Politecnico di Torino

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ENERGETICS

AI-based Energy Information Systems in buildings

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Context of the research activity	The research deals with the development of novel and advanced Energy Information Systems (EIS) solutions based on AI frameworks, with a particular focus on predictive energy management and anomaly/fault detection and diagnosis applications leveraging ontology schema for their deployment in commercial and industrial buildings. The research aims to address the main barriers to the definition of AI-based EIS tools to be automatically deployed, fully exploited by human users and easily transferable.
	The building sector accounts for about 40% of total final energy use and harbors enormous potential to save energy and reduce emissions in a cost-effective way. In this context, the building energy management represents a fundamental task for effectively enhancing energy efficiency and reducing the mismatch between the actual and expected energy performance. A robust coupling of IoT sensors data, artificial intelligence (AI) and energy domain knowledge proved to be effective in achieving relevant energy saving by exploiting a variety of advanced energy management solutions. EIS solutions such as energy consumption forecasting, anomaly detection and diagnosis (ADD), advanced energy benchmarking, load profiling, and schedule optimization of building energy systems proved to lead to systematic energy saving and to an average two-year simple payback period. However, the penetration of EIS in building sector is still not

Objectives	satisfactory due to (i) the difficulty to access in a systematic way specific information and data of building and its energy systems, (ii) the lack of interoperability of AI-based solutions, (iii) the low data quality, (iv) low user engagement. A key challenge is then to develop methodologies and interpretable tools that can exploit AI and building digitalization to optimise the daily decision-making process of building energy management. The research will focus on the development of novel and advanced EIS solutions based on AI frameworks, with a particular focus on predictive energy management, anomaly/fault detection and diagnosis applications leveraging ontology schema for their deployment in commercial and industrial buildings. The objectives of the proposal are aimed at bringing a significant development of knowledge in the areas of interest of the PNRR. In addition, the research proposal has a strong transversal approach between topics related to AI and those related to smart monitoring, energy management and building physics, in line with the trajectories defined in the SNSI and in the PNR to encourage the adoption of an open approach to innovation. In this perspective, the research activities aim to address the following issues that today represent the main barriers to the definition of AI-based EIS tools to be automatically deployed, fully exploited by human users and easily transferable among similar application cases. • Automatic setting of hyperparameter in AI-based EIS solutions: defining a search space range for hyperparameter identification of an AI-based process is not a trivial task. In addition, for processes, such as anomaly detection and diagnosis and predictive management in buildings that are strongly related to the physics of the considered system it is crucial to exploit domain knowledge to avoid inconsistent learning/knowledge extraction from data. • Cold-start of data-driven energy management solutions: an important issue in the deployment of AI-based EIS solutions is the so-called "cold-start problem" where the process may start with the not correct model and/or a sub-optimal configuration requiring considerable time to obtain robust results. To this purpose, the optimal configuration and the selection of models need to be supported also by the availability of an adequate amount of data and the definition of an effective re-training schema for avoiding the running of the analytics process with poor results. • Scalability and interoperability of AI-based energy management solutions: buildings are currently stand-alone entities from the point of view of data representation, with a mix of standardized and custom metadata schemas to describe equipment, measurement points and parameters within the building. Therefore, the development of advanced EIS exploiting data must be done with a bespoke solution, which is impractical and thwarts the scaling-up of existing analytics tools. Annotating data so that they can be re-used in a meaningful way, regardless to the building typology and location, is a task that can be achieved employing metadata schemes (e.g., ontology, semantic model) that can be effectively applied for applications in the energy and building field. • Handling streams of building-related data: selecting the most appropriate algorithm and tuning its hyper-parameters is a difficult task when dealing with on-line in-field applications. In this perspective, the definition of robust AI-

	based EIS tools should include the development of effective incremental learning strategies and tuning techniques to make energy management solutions suitable for evolving data streams. • Break the trade-off between analytical process complexity and interpretability: building professionals are typically suspicious towards the results of data-driven processes because they cannot always fully interpret the model inference mechanism. This represents a huge barrier that can compromise the level of user engagement respect to EIS solutions. In that perspective it is becoming more and more important to develop analytics tools capable of providing feedbacks about the reasons behind a certain AI framework outcome with robust indications of the supporting and conflicting evidence towards it by means of explainable artificial intelligence.

Skills and competencies for the development of the activity	• Data-driven building energy management; • Energy data analytics technologies; • Building physics and HVAC systems; • Physics-based and data-driven based modeling of digital twins for the built environment and building energy systems; • Programming skills (Python and R environment are considered preferential); • Knowledge of simulation environment for the assessment of predictive building energy management strategies.