



# Un patrimoine pour l'avenir, une science pour le patrimoine

Heritage for the Future, Science for Heritage

**Une aventure européenne  
de la recherche et de l'innovation**

A European Adventure for Research and Innovation

**Colloque / Symposium**

15 - 16 Mars 2022 / March 15 - 16, 2022

**Louvre / Bibliothèque nationale de France / PARIS**

Un événement organisé dans le cadre  
de la présidence française du Conseil de l'Union européenne\*

# A Methodology for Built Heritage Energy and Environmental Improvement : the BEEP Project

Elena GIGLIARELLI<sup>1</sup>, Filippo CALCERANO<sup>2</sup>, Letizia MARTINELLI<sup>3</sup>, Luciano CESSARI<sup>4</sup>

<sup>1</sup>Researcher, Institute of Heritage Science of the National Research Council of Italy (ISPC-CNR), Italy

<sup>2</sup>Researcher, ISPC-CNR, Italy

<sup>3</sup>Research fellow, ISPC-CNR, Italy

<sup>4</sup>Research associate, ISPC-CNR, Italy

## Résumé

Le projet BEEP propose une Modélisation des Informations du Bâtiment (BIM) appliquée au patrimoine, ainsi qu'une méthode basée sur la simulation pour renforcer l'analyse et la conception d'interventions d'amélioration sur les bâtiments historiques publics. Après avoir mis en place une méthodologie, un mode d'emploi a été développé de la phase d'analyse à la conception des interventions, en passant par la phase de « performance énergétique contractée » afin de soutenir sa mise en œuvre.

**Mots-clés:** énergie du patrimoine bâti, amélioration environnementale, modélisation de l'information, simulation du rendement du bâti, mode d'emploi

**Keywords:** built heritage energy, environmental improvement, information modeling, building performance simulation, guideline

Despite the European Union being an early mover on the climate change adaptation and mitigation policies, and having strongly committed to the energy efficiency regarding the construction sector<sup>1</sup>, coordinated action on built heritage is still lacking<sup>2</sup>. Conservation and environmental design have always had many methodological aspects in common, from the transgenerational timeframe to the need to deal with strongly interdisciplinary, holistic and multidisciplinary approaches and to move into a space of uncertainty on the border between hard sciences and humanities<sup>3</sup>.

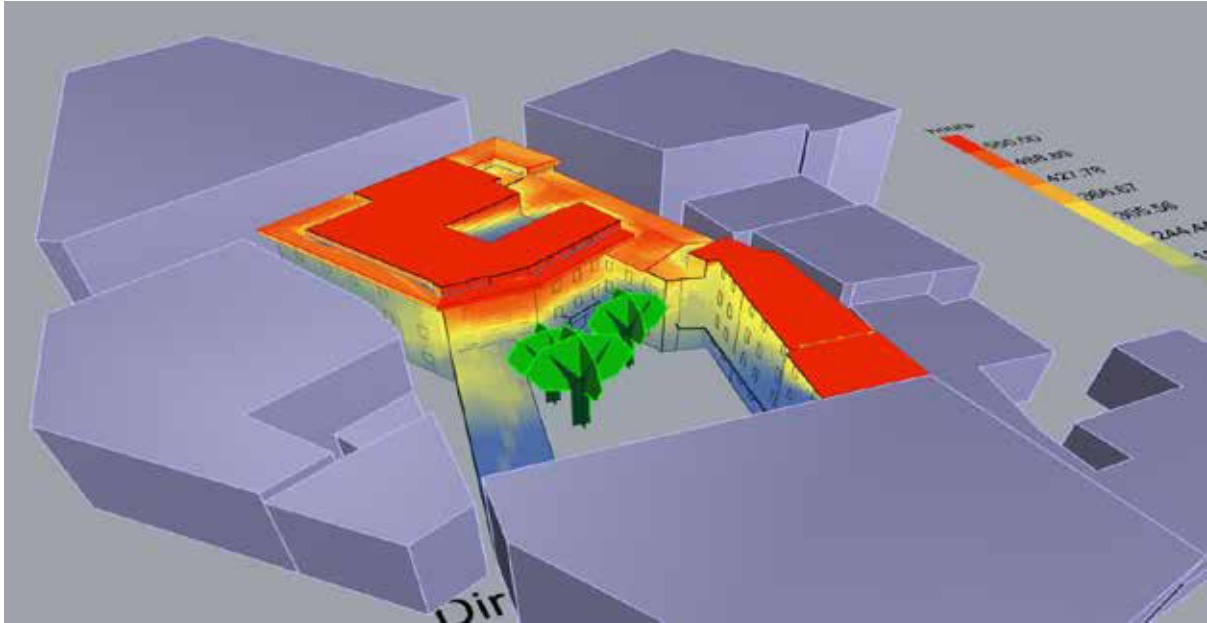
The international scientific debate, animated by research projects such as Sustainable Energy Communities in Historic Urban Areas (SECHURBA), 3ENCULT and the International Energy Agency Solar Heating and Cooling Programme (IEA SHC) task 59<sup>4,5,6</sup> favouring the concept of environmental energy improvement of historic buildings over regulatory compliance (in line with a similar process faced by the built heritage scientific community in the structural field)<sup>7</sup>. Under the *momentum* of the European Green Deal<sup>8</sup>, the cultural heritage stakeholders, led by Europa Nostra, have developed the European Cultural Heritage Green Paper, where heritage is finally framed in its dimension as a key resource and driver for the fight against climate change<sup>9</sup>.

Within this framework, the ENI CBC Med Cross-Border Cooperation initiative is supporting cost-effective and innovative energy rehabilitations relevant to building types and climatic zones, with a focus on public buildings. Under this programme, the BEEP Project 'BIM for Energy Efficiency in the Public sector' is developing an advanced but still a pragmatic methodology to foster built heritage energy and environmental improvement within a joint multidisciplinary framework. BEEP proposes a Heritage Building Information Modelling (HBIM) approach to streamline a centralised, updated and consistent information system capable to support the whole process, from the building analysis (that involves historical and architectural analyses, geometric surveys - both traditional or advanced -, general conservation state evaluation and energy and environmental analyses), to the design of the interventions through a simulation-based approach. The final process regards the

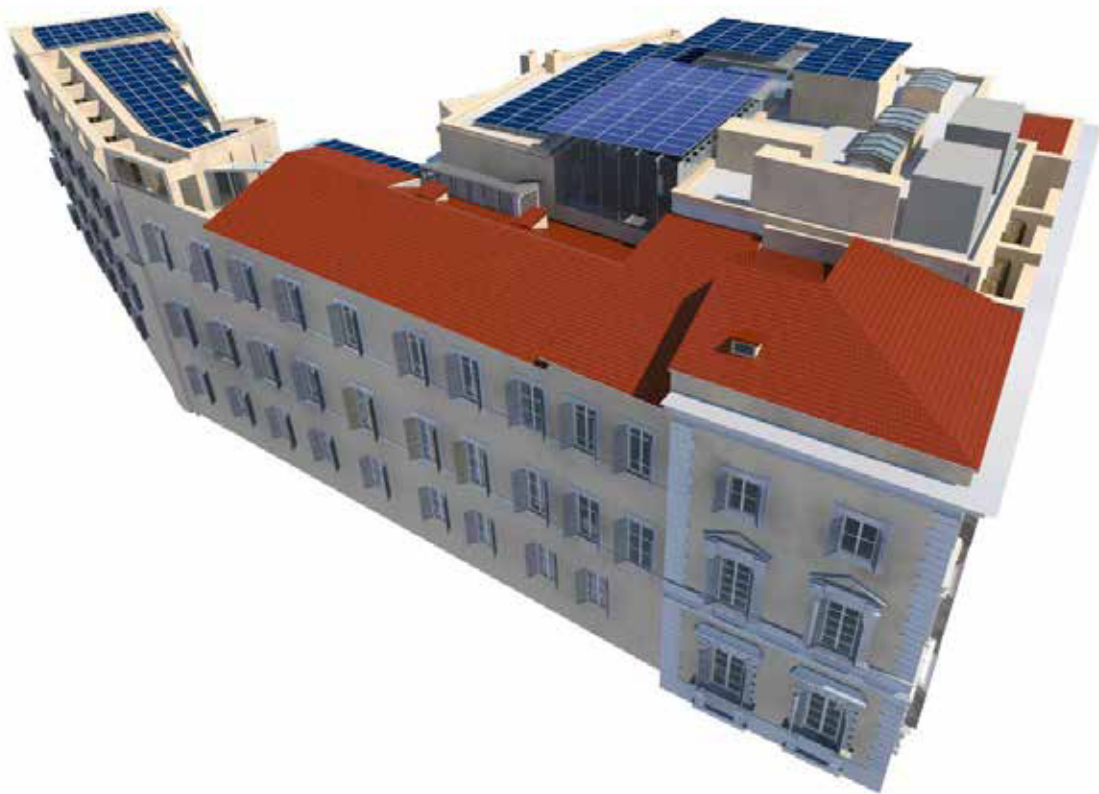
development of the Energy Performance Contracting (EPC), a financing mechanism used to support this kind of intervention reducing the financial barriers of built heritage owners.

Thanks to a clear definition of model use and a data mapping of analysis input, the methodology organises the results to feed into a Common Data Environment (CDE), which is a central repository where the HBIM and the Building Performance Simulation (BPS) models are the focal points. To this end, BEEP also addressed a 'BIM to BP' interoperability workflow (a process still in the early stages of development), proposing best modelling practices for different combinations of software chosen by the consortium. BEEP promotes the use of dynamic BPS as one of the most efficient non-destructive tools to understand and analyse complex phenomena and provide feedback on the energy, environmental and conservation implication of the intervention strategies<sup>10</sup>.

For the simulation phase, the methodology requires a calibrated *ante-operam* energy model, based on the data available on the building (energy bills, indoor monitoring, tailored weather data). The whole analysis phase, integrated with *ante-operam* simulation results, informs the development of design solutions, that are also evaluated with *post-operam* simulations. The other criteria for designing the different solutions are the compatibility with the guiding principles of restoration, the technical and constructive compatibility with the existing structure and the environmental and economic sustainability. At the end of the process, design solutions and evaluations are incorporated into the CDE to support the development of Energy Performance Contracts, that can be based on a shared or guaranteed saving model.



**Figure 1.** Palazzo Maffei Borghese, Rome. Numerical simulation of the sunshine hours during the winter months, performed for an optimised planning of the positioning of the measurements point of the heat flux meter analysis. A combination of Rhino software with Grasshopper and Ladybug environmental analysis plugin were used. © ISPC CNR | BHiLab



**Figure 2.** Palazzo Maffei Borghese, Rome. Render view of some of the energy efficiency improvement: photovoltaic panel system on the roof, the bioclimatic buffer space and the replacement of window shadings. © ISPC CNR | BHiLab

BEEP process was translated into a guideline<sup>11</sup> to provide support to AEC experts and stakeholders as a mean to foster the use of advanced technology capable to enhance transparency and reduce uncertainties in the construction sector. The guideline supports the stakeholder through the analyses and design steps in progressive levels of detail, according to the data available on the building, its complexity and the resources available. The workflow was tested and contextualized in nine case studies in Italy, Spain, Cyprus, Lebanon, Egypt, Palestine and Jordan.

The paper presented the framework and methodology proposed by the BEEP project on energy and environmental improvement of public-owned built heritage. The case study application proved the workflow flexible and sound to be scaled to a wide range of public historic buildings, and in different national contexts where either the availability of advanced analysis workflows, professional skills and market maturity of design solutions are lacking. BEEP guideline capitalisation can help fill the methodological gap when applying advanced digital workflows to complex historic buildings.

## Acknowledgments

BEEP project is funded by the EU under the ENI CBC Med Programme, Grant Contract A\_B.4.3\_0033.

---

<sup>1</sup> EBPD 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency Pub. L. No. 32018L0844, OJ L 156 (2018).

<sup>2</sup> MAZZARELLA, Livio, 'Energy Retrofit of Historic and Existing Buildings. The Legislative and Regulatory Point of View.' *Energy and Buildings*, Special Issue: Historic, historical and existing buildings: designing the retrofit. An overview from energy performances to indoor air quality, 95 (May 15, 2015): p23–31.

<sup>3</sup> GIGLIARELLI, Elena, CALCERANO, Filippo, CESSARI, Luciano, 'Heritage Bim, Numerical Simulation and Decision Support Systems: An Integrated Approach for Historical Buildings Retrofit.' *Energy Procedia*, Climamed 2017 Matera, Italy, 133 (October 1, 2017): p135–44.

<sup>4</sup> GIGLIARELLI, Elena, CALCERANO, Filippo, CESSARI, Luciano, 'Analytic Hierarchy Process. A Multi-Criteria Decision Support Approach for the Improvement of the Energy Efficiency of Built Heritage.' In *3rd International Conference on Energy Efficiency in Historic Buildings 2018, EEHB2018* Edited by Tor Broström, Lisa Nilsen and Susanna Carlsten. Visby, Sweden, September 26-28, 2018: Uppsala University, Department of Art History, 2018.

- <sup>5</sup>. TROI, Alexandra, BASTIAN, Zeno, *Energy Efficiency Solutions for Historic Buildings. A Handbook*. Berlin, Boston: Birkhäuser.
- <sup>6</sup>. AKKURT, Gülden Gökçen, ASTE, Niccolò, BORDERON, J., BUDA, Alessia, CALZOLARI, Marta, CHUNG, Daniel, COSTANZO, Vincenzo, et al. 'Dynamic Thermal and Hygrometric Simulation of Historical Buildings: Critical Factors and Possible Solutions.' *Renewable and Sustainable Energy Reviews* 118 (February 1, 2020): 109509.
- <sup>7</sup>. CARBONARA, Giovanni, 'Energy Efficiency as a Protection Tool.' *Energy and Buildings*, Special Issue: Historic, historical and existing buildings: designing the retrofit. An overview from energy performances to indoor air quality, 95 (May 15, 2015): p9–12.
- <sup>8</sup>. EUROPEAN COMMISSION. 'Investing in a Climate-Neutral and Circular Economy. The European Green Deal,' 2020.
- <sup>9</sup>. POTTS, Andrew, 'European Cultural Heritage Green Paper.' Europa Nostra, The Hague & Brussels, March 2021.
- <sup>10</sup>. GIGLIARELLI, Elena, CALCERANO, Filippo, D'UFFIZI, Francesca, DI BICCARI, Carla, MANGIALARDI, Giovanna, and CAMPARI, Massimo, 'From Heritage BIM to BPS, a Computational Design-Based Interoperability Approach.' In *Building Simulation 2019*, Rome. Rome, 2019.
- <sup>11</sup>. GIGLIARELLI, Elena, CALCERANO, Filippo, MARTINELLI, Letizia, THRAVALOU, Stavroula, ALEXANDROU Kristis, ARTOPOULOS Georgios, 2021. 'Guidelines for EE-HBIM Development of Existing Buildings.' <https://doi.org/10.5281/zenodo.6393028>