Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 143 (2017) 289–294

Energy Procedia

www.elsevier.com/locate/procedia

World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference, WES-CUE 2017, 19–21 July 2017, Singapore

Development of an Innovative Energy Modelling Framework for Design and Operation of Building Clusters in the Tropics

Catherine Conaghan[a]*, Darren Jordan[a], Ruggiero Guida[a], Rohan Rawte[a], Don McLean[a], Majid Sapar[b]

[a] *IES, 30, Cecil Street, #19-08, Prudential Tower, Singapore 049712*
[b] *Building and Construction Authority, 200 Braddell Road, Singapore 579700*

Abstract

Efficient building design, and management of this through to the building's operation is critical as sub-optimal performance becomes difficult to detect and assess once in the operational stage. Building energy modelling can facilitate this through identifying operational drift away from the optimal building performance. However existing energy modelling tools fail to meet many of the needs to manage this process, due to the excessive complexity of modelling frameworks. Furthermore, models are not typically integrated with operational information from buildings to facilitate and maintain building performance in the operational stage. The aim of this project is to demonstrate an innovative energy modelling framework for clusters of buildings to improve their design, operation, compliance, data management and analytics. This case study considers new and existing buildings within the BCA Academy Campus in Singapore over three phases to compare and determine the potential for optimal building performance across the campus. Phase 1 creates a 3D masterplanning model used to store, visualise and compare key building parameters to enable advanced design and compliance planning. In Phase 2, more detailed building energy models are created for two proposed new campus buildings, which are used to simulate and analyse the impact of various design options, and guide optimal building design in line with BCA requirements. Phase 3 focuses on creating a highly calibrated detailed model of an existing building, where measured data is used to improve the level of accuracy between the model and the actual performance to with-in +/-5%. This allows for accurate simulation to assess and further improve the buildings performance virtually, ahead of making actual changes in the building.

Peer-review under responsibility of the scientific committee of the World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference.

* Corresponding author. Tel.: +44 141 945 8500; fax: NA
E-mail address: catherine.conaghan@iesve.com

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference.
10.1016/j.egypro.2017.12.686

Keywords: building energy modelling, modelling framework, IESVE, BCA, 3D modelling, masterplanning, model calibration, tropics

1. Introduction

There is increasing evidence regarding the mismatch between the optimal and actual energy performance of buildings as they transition from the design stage through to the operational stage, even in energy-efficient buildings [1]. This issue is becoming increasingly observed as buildings and cities integrate 'Smart' Technologies providing building owners with a higher level of data and transparency with respect to the performance of their buildings. It has been estimated between 25%-45% of energy consumed by HVAC systems in commercial buildings is wasted due to faults alone [2]. In tropical climates such as Singapore, where Air Conditioning is the typically the primary consumer of energy in buildings (up to 50% of consumption [3]), sub-optimal or faulty operation of these systems can have a significant impact in terms energy consumption and user comfort. Other causes of performance away from intended optimal design include inaccurate initial design assumptions, occupancy behavior influence and facility management [4]. In short, the absence of on-going monitoring and analysis can permit the continued sub-optimal performance of operational buildings, typically resulting in additional energy consumption, cost and/or poor user comfort.

Building Energy Modelling (BEM) is extensively used to assess building performance at the design stage (often for code compliance or voluntary environmental rating systems) as it offers an in-depth and accurate representation of the building parameter's dynamic interactions and resulting energetic performance. However, BEM can also play an important role in the building's operational stage in addressing the performance gap described. Creation of BEMs representative of the buildings actual operating conditions can be useful in identifying sub-optimal performance, system faults and can better determine the implications of proposed energy conservation measures (ECMs) and retrofit options to the building in terms of consumption, cost and comfort.

Despite these benefits, studies have shown that non-expert modellers rarely complete accurate, quality energy models for existing buildings during the operational stage due to (i) a lack of consistent standardized frameworks, (ii) the expense and time needed to obtain the required operational data and (iii) the lack of integrated tools and automated methods to assist in the modelling and analysis [5]. A collaborative project undertaken by IES and the BCA focused on demonstrating and assessing an innovate energy modelling framework which employs appropriate levels of models for different levels of analysis, from clusters of buildings down to individual building level with the aim of identifying performance issues and improving building(s) design, operation, compliance, data management and analytics. The project was based on the BCAA (Building and Construction Authority Academy) Campus, Singapore and was carried out in 3 Phases introduced below, with the different level of models as defined for the analysis discussed in the following sections described in Table 1.

- **Phase 1 Masterplanning at Community Level** which involved the development of a 3D masterplanning model for the BCAA campus to model, store, visualise and compare a range of key building parameters enabling collaborative analysis and management of building data for clusters of buildings (Level 1 models)
- **Phase 2 New Building Design Performance Evaluation** which focuses on the BEM and simulated analysis to optimise the design of two new buildings planned for the BCAA campus (Level 2 and 3 models)
- **Phase 3 Integration with BMS and CI2 Analysis** where a calibrated BEM was developed for one campus building achieve the next level of improving energy efficiency in existing 3-storey ZEB (Level 4 models)

Table 1. Model Levels description

Model Level	Description	~No. of Model Inputs
Level 1	Shell of the building represented as a single zone with simplified HVAC inputs	~25
Level 2	Level 1 + Number of floors added to model and defined as separate zones	~25-40
Level 3	Level 2 + each room added to model and defined as separate zones	>100
Level 4	Level 3 + sub-zones to account for HVAC system type and lighting control measures	>150