ENERGETICS

AMMIN/EURAC - Building Envelope Continuous Commissioning for reducing Energy and Comfort Performance Gap

Funded By	EURAC RESEARCH [P.iva/CF:01659400210] Politecnico di TORINO [P.iva/CF:00518460019]

Supervisor	FAVOINO FABIO - fabio.favoino@polito.it

Contact	Giuseppe De Michele

Context of the research activity	Buildings are expected to guarantee high levels of energy performance, indoor environmental quality, and resilience over their entire lifecycle. However, ensuring that buildings operate as designed remains a major challenge, particularly in the context of climate change, increasing system complexity, and the growing diffusion of advanced technologies. In this scenario, the gap between predicted and actual performance—the so-called performance gap—is still widely documented and represents a critical issue for both energy efficiency and occupant comfort. Continuous Commissioning (CCx) or On-going Commissioning (OCx) has emerged as a promising approach to address this gap, enabling the ongoing monitoring, diagnosis, and optimization of building performance during operation. While this approach is increasingly applied to HVAC systems, its application to advanced and dynamic building envelope systems remains largely underexplored. These type of envelope systems, which are more and more adopted mainly in tertiary buildings, are characterized by dynamic and adaptive behaviour, integrating technologies such as responsive shading systems, electrochromic glazing, phase change materials, and decentralized ventilation and energy production systems. These systems actively mediate between outdoor and indoor environments, controlling heat, light, and mass transfer in response to changing boundary conditions. While such complexity offers unprecedented opportunities for energy savings and comfort improvement, it also introduces significant challenges in terms of performance assessment, monitoring, control in real operating conditions, and durability over the building service life. The proposed research aims to move beyond current monitoring-based approaches. It will do this by integrating short-term experimental commissioning, adaptive Digital Twin calibration, and long-term operational performance assessment within a unified framework for Building Envelopes. Such an approach could enable scalable and cost-effective continuous commissioning strategies, reducing the dependency on extensive long-term sensing infrastructures while maintaining reliable performance assessment capabilities.

Objectives	The main objective of this PhD research is to develop an integrated and scalable framework for the continuous commissioning of Adaptive Building Envelopes, enabling reliable performance assessment of thermo-energetic aspects and their impact on building operations, fault detection, and operational optimization under real-world conditions. This overarching objective will be pursued through the following specific goals: (i) Development of scalable monitoring strategies for façade systems: To investigate and define measurement infrastructures based on the integration of IoT technologies, edge computing, digital twins and existing monitoring systems, addressing the trade-off between low-cost and high-accuracy sensors. The research will propose methodologies for optimized sensor placement and contribute to the standardization of sensor integration and installation within façade components, improving scalability and applicability in real buildings. Particular attention will be given to the development of robust on-site measurement methodologies for façade systems, including sensor selection, uncertainty analysis, monitoring duration, sampling strategies, and data reliability assessment under real operating conditions, considering both short term standard commissioning and long-term continuous commissioning scenarios. Indicative timeline: Months 1–18. (ii) Definition of robust and multi-dimensional KPIs for the characterisation of façades operations: To identify, develop, and validate a set of Key Performance Indicators capable of capturing the dynamic, multi-domain performance of Adaptive Building Envelopes. These KPIs will integrate energy, indoor environmental quality, and operational aspects, and will be specifically designed for continuous computation from monitoring data. Their definition will be guided by scientific literature, regulatory frameworks, and market needs, ensuring both relevance and applicability. The research will also investigate which KPIs and operational parameters can be reliably estimated through indirect measurements and Digital Twin approaches, including parameters such as solar gains and dynamic façade behaviour indicators. Indicative timeline: Months 6–18. (iii) Development of data processing methodologies for reliable performance assessment: To establish standardized procedures for data cleaning, filtering, handling of missing values, and temporal aggregation, with the aim of improving data quality and representativeness. The research will define criteria for selecting meaningful datasets and appropriate sampling strategies to capture the dynamic behaviour of façade systems. The proposed methodologies will support both short-term detailed monitoring campaigns for commissioning purposes and long-term operational monitoring strategies. Indicative timeline: Months 12–18. (iv) Development of hybrid modelling approaches for KPI estimation and interpretation: To design and validate models combining simplified physical approaches and data-driven techniques, capable of translating raw monitoring data into meaningful performance indicators. These models will be robust to incomplete and noisy data and will enable the estimation of KPIs from indirect measurements, as well as the comparison and correlation of different performance indicators. Particular focus will be given to the development of calibrated hybrid Digital Twin models capable of automatically adapting to monitored data and

	maintaining reliable KPI estimation even after the removal of short-term detailed monitoring systems. The research will investigate feedback-based calibration strategies, where limited long-term monitoring data are continuously used to assess model reliability, detect model drift, and trigger recalibration procedures when necessary. Indicative timeline: Months 12–30. (v) Implementation of a continuous commissioning framework for façade systems: To develop and demonstrate an operational framework integrating monitoring, data processing, modelling, and KPI evaluation, supporting applications such as real-time performance monitoring, fault detection and diagnosis, predictive maintenance, and operational optimization. The framework will provide actionable insights for building operators and designers, contributing to improved building performance and reduced performance gap. The framework will support continuous commissioning applications on existing buildings, enabling the evaluation of façade retrofit interventions and operational improvements through Measurement and Verification (M&V) methodologies, with reference to IPMVP approaches. Potential applications will include performance tracking, maintenance support, control optimization, and assessment of intervention effectiveness over time. Indicative timeline: Months 24–36. The proposed approach will be validated through a combination of laboratory experiments, allowing controlled testing and model validation, and at least one field applications on a real building, ensuring robustness and practical relevance under real operating conditions. By addressing the full chain from data acquisition to decision-making, this research goes beyond the current state of the art, which is typically fragmented across disciplines. The proposed framework will enable a holistic, data-driven, and operational approach to façade performance, supporting the transition towards more resilient, efficient, and adaptive building systems. In particular, the research aims to move beyond current monitoring-based approaches by integrating short-term experimental commissioning, adaptive Digital Twin calibration, and long-term operational performance assessment within a unified framework for Adaptive Building Envelopes. The PhD candidate shall carry out their research activities at Politecnico di Torino and at the premises of Eurac Research – Institute for Renewable Energy, as well as, where appropriate, at Italian and foreign research institutions. Throughout the duration of the PhD programme, the scholarship recipient shall, in principle and in accordance with the study plan and course requirements, spend such periods of time as may be necessary for the effective conduct of collaborative research activities at the premises of Eurac Research. Such periods may be non-consecutive. In any event, the activities carried out at Eurac Research shall be compatible with the educational and research activities to be undertaken at Politecnico di Torino in accordance with the training programme and the research project.

	The activity requires a solid background in building physics with a particular focus on building envelope properties, performance, and impact on indoor environment. It is required a basic experience with experimental methods and measurements for characterising building envelope systems (i.e. thermal properties, U-value, g-value characterisation methods in lab and/or in-situ

Skills and competencies for the development of the activity	etc.), as well as programming skills for sensors and data acquisition systems. From the computational side, experience in Python, MATLAB, or equivalent scientific programming tools will be advantageous, especially if accompanied by familiarity with data-post processing. Building Performance Simulation skills are also advantageous, particularly with BPS SW such as Energy Plus (or similar) and/or Radiance, or their interfaces. The candidate should demonstrate ability to define test matrices, assess the consistency and reliability of measurements, compare simulation outputs with experimental observables, and translate multi-source datasets into model parameters and validation metrics.