A Digital Twin solution for optimal energy retrofit decision-making and decarbonization of buildings

PhD-student: Andreas Hyrup Andersen, anhy@mmmi.sdu.dk
Principal supervisor: Muhyiddine Jradi

Background

Decarbonization of the building sector is critical for achieving the European Union's goal of climate neutrality in 2050, as the building stock currently accounts for about 36% of total greenhouse gas emissions in EU. An estimated 97% of buildings in Europe are not energy efficient and the current weighted annual energy-renovation rate is just 1%. Projected scenarios show that achieving the net-zero emission goal will require the annual renovation rate to increase to 3% with a larger share of 'deep' renovations [2]. Increased effort and innovation within building energy retrofitting is essential for facilitating efficient upscaling of building renovation and recent Danish, European and International initiatives and strategies are calling for a wide-scale implementation of building energy retrofitting projects for enhancing the energy performance of the existing building stock and thereby reducing carbon emissions. The increasing interest for the evaluation and assessment of buildings energy retrofit is also visible in the scientific literature, where the number of published papers on the topic has grown steadily over the last decades [3].

Implementation of digital twin technology in building energy retrofitting is a recent innovative proposal with large potential. While the digital twins are newcomers in building energy modeling, their potential for aiding in building energy retrofitting is widely recognized [4].

Objectives

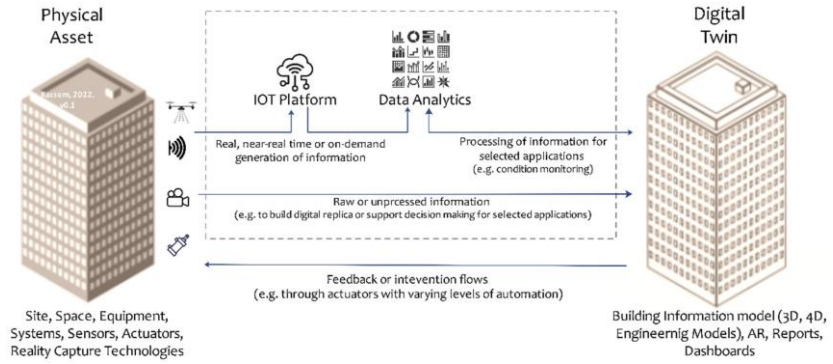
The overall goal of the PhD-project is to investigate, design, develop and demonstrate a digital twin solution for energy retrofitting applications of existing buildings. This goal will be attained through the following objectives:

1. Identification of data-driven energy modelling methods and approaches to support digital twin-based building energy retrofitting with focus towards scalable and automated approaches.

2. Design and development of building energy retrofitting methodology for digital twin solutions for retrofitting applications.

3. Develop a digital twin solution combining both data inputs from the building as well as flexible and scalable models delivering multiple services including retrofit measures assessment, operational management, and performance optimization.

4. Implementation of building energy retrofitting methodology in case studies to demonstrate the functionality and asses the performance for energy retrofit decision-making.



Essential components for creation of a building digital twin [1].

Methodology

First, relevant energy modelling methods will be identified though study of state-of-the-art methodologies within the field and knowledge sharing with colleagues, project partners and experts. The state-of-the-art study will include a literature report, which will be created as part of the PhD courses. Extra focus will be devoted to methods which can be implemented in scalable modelling approaches, especially grey-box methods which rely on limited building documentation.
Then, a methodology will be developed, with the aim to design an innovative yet feasible and implementable approach, inspired by learnings from the method identification process including consideration of current research gaps and challenges. The aim is to create a methodology which is useful for scalable modelling approaches and addresses shortcomings of alternative methods. The methodology design must allow for implementation in relevant projects and real case study buildings.
The methodology for a digital twin design will be used then to develop the data-driven modelling platform which will serve as a basis for multiple services, majorly retrofitting optimization and operational management. The development will be completed in cooperation with industrial project partners on various building case studies. The validity and performance of the developed methodology will thus be tested and demonstrated for real life applications with case study buildings which are planned for energy retrofitting in the next years. Additionally, specific inhouse case studies will be conducted for comparison between different methods as part of the methodology development and demonstration.

[1] Muhammad Shahzad, Muhammad Shafiq, Dean Douglas, and Mohamad Kassem. Digital twins in built environments: An investigation of the characteristics, applications, and challenges. Buildings, 12:120, 01 2022.
[2] Buildings Performance Institute Europe. A guidebook to European buildings efficiency: key regulatory and policy developments. https://www.bpie.eu/wp-content/uploads/2022/02/rev6_SPIPA_EU.pdf. 2022.
[3] Chiara D'alpaos and Paolo Bragolusi. Buildings energy retrofit valuation approaches: State of the art and future perspectives. Valori e Valutazioni, 07 2018.
[4] The Institution of Engineering and Technology. Digital Twins for the built environment. https://www.theiet.org/media/8762/digital-twins-for-the-built-environment.pdf. Accessed 26.09.2022.