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Energy planning and forecasting approaches for supporting physical improvement strategies in the building sector: A review

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ABSTRACT

The strict CO_2 emission targets set to tackle the global climate change associated with greenhouse gas emission exerts so much pressure on our cities which contribute up to 75% of the global carbon dioxide emission level, with buildings being the largest contributor [1]. Premised on this fact, urban planners are required to implement proactive energy planning strategies not only to meet these targets but also ensure that future cities development is performed in a way that promotes energy-efficiency. This article gives an overview of the state-of-art of energy planning and forecasting approaches for aiding physical improvement strategies in the building sector. Unlike previous reviews, which have addressed mainly the strengths as well as weaknesses of some of the approaches while referring to some relevant examples from the literature, this article focuses on critically analysing more approaches namely; 2D GIS and 3DGIS (CityGML) based energy prediction approaches, based on their frequent intervention scale, applicability in the building life cycle, and conventional prediction process. This will be followed by unravelling the gaps and issues pertaining to the reviewed approaches. Finally, based on the identified problems, future research prospects are recommended.

Contents

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1. Introduction

Statistics have shown that the building sector consumes approximately 40% of the world's energy resources and emits around 1/3 of greenhouse gas emissions [1]. From this premise, implementing effective and proactive strategies at this sector is indispensable for achieving the imposed CO_2 emission reduction targets [2]. However, since buildings' energy consumption depends on many interwoven factors including weather conditions, users' behaviour, and buildings' characteristics, urban energy planners require useful tools that assist their urban energy planning decision-making with regards;

- Identifying potential areas that necessitate improvement.
- Choosing the right and most effective strategy (retrofit, technology upgrade, reconstruction, demolition, raise users' awareness, etc.…) based on each scenario.
- Determining the degree of change in energy consumption after certain measures have been applied.

For these reasons, a lot of effort has been made in recent years to develop energy prediction approaches to support physical improvement strategies in the building sector. Each approach does not only address specific problem(s) but also has its frequent intervention scale (micro or macro).

and a particular applicability in the building lifecycle [3]. This has been a subject of great interest to many scholars from various backgrounds who made invaluable effort reviewing and comparing these approaches. For example [3], discussed energy prediction models used in the residential sector within two distinct categories namely; top-down (techno-socioeconomic) and bottom-up (physical). This classification was influenced by the type of envisaged measures (techno-socioeconomic or physical), the level of detail(s) and hierarchical position of data inputs in reference to the whole residential sector. On the other hand [2], classified different energy prediction models into three main categories namely; physical, statistical, and hybrid. Furthermore, they addressed them based on their characteristics, strengths, and limitations while providing some examples on each model. [4] proposed three categories to energy prediction approaches supporting physical improvements in the building sector namely; engineering, statistical, artificial intelligence (neural networks, support vector machine), and grey models. Besides evaluating the strengths and weaknesses of each category, their level of complexity, user interaction friendliness, inputs' level of detail, computation speed, and accuracy were also addressed. [5], however, reviewed and compare in detail previous classifications of these approaches, as shown in (Table 1), while focusing particularly on calibrated engineering methods. However, despite the vital contribution of the above authors, there is no review that has explicitly addressed these methods based on their frequent intervention scale, nor investigated certain prominent approaches which are utilised at the urban scale such as, 2D GIS and 3D GIS (CityGML) based energy planning forecasting methods.

This paper aims to provide a comprehensive review of the current state-of- the- art of energy planning and forecasting approaches for aiding physical improvements strategies in the building sector. Please note that top-down approaches for supporting techno-socioeconomic improvements are outside the scope of this paper; please refer to the work of Swan and Ugursal [3].

We suggest to classify the reviewed approaches based on their intervention scale into building and urban scale approaches as shown in (Fig. 1.), although sometimes there are no clear boundaries as some approaches can be applied at both levels. Influenced by the proposed classification, the content of this review has been organised into 4 sections.

First, Section 2 addresses approaches utilised at the building scale namely; engineering, artificial intelligence, and hybrid but

Table 1
Classification of different energy predictions approaches in previous reviews.

Authors	Classification

[3]	• Top Down models
	• Bottom up models:
	  • Statistical (regression, Conditional demand analysis, neural networks)
	  • Engineering methods

[4]	• Engineering methods
	• Statistical methods
	• Artificial intelligence
	  • Support vector machine
	  • Artificial neural network
	• Grey models (hybrid models)

[2]	• Physical models • Statistical methods (regression, artificial neural networks, support vector machine) • Hybrid models
[6]	• Statistical approaches/regression analyses • Energy simulation programs • Intelligent computer systems (Artificial intelligence)

[5]	• Engineering methods
	  • Calibrated
	  • Forward(non-calibrated)
	• Statistical approaches
	  • Artificial neural networks
	  • Support vector machine
	  • Regression
	• Hybrid approaches