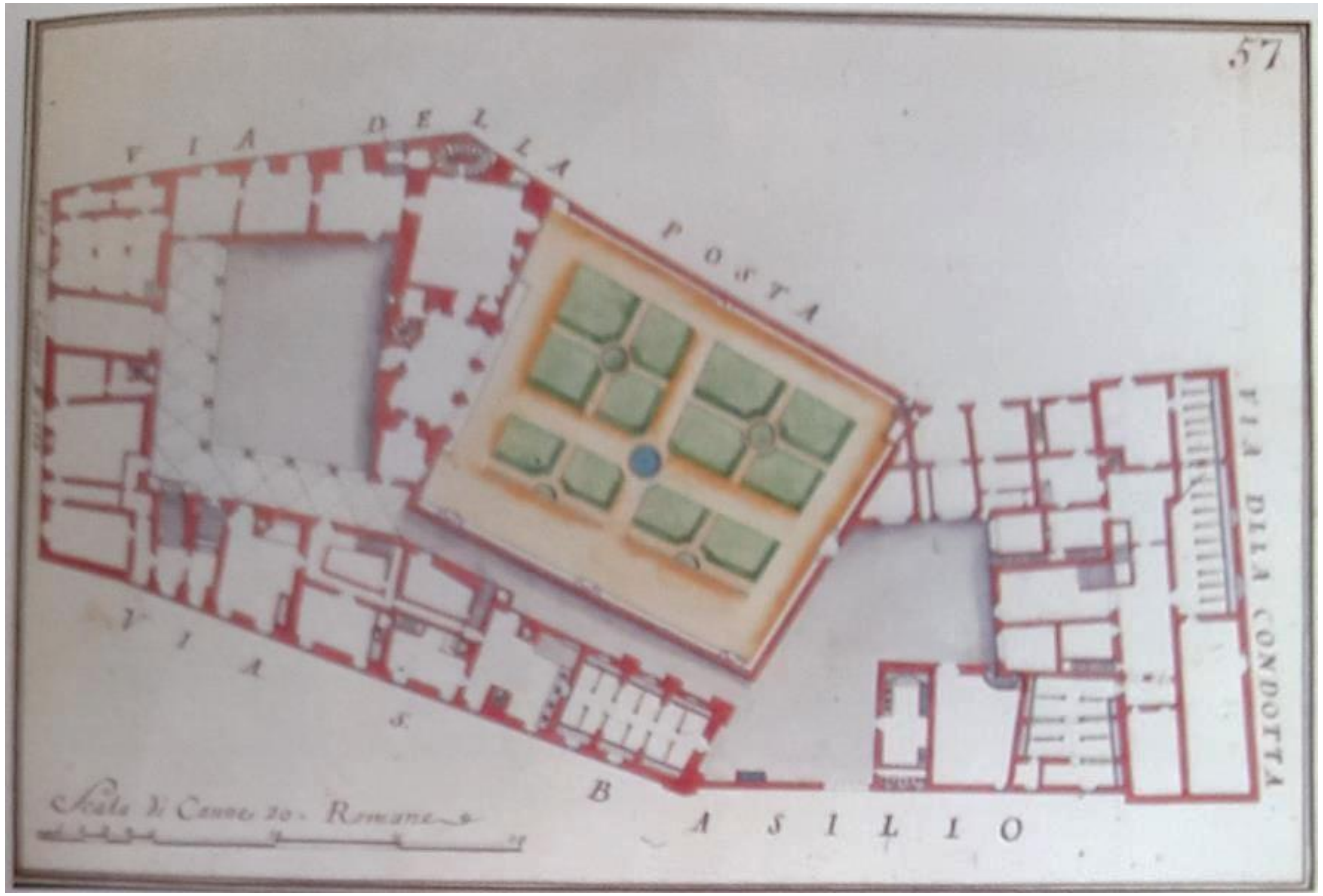
Palazzo Maffei-Borghese

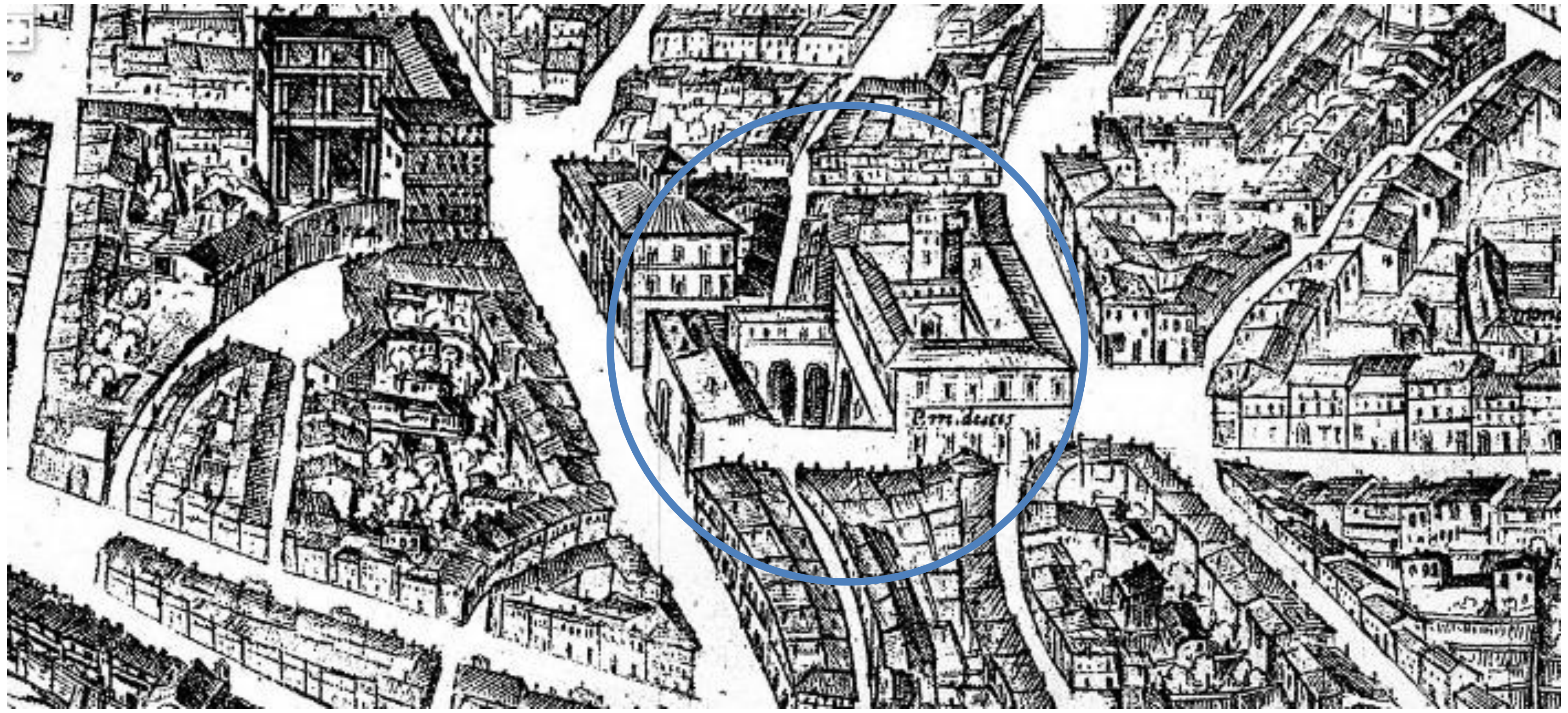
- **Position:** Via del Clementino, 91, Rome Campo Marzio
- **Area:** 6340 m^2
- **Volume:** 24000 m^3
- **Usage:** Avvocatura Generale dello Stato
- **Construction period:** 1400-1700



Palazzo Maffei-Borghese

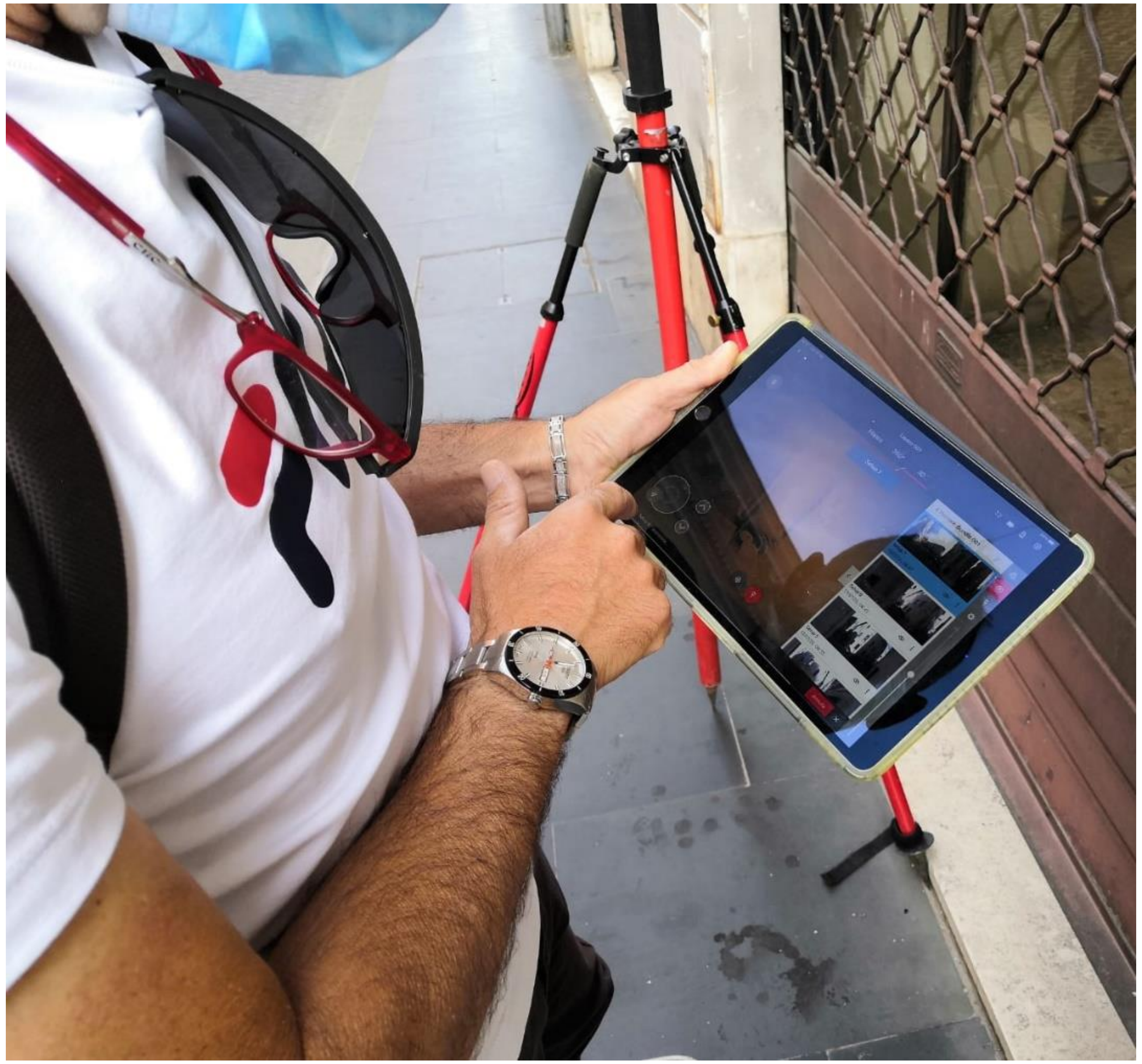
The first activities always involve the historical and architectural analyses, essential for the knowledge of the building also as a starting point for the other analyses.

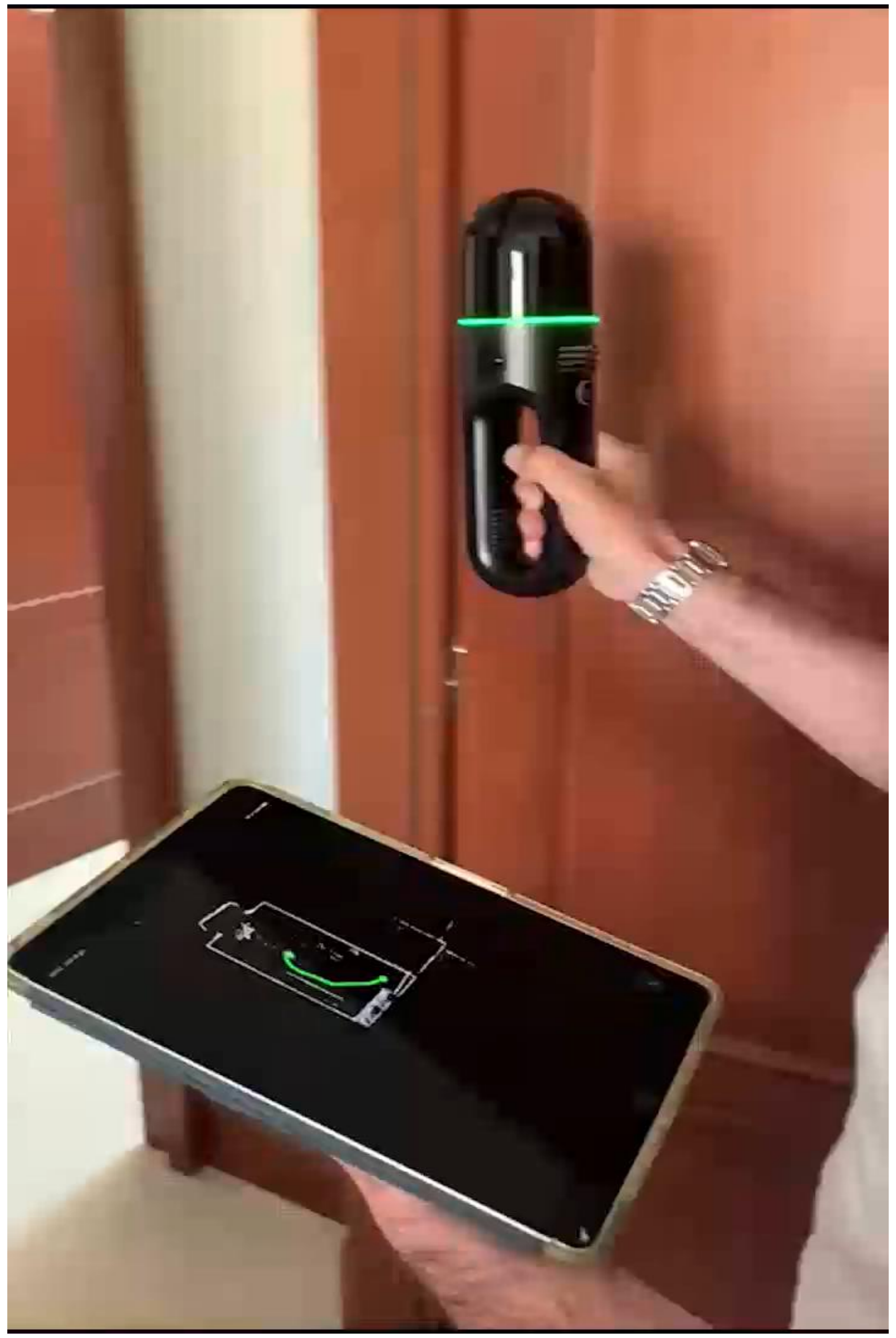




Palazzo Maffei-Borghese

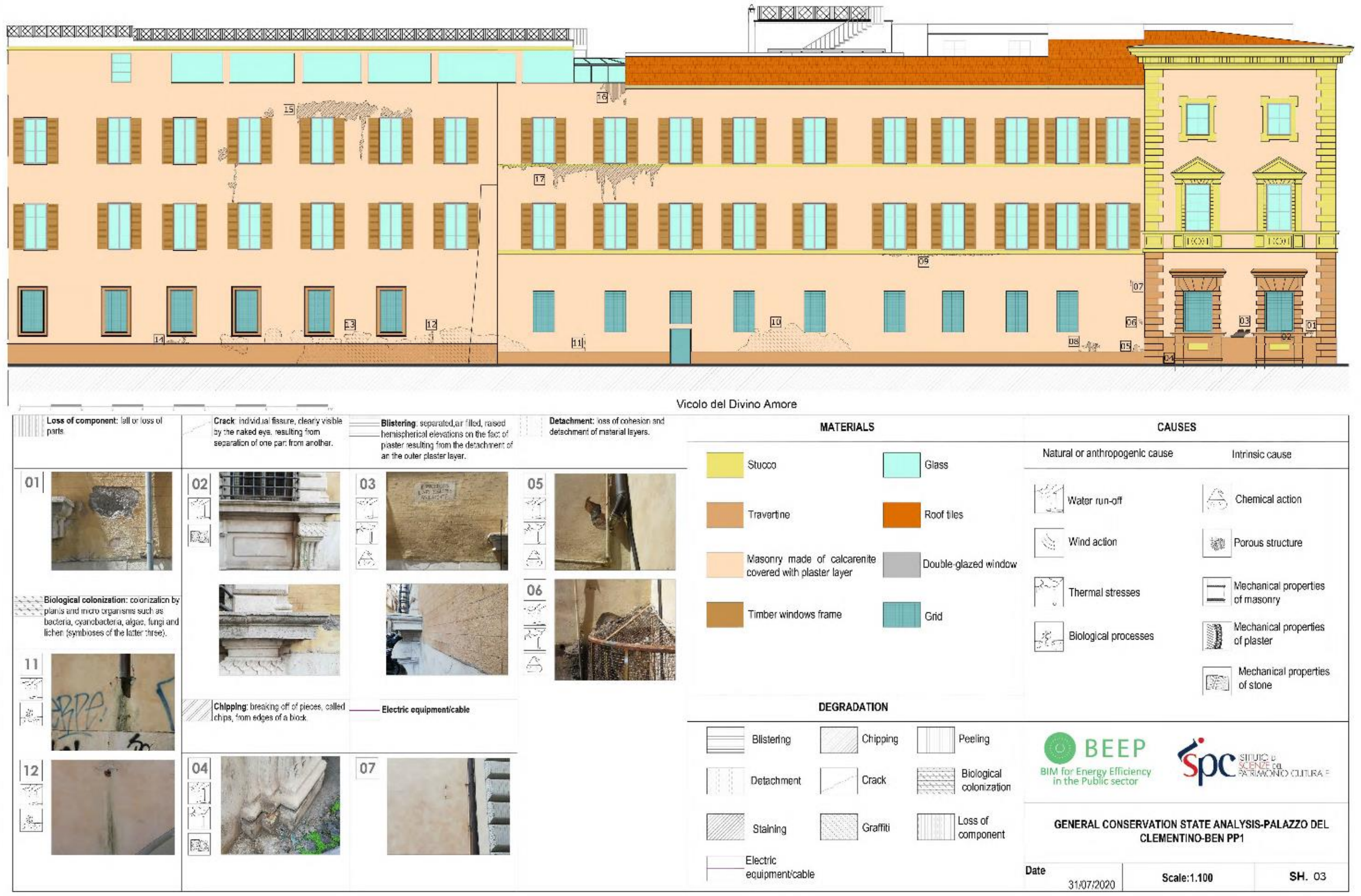
The geometric survey of the building was created by integrating different technologies including Simultaneous Localization And Mapping (SLAM), particularly suitable for the survey of interiors or large building structures due to the rapidity of acquisition





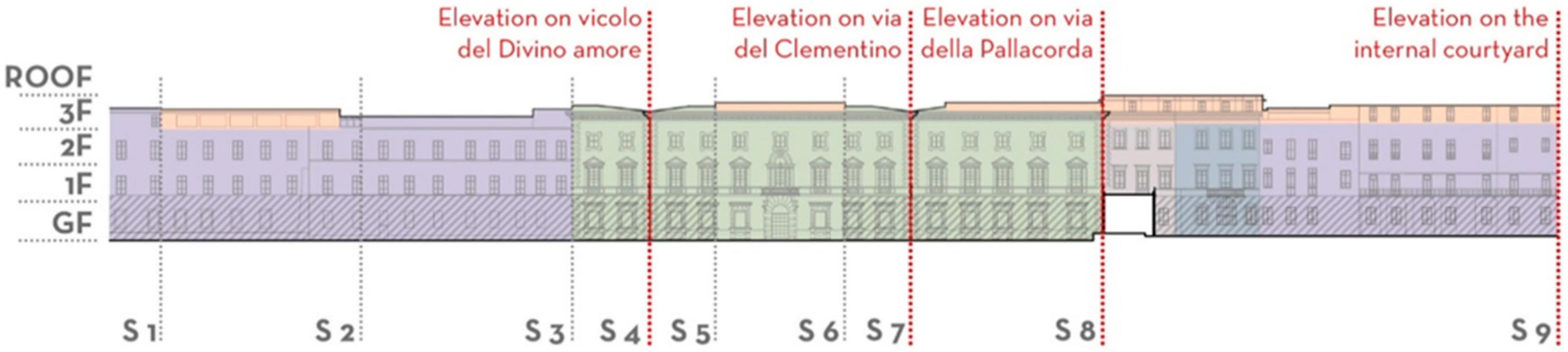
Palazzo Maffei-Borghese

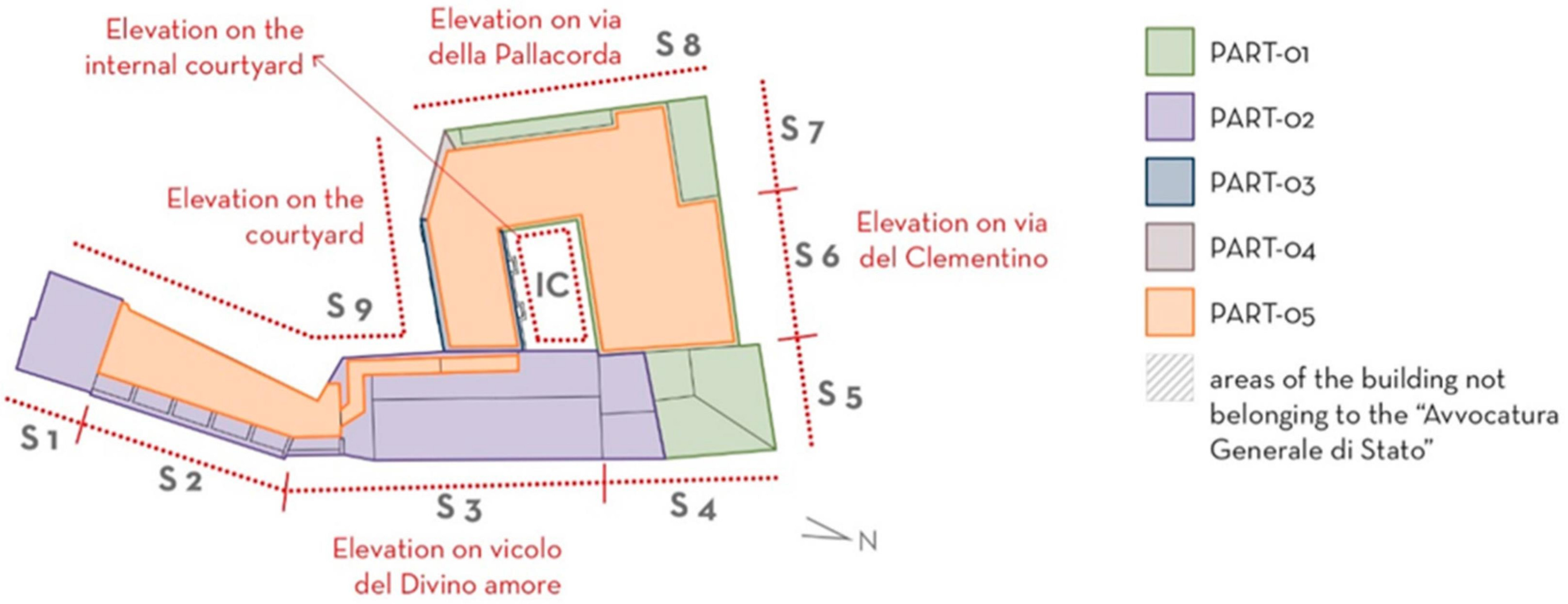
The **general conservation state analysis** was based on a photogrammetric survey to obtain accurate information on the current state of façade surfaces.



Palazzo Maffei-Borghese

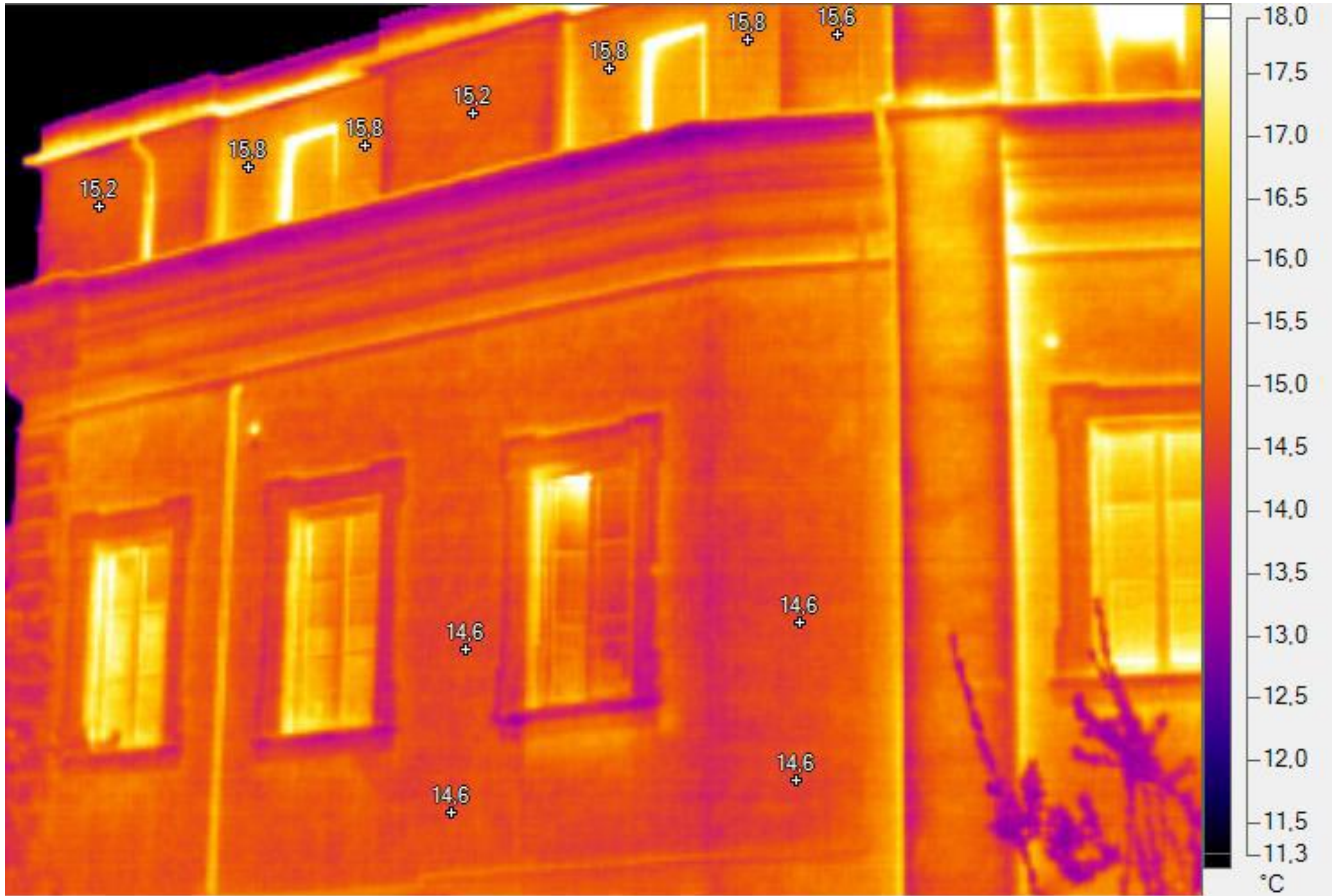
Based on the historical analyses and the documentation gathered, the team developed first hypotheses of homogeneous wall stratigraphies, that were subsequently checked with an infra-red thermographic survey.





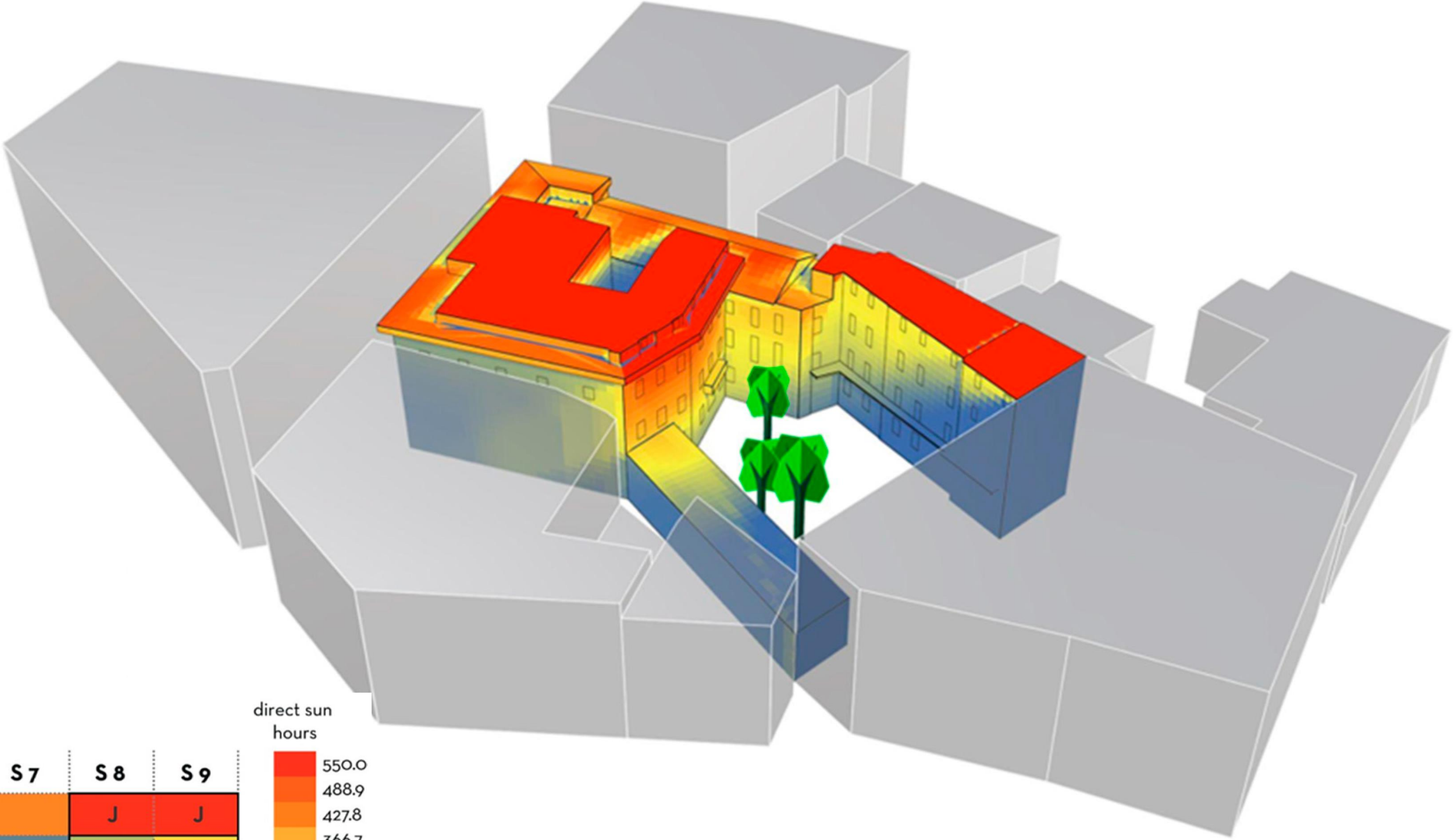
Palazzo Maffei-Borghese

In addition, to check the hypotheses on construction systems, the analysis allowed to spot thermal bridges, roofing construction systems, indoor cracks and infiltrations, and to identify main wall typologies to be measured with heat flux meter analyses.



Palazzo Maffei-Borghese

The selection of the heat flux measurement points was also supported by sunshine hour simulation of the winter months to find the most suitable walls (with less sunshine) to perform the analyses.



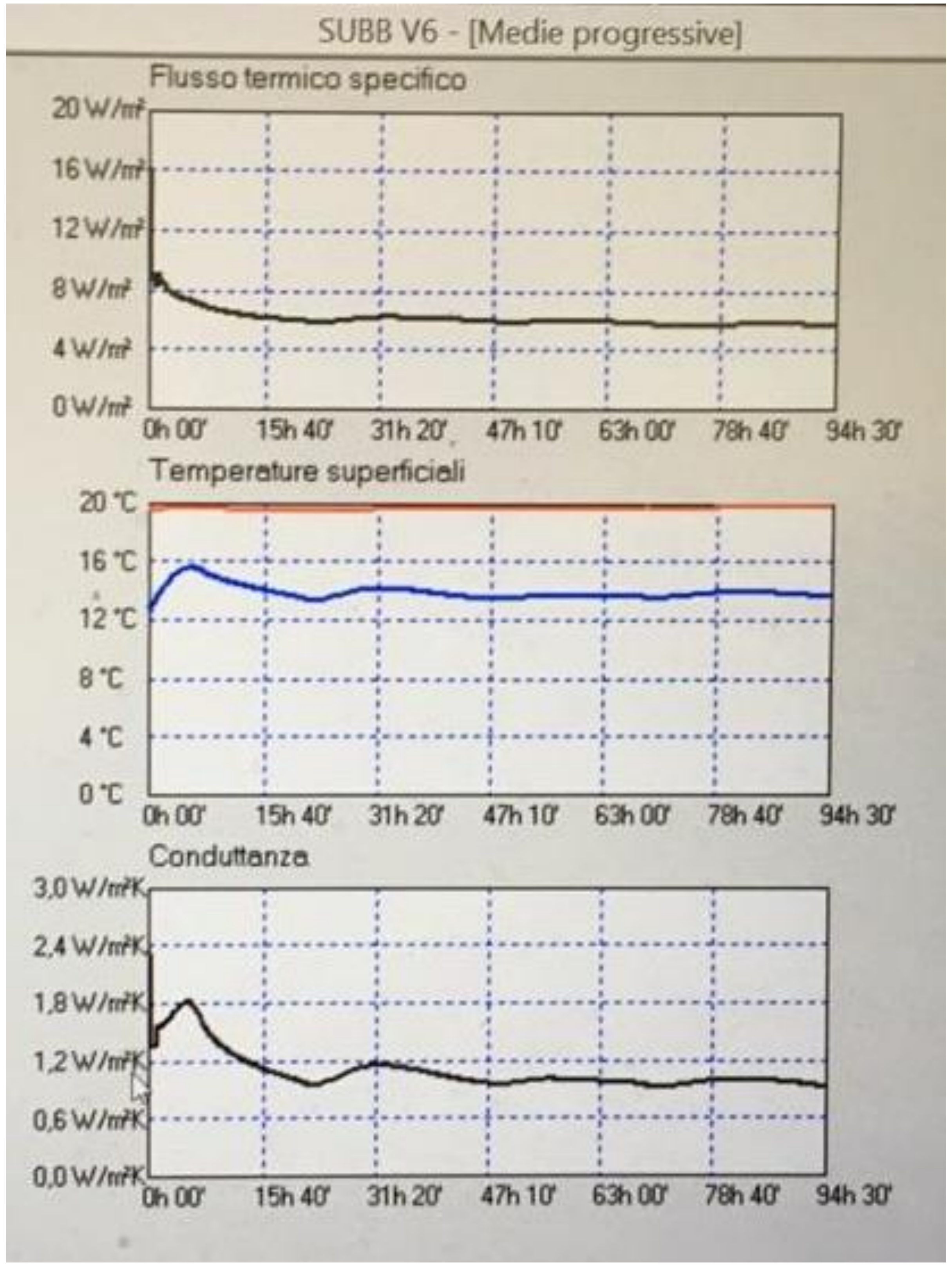
	S1	S2	S3	S4	S5	S6	IC	S7	S8	S9
ROOF	I	K				J	J		J	J
3F	A	H				H	H		H	H
2F	A	B	D	G	G	G	G	G	G	
1F	A	A	C	F	F	F	F	F	F	
GF						E				

Palazzo Maffei-Borghese

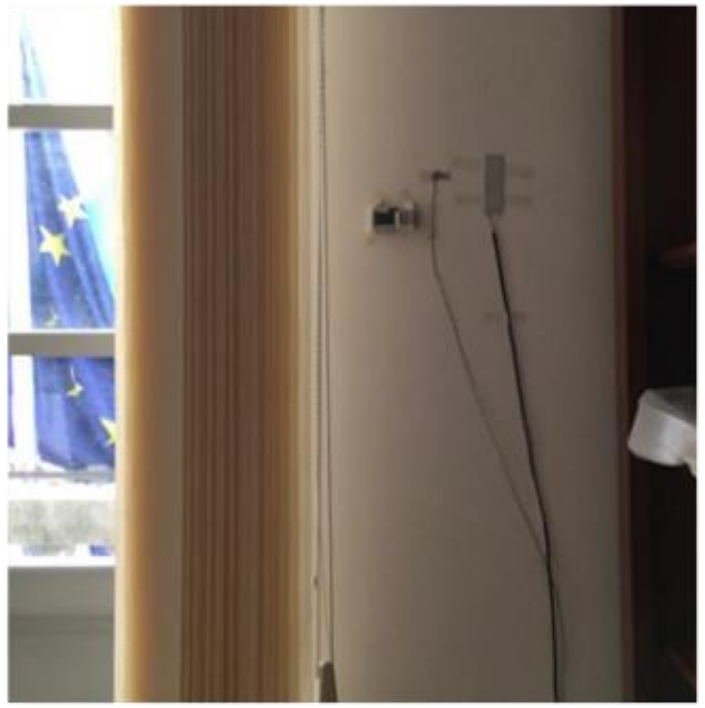
Misura n. 1 - Stanza 220

Misura n. 2 - Stanza 116

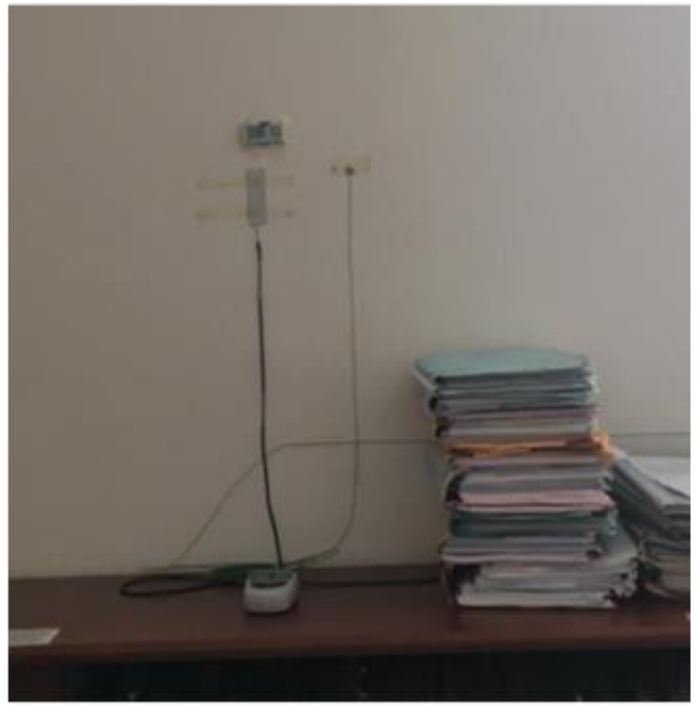
Misura n. 3 - Stanza 127



Misura n. 4 - Stanza 234



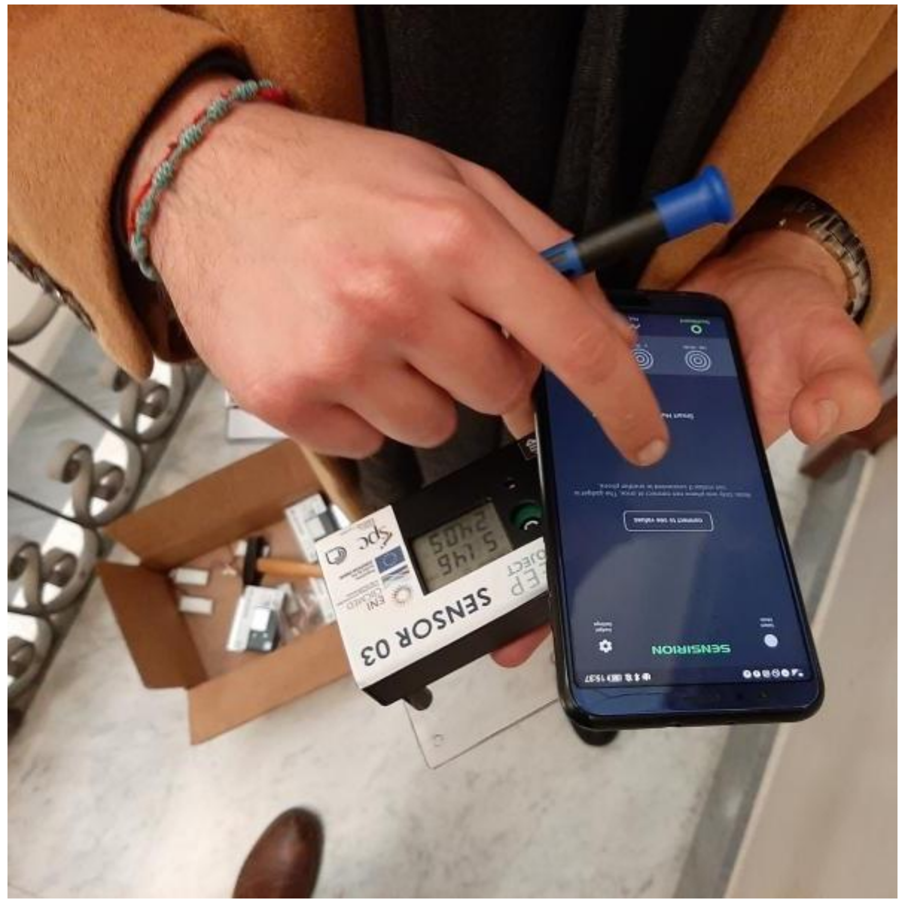
Misura n. 5 - Stanza 105

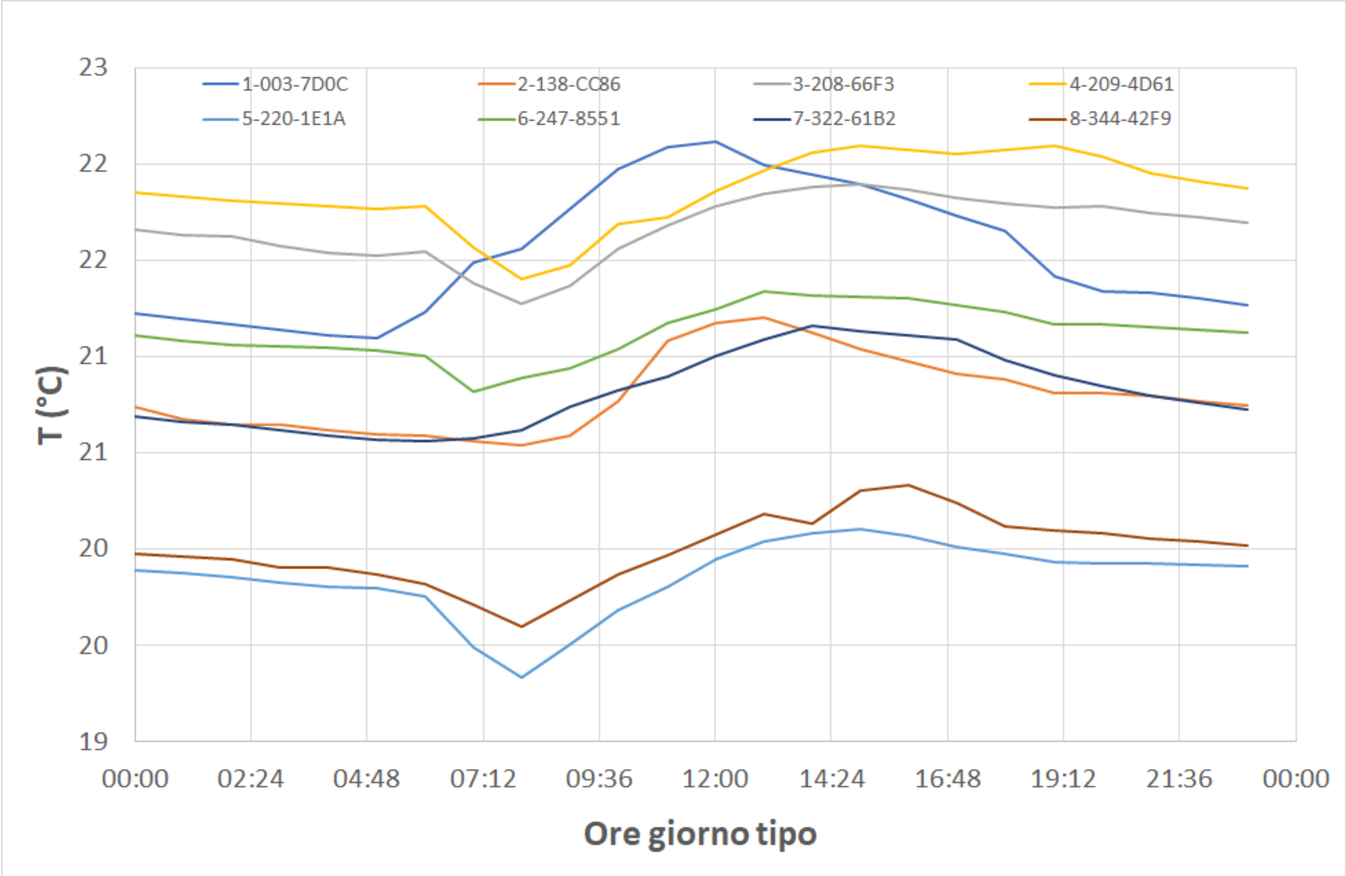


Misura n. 6 - Stanza 209

Palazzo Maffei-Borghese

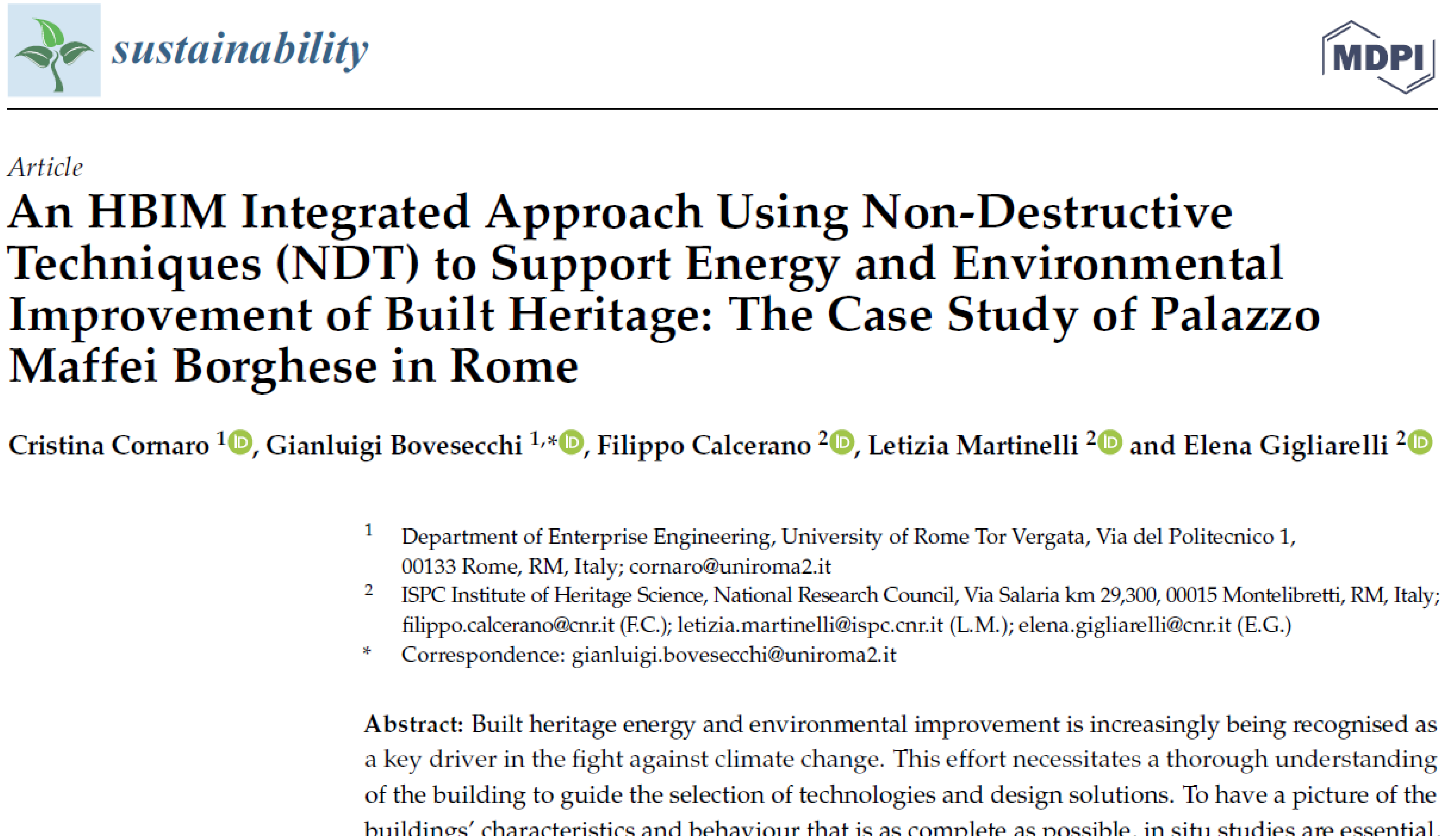
At the same time we also started the indoor environmental monitoring to support both input data for the energy model and further calibration with room temperatures





Palazzo Maffei-Borghese

The HBIM approach followed the whole analysis process also with specific templates for data gathering, streamlining the acquisition of data from fieldwork and allowing the model to evolve along with the consolidation of the hypotheses on the building characteristics,


sustainability MDPI

Article

An HBIM Integrated Approach Using Non-Destructive Techniques (NDT) to Support Energy and Environmental Improvement of Built Heritage: The Case Study of Palazzo Maffei Borghese in Rome

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2 ISPC Institute of Heritage Science, National Research Council, Via Salaria km 29,300, 00015 Montelibretti, RM, Italy; filippo.calcerano@cnr.it (F.C.); letizia.martinelli@ispc.cnr.it (L.M.); elena.gigliarelli@cnr.it (E.G.)
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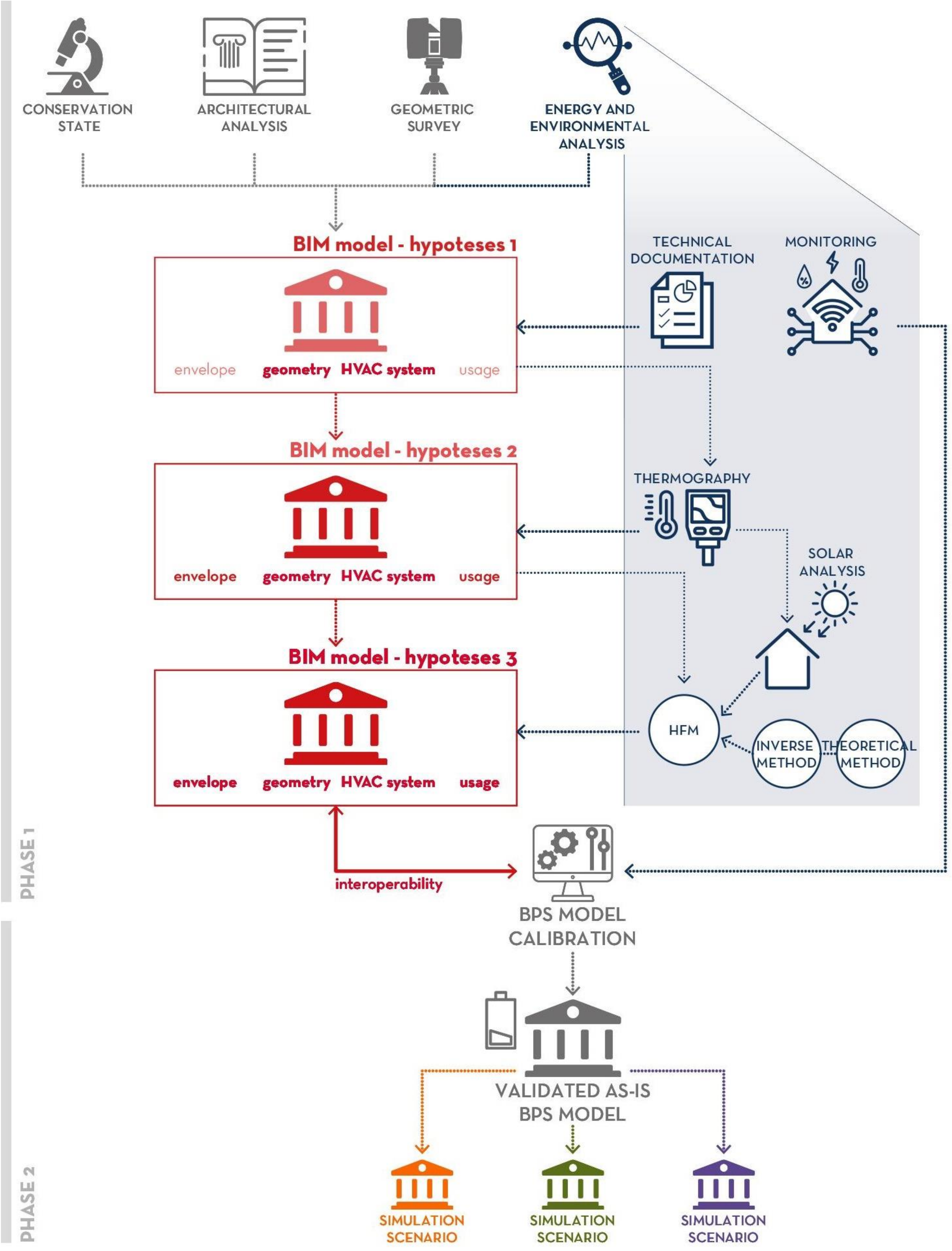
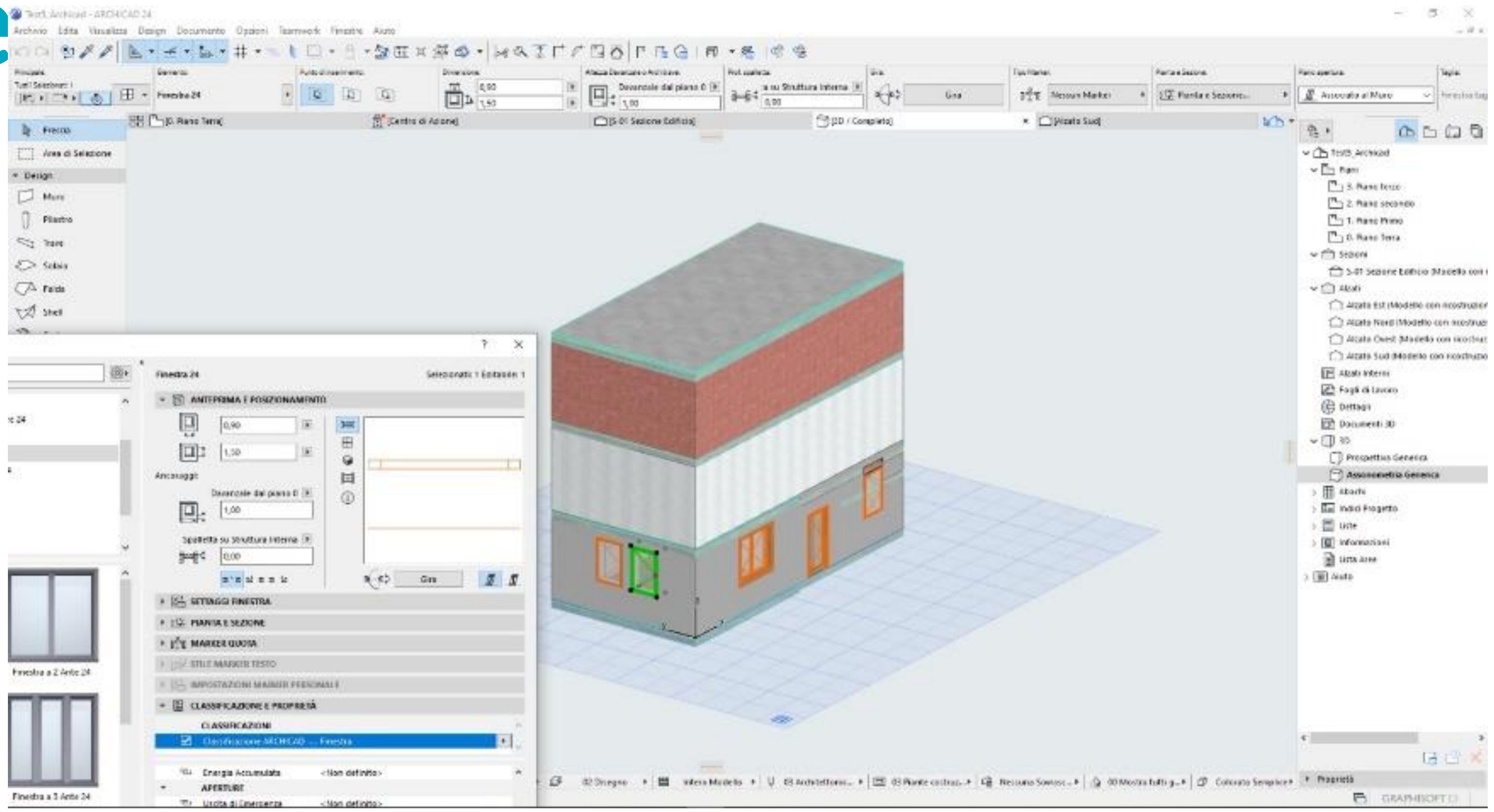
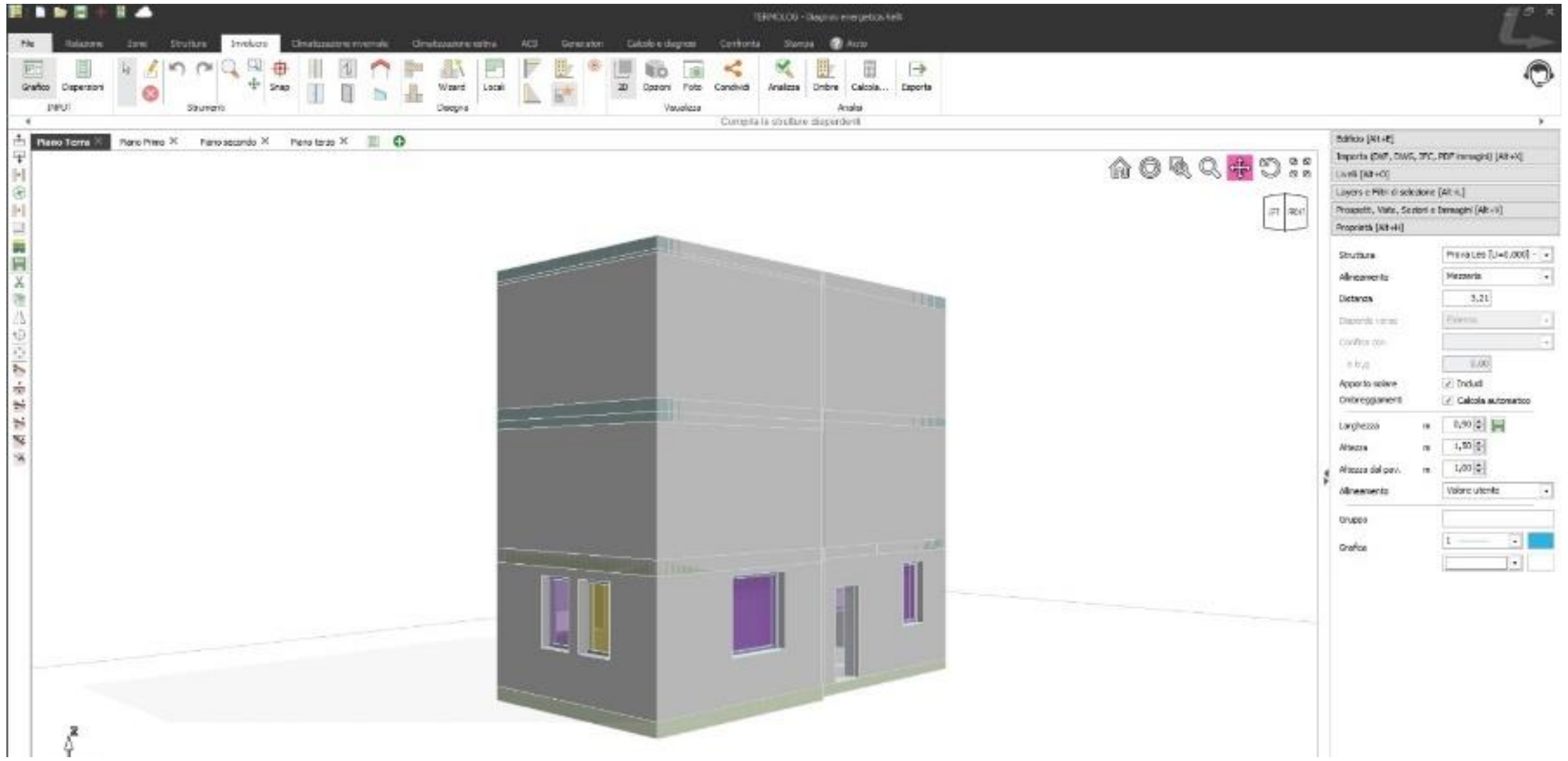
Abstract: Built heritage energy and environmental improvement is increasingly being recognised as a key driver in the fight against climate change. This effort necessitates a thorough understanding of the building to guide the selection of technologies and design solutions. To have a picture of the buildings' characteristics and behaviour that is as complete as possible, in situ studies are essential

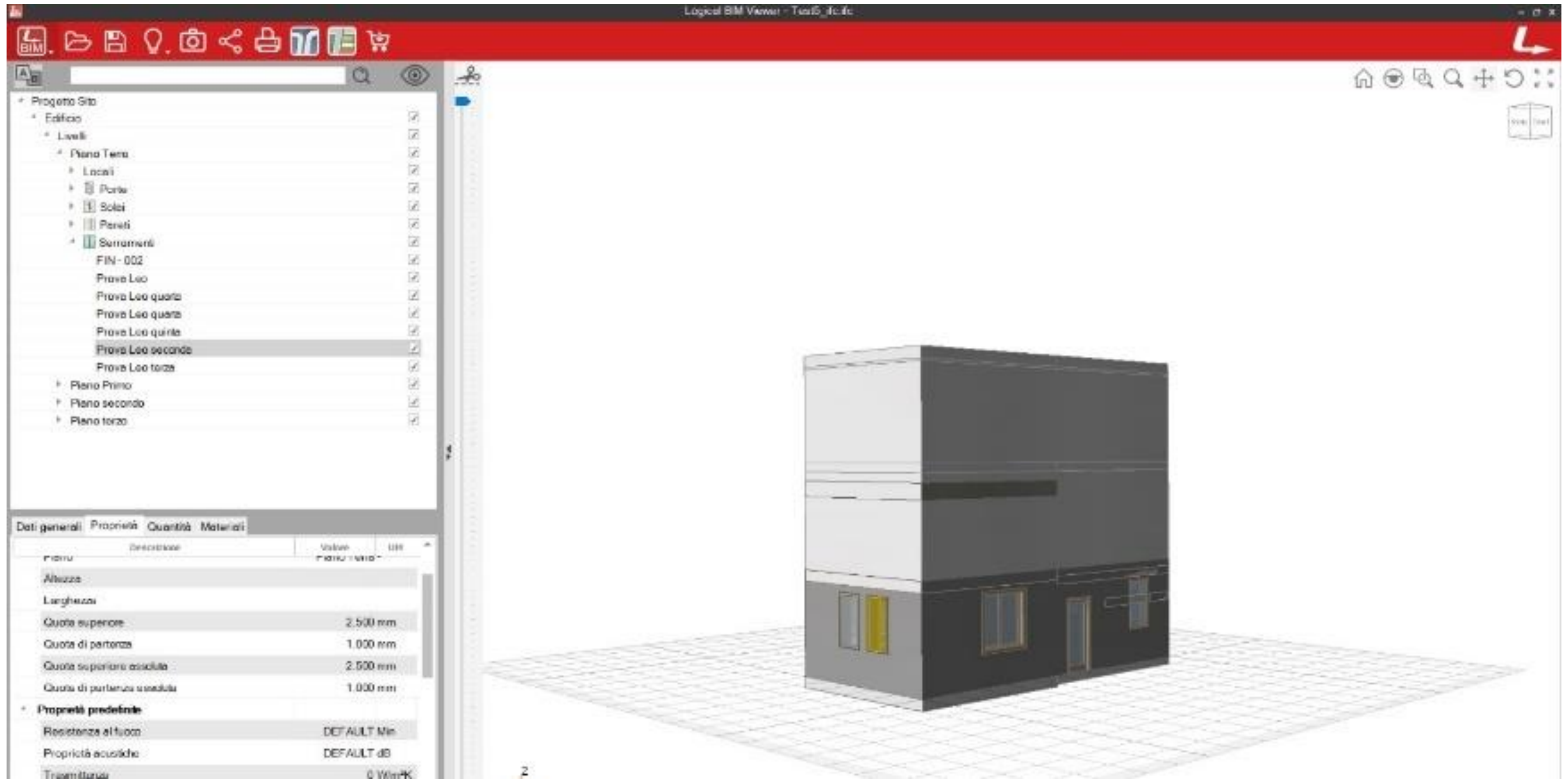


Palazzo Maffei-Borghese

And then we started the interoperability phase through IFC. Here we can see the first tests on simplified models to spot and address general interoperability issues after the knowledge framework and data mapping phase

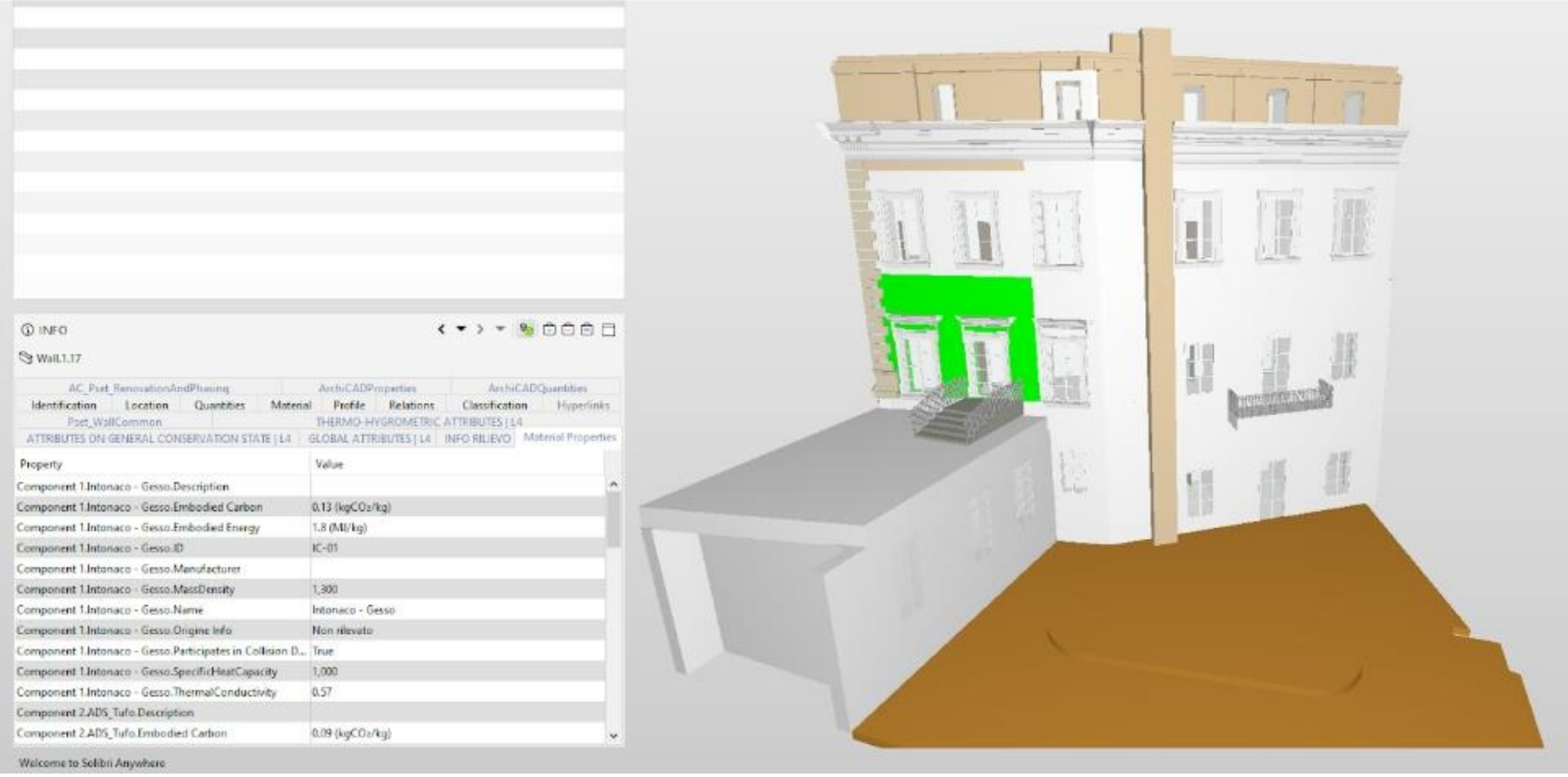


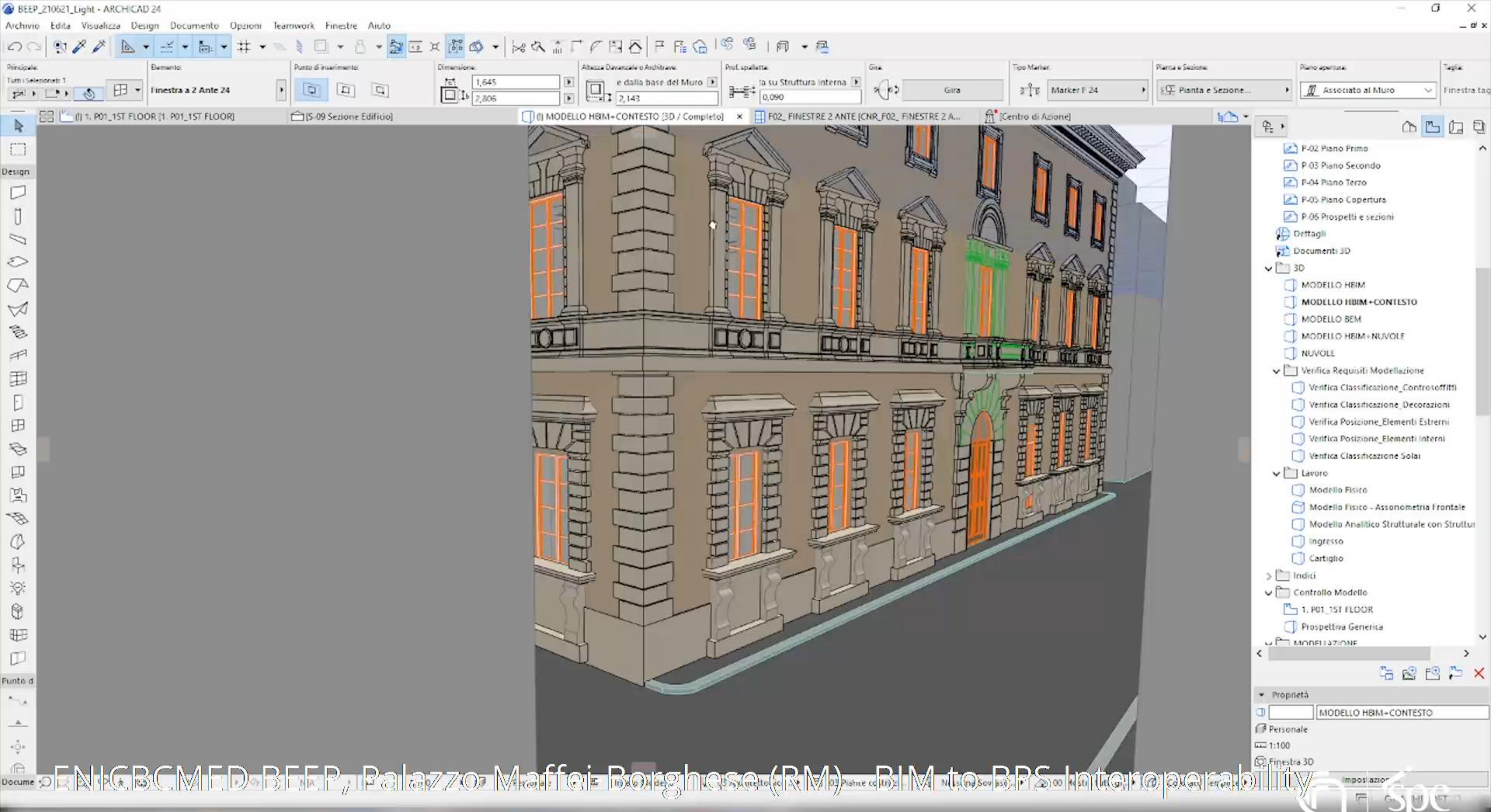




Palazzo Maffei-Borghese

These are the tests on a portion of the case study representative of all case study specific issues (height differences among levels, sloped roofs, large amount of windows, ceilings and vaults..)





ENICBCMED BEEP, Palazzo Maffei Borghese (RM) - BIM to BPS Interoperability

Palazzo Maffei-Borghese

Compatibility and heritage significance

Technical compatibility and feasibility check

Environmental sustainability of the intervention

Technical characteristics

Estimated cost of the intervention

ISOLAMENTO SOLAI

1. piastrelle in ceramica (20 mm)
2. sottofondo (20 mm)
3. lastra acciaio zincato con adesivo (2 mm)
4. pannelli radianti a secco isolati (40 mm)
5. strato di isolamento a pavimento in lana di roccia (80 mm)
6. guaina (1 mm)
7. massetto isolante in conglomerato cementizio (40 mm)
8. soletta in cls armato (180 mm)
9. magrone (100 mm)
10. vespaio in pietrame vulcanico a secco (230 mm)

Rimozione pavimentazione e sottofondo fino al massetto isolante con eventuale guaina, sostituzione guaina, posizionamento isolamento calpestabile in lana di roccia tipo ROCKWOOL Dachrock (8 cm), strato in pannelli radianti a secco isolati e ricoperti da piastra sottile in acciaio zincato tipo TERATEC DRY(4,2 cm), sottofondo e piastrelle.

ISOLAMENTO INVOLUCRI ESTERNI

1. intonaco termoisolante naturale (20 mm)
2. isolamento a cappotto in aerogel (30 mm)
3. intonaco di calce e cemento (40 mm)
4. muratura in pietra (calcare di Castelluccio 836 mm)
5. strato di tenuta (1 mm)
6. strato di finitura in intonaco (20 mm)

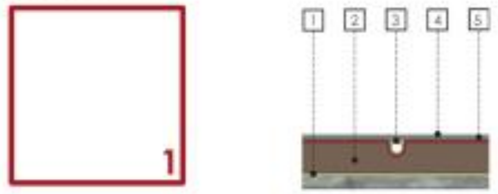
Isolamento delle chiusure verticali con applicazione di uno strato di isolamento a cappotto in pannelli di aerogel da 3 cm protetto da rete in fibra di vetro annegata in uno strato di finitura esterna in termointonaco naturale tipo DiathoniteEvolution(2 cm, totale +5cm rispetto al filo attuale).

ISOLAMENTO TETTI

1. strato di copertura discontinua in tegole fotovoltaiche (20 mm)
2. pannelli in legno (12 mm)
3. intercapedine ventilata (60 mm)
4. guaina traspirante (40 mm)
5. isolante in fibra di legno (40 mm)
6. isolante in fibra di legno (160 mm)
7. barriera al vapore (1 mm)
8. pannello di legno multistrato (12 mm)
9. cartongesso antincendio (15 mm)

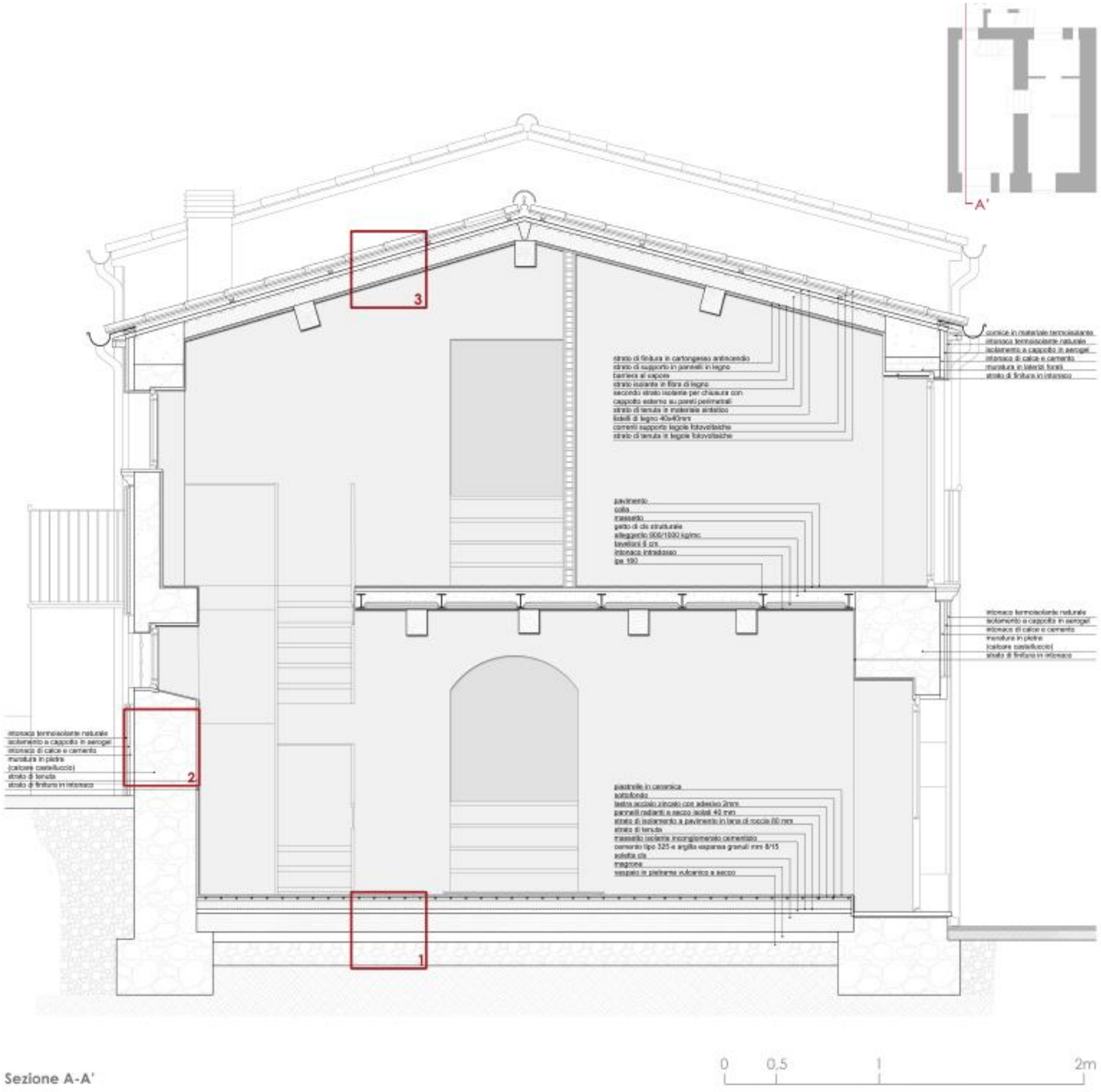
Isolamento del tetto a sud con rimozione copertura fino alle strutture esistenti in legno, realizzazione strato di finitura interna in pannelli di cartongesso antincendio (1,5 cm) e pannelli tipo OSB(1,2cm) con barriera al vapore fissati all'orditura delle capriate. Applicazione nell'estradosso fra le capriate di uno strato di strato isolante ad elevata capacità termica in fibra di Legno tipo CELENIT Nfino al filo del cordolo, compresi le fasce da 4cm in corrispondenza delle capriate (spessore complessivo 16 cm), applicazione di ulteriore strato di isolamento in fibra di legno per isolare il ponte termico lineare del cordolo ricongiungendo l'isolamento della copertura al cappotto esterno. Posa in opera guaina traspirante e realizzazione supporto listellato per tegole di copertura fotovoltaiche tipo Techtile Energ con camera ventilata sottostante atta anche al passaggio dei cavi (6cm).

IMPIANTI



1. barriera umidità
2. pannello isolante
3. tubazione
4. lastra acciaio zincato con adesivo
5. lastra acciaio zincato

Inserimento di pannelli radianti e istallazione di caldaia a condensazione per alimentare anche i radiatori esistenti. Il fluido in uscita a 60°C viene trasmesso ai radiatori, dai quali torna a 50°C e viene poi miscelato per scendere alla temperatura necessaria a servire i pannelli radianti (30-35°C) da cui poi torna alla caldaia. È necessaria una valvola di sicurezza per controllare che la temperatura del pavimento radiante resti sempre all'interno della soglia voluta.



Sezione A-A'

Palazzo Maffei-Borghese

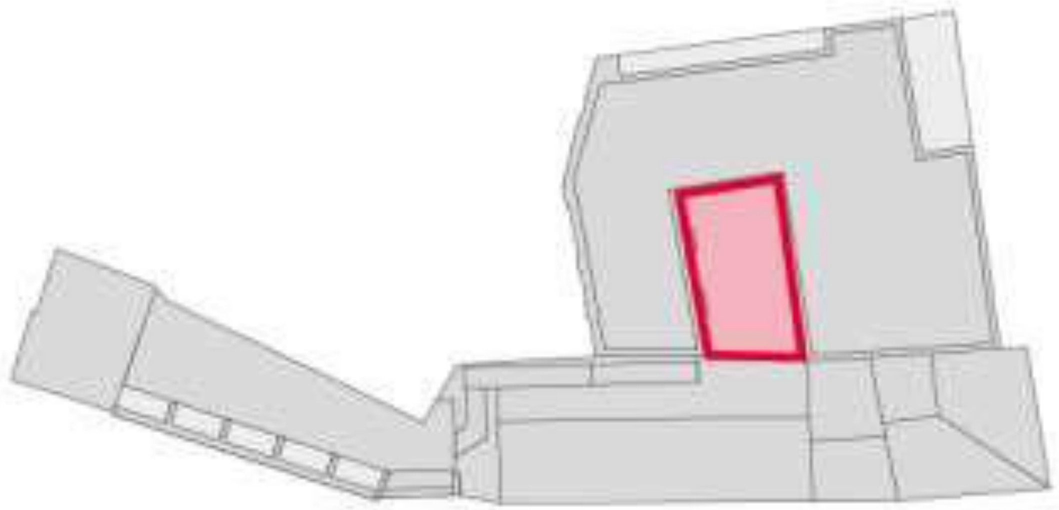
Int. Code	Name of Intervention	Short term scenario	Middle term scenario	Long term scenario
IT1P01	Insufflation of empty hollow masonry cavities of third floor	X	X	X
IT1P02	External insulation of the south-east wing on Vicolo del Divino Amore		X	X
IT1P03	Insulation on the intrados of wooden pitched roof	X	X	X
IT1P04	Insulation on the intrados of steel pitched roof	X	X	X
IT1P05	Extrados insulation of slabs towards the AHU unheated spaces	X	X	X
IT1P06	Extrados insulation of flat roofs		X	X
IT1P07	Extraordinary maintenance of windows to reduce infiltrations	X	X	X
IT1P08	Bioclimatic photovoltaic Buffer Space			X
IT1P09	Restoration of window shadings			X
IT1A01	Upgrading of existing heat pumps	X	X	X
IT1A02	Building Automation and Control Systems		X	X
IT1A03	Mechanical Ventilation	X	X	X
IT1A04	Artificial Lighting upgrade	X	X	X
ITI1R01	Photovoltaic System	X	X	X

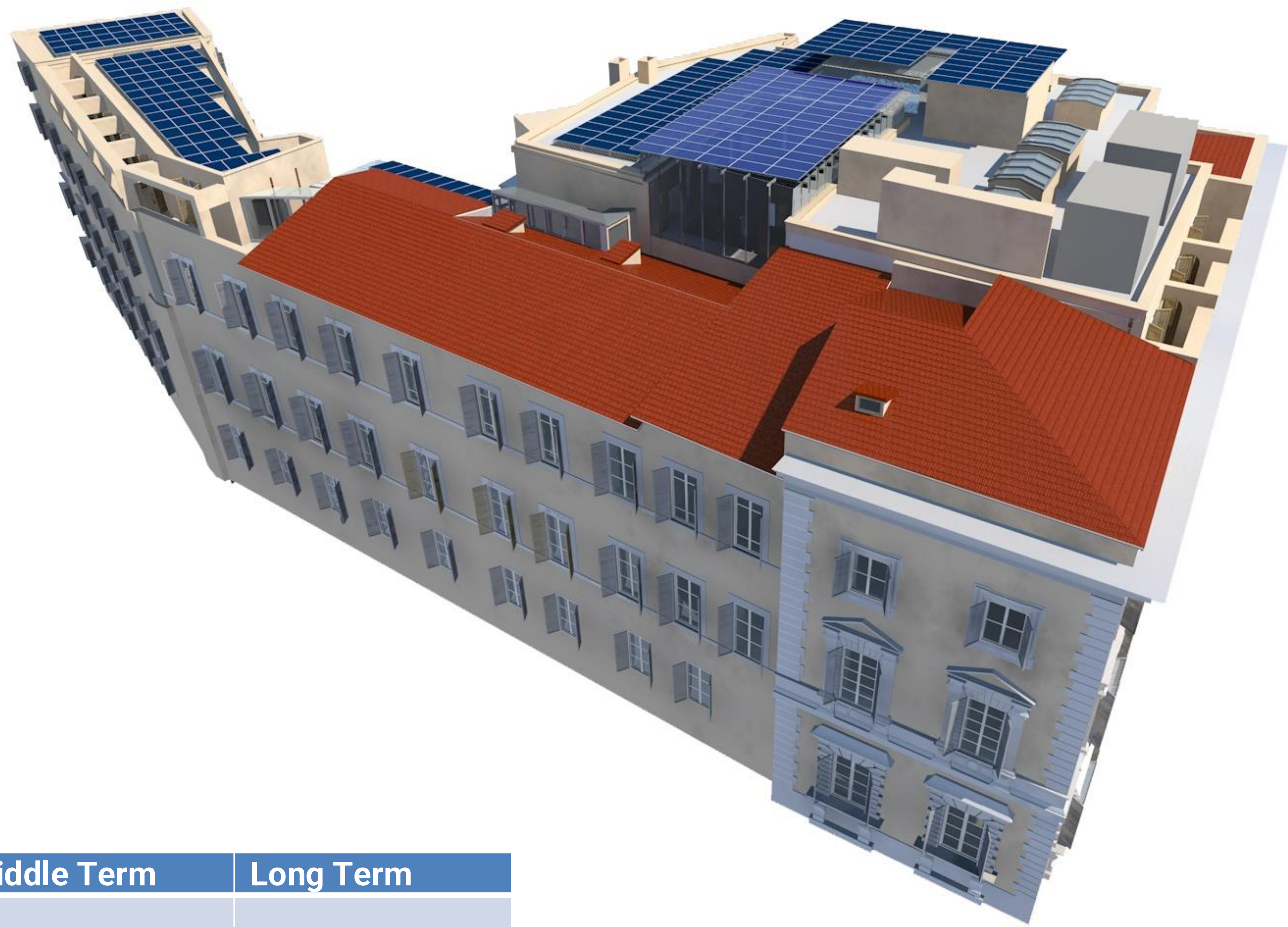
Palazzo Maffei-Borghese

Shading systems

Natural ventilation

RES Generation, Distribution and Use

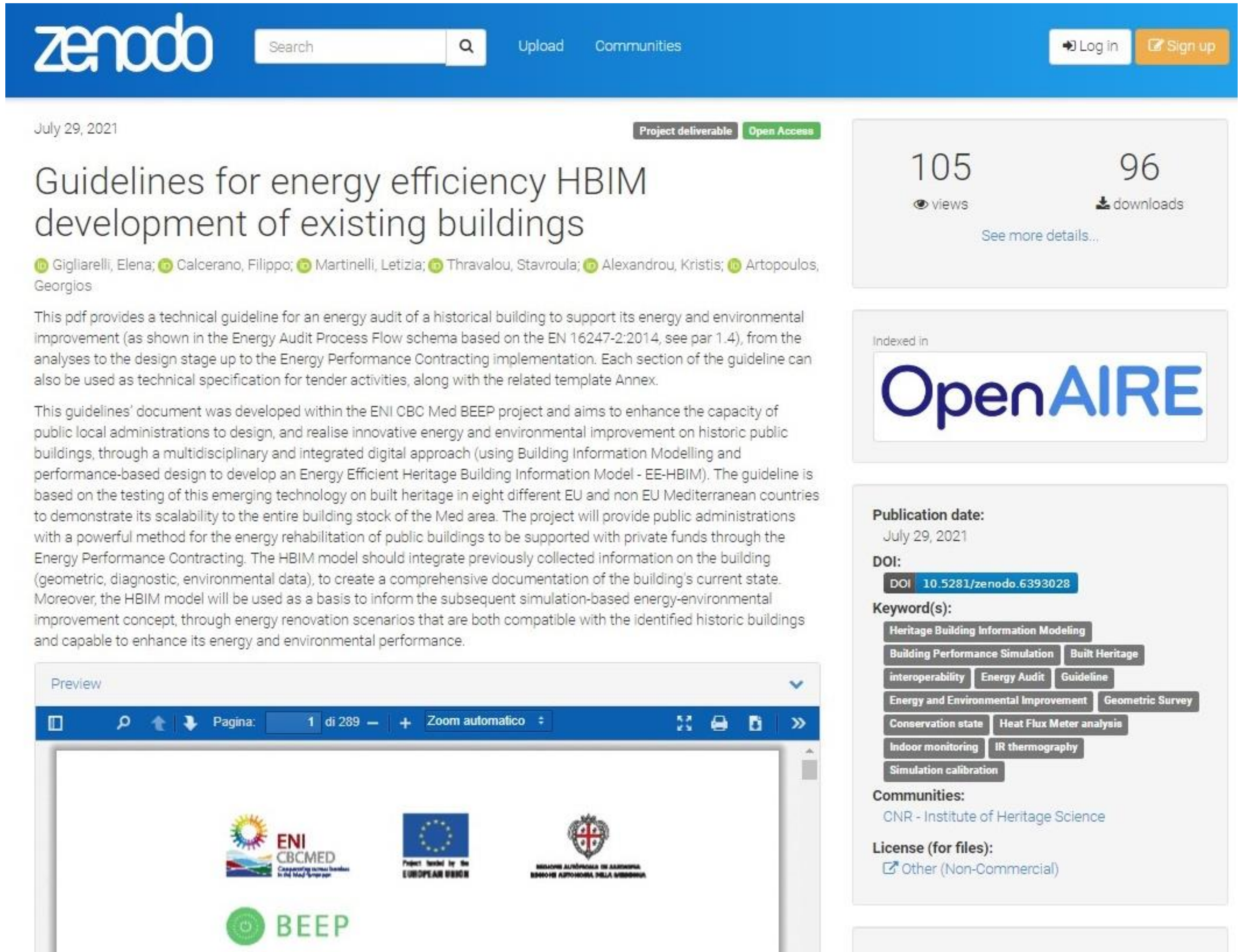




Parameters	Existing building	Short Term	Middle Term	Long Term
Total Energy consumption [kWh/annual] (analysed services)	446.434	139.812	84.544	57.629
Energy consumption percentage reduction	/	69%	81%	87%

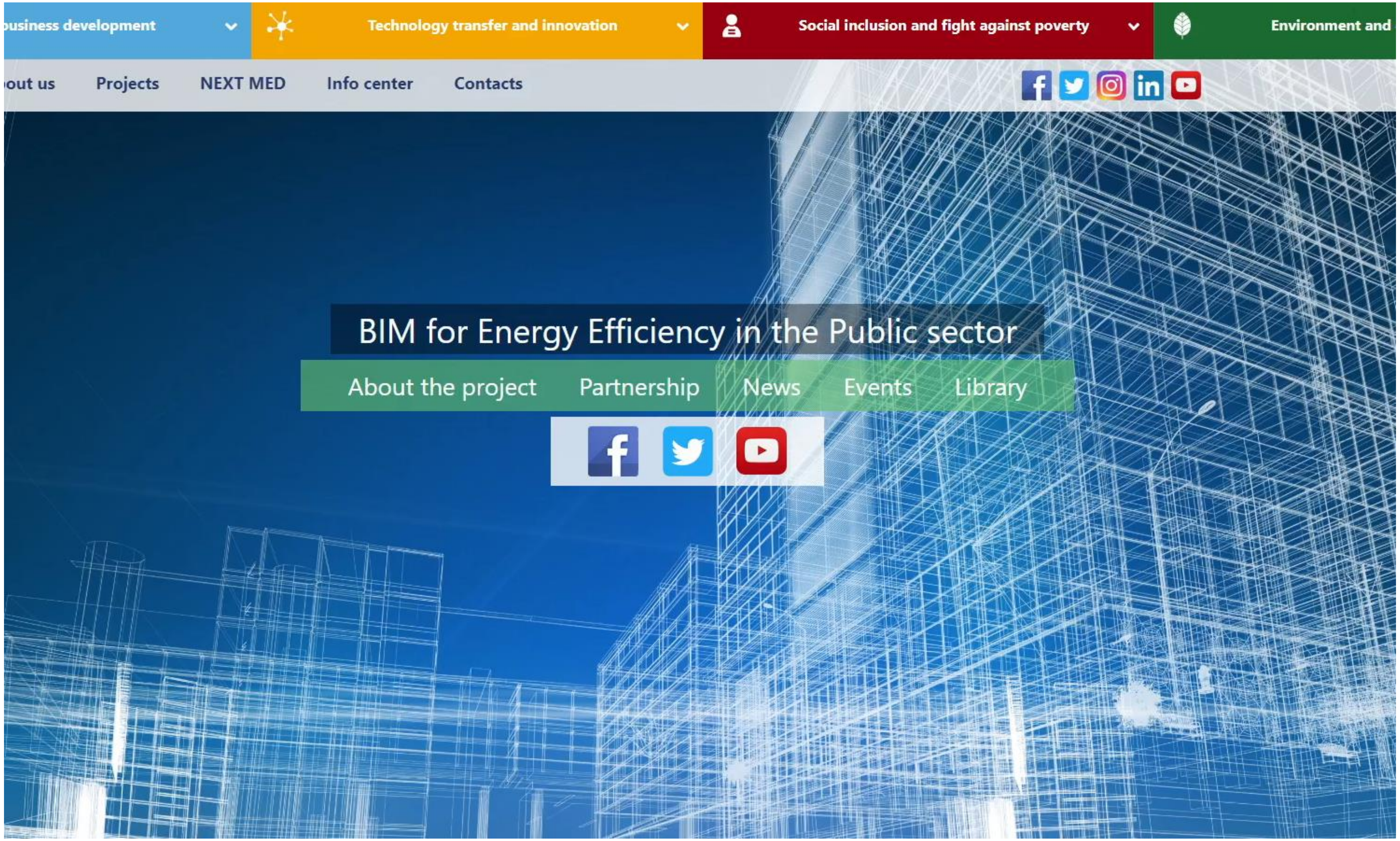
The guideline

A guideline to apply the workflow was published in Zenodo, an open-access repository by the European OpenAIRE program. It has been also published as a book with CNR Edizioni.



Main results

BEEP achieved the first BIM-based implementation of this kind in Jordan, Public administrations like the Valencian region and the municipality of Nicosia committed to use the workflow and in Lebanon BEEP had a major role in the release of the first regulation on energy efficiency in the country,



Global involvement

The project experts were involved in expert teams, defining BIM to BPS interoperability and HBIM processes at national and international levels with the buildingSmart and IBPSA involvement and, in the coming months ,with the International Energy Agency.

buildingSMART International

iea International Energy Agency

Information Delivery Manual (IDM) Development for Building Information Modelling (BIM) and Building Energy Modelling (BEM) Workflows

Also known as:

“Technical Report for BIM-BEM Workflows”

A technical report providing an overview of requirements for developing IDMs and corresponding data exchange specifications between building information modelling and building energy modelling, simulation, and analysis throughout a project lifecycle

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IEA EBC - Annex 91 - Open BIM for Energy Efficient Buildings

International Building Performance Simulation Association

EBC Energy in Building and Communities Programme

COP and climate action advocacy

And thanks to our results we were able to back up the advocacy on Built heritage as part of the solution to climate change at COP 27, 28 and at the recent Buildings and Climate Global Forum of paris as part of COP28 follow up

culture @ COP27

COP28 UAE

Thanks for your attention!

Filippo Calcerano
CNR Institute of Heritage Science

filippo.calcerano@cnr.it