AI Methods for Designing Energy-Efficient Buildings in Urban Environments

Sirine Taleb, Aram Yeretzian, Rabih A. Jabr, Hazem Hajj *
American University of Beirut, Beirut, Lebanon
{st60, ay10, rj30, hh63}@aub.edu.lb

Abstract

Designing energy-efficient buildings is an essential necessity since buildings are responsible for a significant proportion of energy consumption globally. This concern is even more critical in urban environments where it is harder to understand and model energy use. Recently, Artificial Intelligence (AI) and Machine Learning (ML) have been explored for improving the energy consumption in buildings. However, the advances in AI and ML have not been fully exploited in the building design process. This paper aims to highlight the gap between the advancements in AI and its applications for energy-efficient buildings in urban environments. The article discusses opportunities in this direction and suggests future research to have buildings adapt to the ever-changing situations.

1 Introduction

Population growth is causing further urbanization in the world which requires a growing energy demand. Urban building energy use is remarkable and it is one of the causes of global warming [1]. Buildings should have feasible design options to provide thermal comfort while mitigating energy use. In addition, incident solar radiation (insolation) is one important factor that is directly proportional to the need for space cooling demands; thus further increasing the energy demands [2]. Therefore, academic researchers and decision makers are studying the different factors that affect the energy efficiency of buildings. Recent advancement in the field of Artificial Intelligence (AI) is fueling further developments towards a more effective world. Yet, AI has not been fully exploited in the field of energy-efficient buildings and there is still room for important advancements. In this paper, we explore some of the research gaps that can be filled by exploiting the advancements in the field of AI. We aim to ask the following research questions:
RQ1: Why is using ML to forecast the energy consumption in buildings important?
RQ2: What AI advancements can make a difference in proposing more energy-efficient buildings?

2 Related Background

2.1 AI Advancements Used in Various Energy Fields

With the introduction of intelligent technologies that collect data about energy in various fields, several AI-based ensemble methods have been proposed [3]. In terms of Renewable Energy (RE), data is being used to match the supply with the demand. AI tools are used to forecast the energy supply of some RE sources for better adjustments [4]. For example, there are some methods that use hybrid forecasting model for wind power forecasting based on grey relational analysis [5]. In addition, artificial neural network (ANN) are currently investigated to model the conventional solar energy and assess the effect of significant pillars on energy intake [6].

*Maroun Semaan Faculty of Engineering and Architecture (MSFEA)

NeurIPS 2021 AI for Science Workshop.

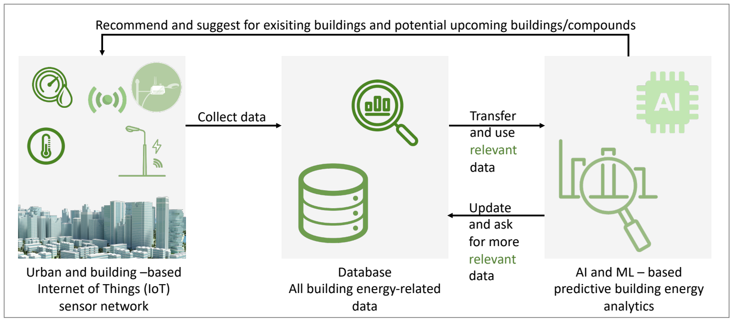

Figure 1: Predictive AI and ML-based techniques for energy-efficient buildings in urban environments.

2.2 The Use of ML to Predict Building Energy Consumption

Most recent works that use machine learning focus on deploying deep learning to develop energy management systems [7]. The amount of energy consumed in residential and commercial apartments is predicted using the family of ensemble approaches such as regression trees, random forests, bagging, boosting and stacking [8]. To model the energy spent on cooling/heating the building, the traditional way was to collect data from monthly utility bills to build regression models. However, although such models can give accurate estimation of the amount of consumed energy, they can rarely be used for optimization in order to obtain an energy-efficient building due to the fact that the main components of the building cannot be changed such as the orientation, the dimensions and the location of windows. Therefore, we aim to use ML to model the energy consumption at the early stages of designing the building in an urban environment. In our previous work, we developed a tool that can be used by architectural design teams to design energy-efficient buildings based on an optimization approach that minimizes insolation [2, 9].

3 Research Gaps and Opportunities

Machine Learning (ML) is a domain that is transforming many research fields and industries; yet, ML is still considered underdeveloped in energy predicting applications [10]. Specifically, using ML to develop more energy-efficient buildings can improve people's productivity in their living and working environments. There are several factors that affect the models used to assess the energy consumption of buildings such as temperature, humidity, window location, ventilation and other individual characteristics of the building. However, one very important but yet to be explored factor is the effect of other existing buildings on the energy model of the target building being studied. As shown in Figure 1, the overall flow of data and information is affected by the sensors that are placed in urban environments. More buildings are using built-in sensors to monitor the temperature, light, humidity, and motion to minimize energy consumption [11].

In addition, when designing any building or facility in urban environment, there are several factors that have to be used in predicting the energy performance such as the shadowing from surrounding buildings. This inter-sectional effect between the energy models of several buildings in an urban environment has a huge room of improvement in the whole process starting from the intelligent construction of the sensor network and the software tools used to receive data to the last step of predicting energy consumption and/or designing the building. Future directions include proposing energy models for buildings and integrating with other urban models that consider thermal comfort of occupants indoors and outdoors. Other sample ML-based problems include predicting the occupancy, proposing smarter lightning strategy, predicting changes in wind patterns to increase stability of wind turbines, predict the sun movement and its effect on shadows casted by surrounding urban built environment.

4 Conclusion

In this short paper in the attention track, we contribute by revealing the research gaps that exist between the field of AI and the goal of having energy-efficient buildings especially in the urban environments. As part of our future work, we will continue to use AI to propose energy-efficient urban environments and further explore the effects of AI on insolation and thermal comfort of occupants in the buildings and the urban surroundings.

References

[1] Ascione, F., Bianco, N., De Masi, R. F., Mauro, G. M. & Vanoli, G. P. (2017). Resilience of robust cost-optimal energy retrofit of buildings to global warming: A multi-stage, multi-objective approach. *Energy and Buildings*, **153**, 150-167.

[2] Taleb, S., Yeretzian, A., Jabr, R. A. & Hajj, H. (2020). Optimization of building form to reduce incident solar radiation. *Journal of Building Engineering*, **28**, 101025.

[3] Wang, Z., Wang, Y. & Srinivasan, R. S. (2018). A novel ensemble learning approach to support building energy use prediction. *Energy and Buildings*, **159**, 109-122.

[4] Ahmad, T., Zhang, H. & Yan, B. (2020). A review on renewable energy and electricity requirement forecasting models for smart grid and buildings. *Sustainable Cities and Society*, **55**, 102052.

[5] Hao, Y. & Tian, C. (2019). A novel two-stage forecasting model based on error factor and ensemble method for multi-step wind power forecasting. *Applied energy*, **238**, 368-383.

[6] Pazikadin, A. R., Rifai, D., Ali, K., Malik, M. Z., Abdalla, A. N. & Faraj, M. A. (2020). Solar irradiance measurement instrumentation and power solar generation forecasting based on Artificial Neural Networks (ANN): A review of five years research trend. *Science of The Total Environment*, **715**, 136848.

[7] Huang, X., Zhang, D. & Zhang, X. (2021) Energy management of intelligent building based on deep reinforced learning. *Alexandria Engineering Journal*, **60**(1):1509–1517.

[8] Sun, Y., Haghighat, F. & Fung, B. C. (2020). A review of the-state-of-the-art in data-driven approaches for building energy prediction. *Energy and Buildings*, **221**, 110022.

[9] Taleb, S., Yeretzian, A., Jabr, R. A. & Hajj, H. (2020). Energy Optimization of Climate Adapted Buildings in an Urban Context: The Case of Subtropical Climate. *35th PLEA Conference: Planning Post Carbon Cities*, 1-3 September 2020 A Coruña, Spain.

[10] Spangher, L., Gokul, A., Palakapilly, J., Agwan, U., Khattar, M., Ma, W. J. & Spanos, C. (2020). OfficeLearn: An OpenAI Gym Environment for Reinforcement Learning on Occupant-Level Building's Energy Demand Response. In *Tackling Climate Change with Artificial Intelligence Workshop at NeurIPS*.

[11] Mehmood, M. U., Chun, D., Han, H., Jeon, G. & Chen, K. (2019). A review of the applications of artificial intelligence and big data to buildings for energy-efficiency and a comfortable indoor living environment. *Energy and Buildings*, **202**, 109383.