

Popular science summary of the PhD thesis

PhD student	Esben Visby Fjerbæk
Title of the PhD thesis	Semantics-Driven Digital Twins for Physics-Based HVAC Performance Optimization
PhD school/Department	DTU Construct

Science summary

Buildings account for approximately one-third of global energy consumption. While massive efforts are being made to reduce energy consumption, energy waste still occurs across the entire building stock. Much of this energy waste can be attributed to suboptimal control of heating, ventilation, and air-conditioning (HVAC) systems, which alone account for approximately 12% of global energy consumption.

In modern buildings with highly varying loads, tuning HVAC controls is complicated as the process must factor in multiple, opposing objectives. To address these issues, the concept of digital twins has recently gained broad attention in research and industry as a tool for monitoring and optimizing building operation. However, creating digital twins requires substantial manual work to gather and connect data from multiple, fragmented sources.

This thesis presents a digital twin generation framework built around a data platform that organizes data from building information models and building management systems into *semantic models*, utilizing existing, standardized modeling schemas for the representation of HVAC systems and buildings. The platform is tied to a set of tools that generate and calibrate digital twin simulation models in the Modelica modeling language.

The digital twin generation framework was utilized in three use cases to showcase applications for full-system simulation, airflow estimation, and model calibration. Additionally, a fourth use case used the digital twin data platform as the foundation for an algorithm that optimizes the supply air temperature in a multi-zone ventilation system. The algorithm was tested on a case building and showed energy reductions of approximately 50% and thermal comfort improvements of approximately 40%.

The presented work outlines a pathway to a unified framework that enables building operators to achieve the absolute performance potential of their systems through optimization of HVAC controls with minimal manual effort. By bridging the gap between fragmented data sources and executable physics-based simulations, this research provides a scalable foundation for digital twin implementation. Ultimately, this approach ensures that buildings not only perform as designed but can be periodically optimized to meet the evolving needs of modern facilities.

Please submit the summary to the department PhD coordinator together with your thesis