Doctoral Dissertation
Doctoral Program in Energy Engineering (37th Cycle)

Implementation of Standard Calculation Models for the Assessment of Technical Building Systems and of the Whole Building Energy Performance

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Summary

Over the past decades, growing awareness of climate change and energy poverty has significantly increased the importance of the energy and environmental performance of buildings, both in Europe and worldwide. The building sector improvement, due to its major contribution to energy consumption and greenhouse gas emissions, became a key focus for the transition toward a more sustainable and carbon-free society. Efforts to improve the energy and environmental performance of buildings generally follow two main paths. The first one concerns the technological enhancement of building construction materials and HVAC equipment. The second, equally important, involves the improvement of the methods for designing, modelling, and assessing the performance of the building's envelope and technical building systems.

Focusing on the latter, the European Union introduced several directives, such as the Energy Performance of Buildings Directive (EPBD), to promote advancement in the field.

Despite noticeable developments, a substantial mismatch between the state of the art of the procedures to assess the energy performance of buildings, and the data and skills of the professionals is still present. On one side, the most updated procedures are extremely accurate, but require complex data and high-level skills to be applied. On the other side, the reality of market practices still reflects limited data availability – due to a lack of product information and on field measurements – and, in many cases, a lack of proficiency in advanced simulation tools among designers and certifiers.

To bridge this gap, many national regulations, including those in Italy, mandate the use of simplified procedures for the assessment of building energy performance. These methods are often based on outdated procedures and are unable to match the evolution of the technologies and system interaction. While being simple, their oversimplification can lead to significant inaccuracies, potentially compromising design decisions, policy compliance, and financial assessments.

Since it may not be possible to deploy the more advanced and detailed procedures, and several simplified procedures are not providing enough accuracy or robustness, a change is needed.

The goal of this thesis is to improve their predictive capabilities without sacrificing their usability, thus ensuring a broader, more reliable application in everyday engineering and certification contexts.

Given the breadth of the topic, this research focuses on a specific yet critical area: technical building systems, with particular emphasis on HVAC systems that use water as the primary heat transfer fluid. These systems are widely deployed across Europe and represent a substantial share of energy use in both residential and non-residential buildings.

The work begins with an analysis of current simplified and detailed procedures for the assessment of technical building system (TBS) energy performance. Their methodological structures, input requirements, and theoretical assumptions are critically examined to highlight both strengths and weaknesses.

A comparative evaluation was then performed to assess the accuracy of simplified procedures compared to detailed simulation models. The study focused on widely used technologies such as boilers, chillers, thermal energy storage tanks, and zone heat emitters. Multiple case studies were analysed, varying in terms of geometry, building envelope, climatic zone, building use, and installed systems. For each case, different procedures were applied, and the results were compared based on energy use, performance parameters, and temperature profiles. The results showed significant differences between the methods, with noticeable variations depending on the applied procedure.

The single-component analysis was followed by a study of the application of various advanced simplified methods for assessing the whole building energy performance. At first, the results of an office building, located in Italy, were presented, with a comparison between the procedures that are mandatory by law and the ones currently available in Europe.

A cost-optimal procedure currently implemented in Italy was then outlined. Based on the cost-optimal solution of a case study, advanced methods were applied to the HVAC systems. Though the annual results showed negligible differences, the single contribution of the systems highlighted noticeable variations. These differences, however, were hidden by counterbalancing effects. Finally, a brief focus was put on energy performance certificates, highlighting possible procedural improvements.