UNIVERSITI TEKNOLOGI MARA

DEVELOPMENT OF COMPREHENSIVE M&V SOFTWARE FOR IMPROVED WHOLE FACILITY ENERGY SAVING WITH RISK ASSESSMENT

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ABSTRACT

In Malaysia, buildings consumed 14.3% of total energy demand, 48% of electricity use and correspondingly are also responsible for carbon emission. Since, Energy Conservative Measure (ECM) have been adopted as a key element in reducing energy use and carbon emission. However, the Measurement and Verification (M&V) of the savings from the ECMs are still new practice particularly in Malaysia. Besides, it did not consider risk assessment in its evaluation. Imprecise savings determination due to incomplete M&V evaluation and uncertain factors may lead practitioners in making inappropriate investment risk decisions. Furthermore, there is lack of commercial M&V software equipped with risk assessment available to assist practitioners in performing M&V activities. This research presents two comprehensive and user-friendly M&V software, i.e. Module 1 and Module 2. Module 1 is established to perform the M&V activities aligned with International Performance Measurement and Verification Protocol (IPMVP). Module 2 is developed to provide comprehensive framework by computing and evaluating the impact of ECMs on the building in terms of energy saving, cost saving, payback period and financial indicator, i.e. NPV and IRR. Module 2 used Monte Carlo Simulation (MCS) as computation engine. Within the developed software, regression technique is adopted in its methodology. From the developed M&V software, regression technique revealed that more than one parameter are actually affecting energy use in building. It can be validates based on highest value of 0.87 for R^2 and lowest value of 0.0161 for *CV-RMSE*. Further analysis showed that energy savings for each case are deemed to be statistically valid since it is larger than twice standard error of the baseline value. From the findings, Module 2 only have a small percentage error compared to Module 1. The percentage error in energy savings for case1, case 2 and case 3 is 0.052%, 0.183% and 0.388% respectively. At the 95% confidence level, Module 2 provides a wider investment possibility and a narrower precision interval, hence better accuracy. It is considered that the developed M&V software can provide a comprehensive M&V activity equipped with broaden savings and investment risk framework to the practitioners.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Energy is one of the most essential elements for a modern life and plays a vital role in the development of economy, infrastructure and urbanisation for a country. The rapid growth in these sectors has boosted energy demand in Malaysia. In 2014, total energy demand in Malaysia has increased by 63.1% from 1994 to 52,209 ktoe shared by various sectors, namely transportation 46.6%, industry 25.2%, commercial and residential 14.3%, non-energy use 11.9% and agriculture 2.0% [1]. Malaysia's energy demand are deemed to grow up until 2030 [2]–[6]. Therefore, sustainability, energy security and climate change are the real challenges to Malaysian government.

According to [7][8], the existing building accounts approximately 40% of the global total energy demand and 30% of global greenhouse gas (GHG) emission. In Malaysia for instance, commercial and residential building consumed about 14.3% of total energy demand and 48% of electricity usage [9][10]. The air conditioning and ventilation system utilised up to 58% of total electricity usage in the building, followed by 20% of lighting, 19% of office equipment and 3% of others [11][12]. One of the solutions to reduce the energy comsumptions and GHG emissions is by implementing energy efficiency (EE) measures in the building.

The previous studies have reported an impressive amount of 75% of energy and 35% of GHG emissions could be saved by simply applying building retrofit [13]–[16]. Thus, implementation of building retrofit offers significant opportunities for lessening energy consumptions and GHG emissions. Despite its ability in handling these issues, retrofit seems suffers from several major drawbacks. One of the major drawbacks is the discrepancy between actual and predicted savings in reporting the savings. It is often uncertain due to the changes in weather conditions, in-site equipment, building operation schedule and other factors affecting the energy use. The imprecise savings determination with the uncertain factors may lead to the inappropriate investment decisions for building retrofit. Consequently, the investors, and building owners refused to implement and invest in the retrofitting project.