Building Energy Management Applications

Implementation of a Building Energy Management System, including Technical Audit and Measurement and Verification planning

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Abstract

Global warming and energy supply security are two of the most urgent issues that are being addressed in the European Union. The building sector has a substantial share in both energy usage and CO_2 emissions. The residential and tertiary sector accounts for approximately 40% of the total final energy consumption in the EU. In this thesis, the partial results of the evaluation of a cloud-based Building Energy Management System under development are shown. First, a technical audit was done in the building. After some insight to the implementation, the energy savings were determined with the measurement and verification process of International Performance Measurement and Verification Protocol. Then, the energy consumption forecasting feature of the system was evaluated. Finally, a business plan was created for the future distribution of this product. The objective of the thesis was to introduce and evaluate the Building Energy Management System and finally, to develop a business model for the commercialization of the system. First, it was found, that the system reached considerable energy savings in the summer in a pilot project in Barcelona. Second, the energy forecasting feature of the system has errors on an hourly basis; which is acceptable from a product under development. Third, a business plan is drawn up for the growing market of Building Energy Management Systems.

Key-words: energy, management, efficiency, measurement and verification, Building Energy Management System, BEMS

1 Introduction

Global warming and energy supply security are two of the most urgent issues that are being addressed in the European Union. Understanding the possible future consequences of these issues, the Member States of the EU set the 2020 targets; Reaching 20% lower CO_2 emissions compared to the 1990 level, increasing energy efficiency by 20% and increasing the share of renewable energy sources (RES) in the energy mix by 20% [1]. The building sector has a big share in both energy usage and CO_2 emissions. Around one third of the energy consumption of the building sector is for the European non-residential buildings [2]. In order to address these issues, the European Institute of Technology is investing in KIC InnoEnergy to foster sustainability in the energy sector. KIC InnoEnergy is financing the Building Energy Efficiency Management & Smart Grid Integration Tools (BEEST) project, which is developing a new cloud-based Building Energy Management System. This system is practically a suite of apps that work as a layer on the existing Building Management System of the buildings. Two of these apps, START-UP PRODUCT 2 and START-UP PRODUCT 1 are evaluated in this paper.

2 Methodology

The paper is following the main steps of the practical implementation process of an Energy Conservation Measure in a building then evaluates the results. The audit of the building, the implementation of the Energy Conservation Measure, the data collection before and after the implementation and the calculation of normalised savings are these steps. Besides the verification of savings due to the START-UP PRODUCT 2 app, the results of START-UP PRODUCT 1 app is also evaluated in four pilot buildings, namely ICAEN, Av. Roma, NH Waalwijk and De Lijn Gentbrugge. Finally it suggests a business plan for the distribution and selling of the START-UP products.

First of all, the pilot building is audited. The audit consists of practical and technical considerations as the pilot project is not expected to generate profits for START-UP or the building owner. In a real project, besides the technical feasibility, an economical feasibility study is also essential before the implementation of an Energy Conservation Measure. Then, all the meters' and sensors' data is directed to the cloud system of the Dexcell Energy Manager, data is collected and the START-UP apps are trained to create the energy model of the building.

Regression analysis is used to evaluate and to normalise energy consumption data before and after the implementation. Last years' energy consumption is used as the baseline period for the energy savings verification process that is following the practices of International Performance Measurement and Verification Protocol [3].

3 Results and discussion

The ICAEN building is the first pilot project for commissioning and testing START-UP PRODUCT 2, the app which provides automated control over the BMS. PRODUCT 2 is being commissioned and tested, while PRODUCT 1, the app that forecasts energy consumption on hourly resolution, is functioning.

The normalized energy savings method is a practical way to examine the energy consumption of a building in different periods and weather conditions. Due to the type of data and resources available, the Degree Days (DD) method is applied in the analysis. In the normalizing process the use of fine weather data, properly chosen base temperature and carefully handled energy data is required to have satisfying results.

It is visible on Figure 1 that in October and May of the baseline period there is no significant heating or cooling need. It is also visible that in the months of November and April there is a mix of cooling and heating. This phenomenon is due to the big difference in daily minimum and maximum temperatures [4]. As a consequence May, October, November and April are considered to be transitional months. In the regression analysis the regression equation is determined using June, July, August and September for the summer season, while the December, January, February and March for the heating season. However the regression equation is calculated in both seasons based on four months, the normalized energy savings for the transitional period are calculated assuming the same thermal behaviour.

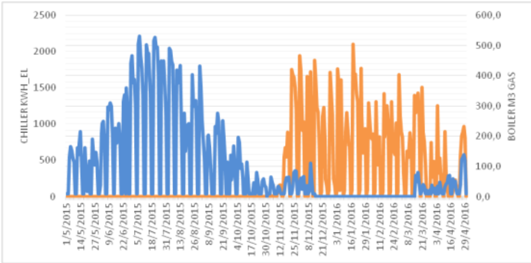

Figure 1 Energy consumption of heating and cooling in the baseline period

The Building Energy Management System is commissioned on May 2016 and the energy use data is evaluated after five month, in October 2016. This period, called reporting period, covers the intensive summer when it is possible to make partial conclusions about the energy savings potential of the system.

The BT is chosen for the building for the cooling season based on the historical energy consumption. Figure 2 shows the values of the Coefficient of Determination for different base temperatures in summer.

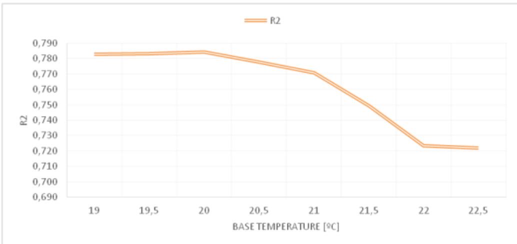

Figure 2 1R^2 values for different Base Temperatures

In summer, the regression analysis is calculated for the Cooling Degree Days (CDD) and the electricity consumption. Only weekdays are taken into account in the regression analysis as the office is out of use on the weekends. To improve the accuracy of the energy model, all the official local and national holidays are removed from the dataset.

The linear regression in the summer period can be seen on Figure 3. The electricity use of the chillers and the CDDs are compared and the Coefficient of Determination with the regression equation is visible.

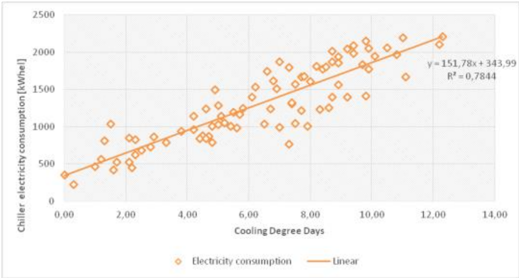

Figure 3 Linear regression analysis for CDD and electricity consumption

The result of the regression analysis is shown as Equation (1). This equation is used for normalising the baseline summer period.

$$y = 151.78x + 343.99 \qquad (1)$$
$$R^2 = 0.7844$$

After examining the winter data set, one can conclude that the relation between Heating Degree Days (HDDs) and heating energy consumption is not logical. In other words, the energy used according to the gas meter for heating is not correlated with the outside temperature. However the data set gives a positive slope, the regression analysis on daily basis provides the value of R^2=0.1 that is unacceptably low. On a monthly basis the slope of the regression is negative. As a result of the low quality data set, the savings of the Energy Conservation Measure cannot be calculated for winter with this approach.

3.1 Normalized energy consumption

Normalization is a process that makes the comparison of different years' data possible. Normalizing energy data to fixed conditions is necessary to calculate normalized energy savings. There are two ways of fixing conditions for calculating normalized savings; to use the conditions of the baseline period or use a period before the baseline. In order to increase the quality of the weather normalization, a longer period's average can be used. The normalisation is done with two years data pervious the baseline period.

The regression equation of the reporting period is determined using the same base temperature for the DD as in the baseline period. Equation (2) is the regression equation in the reporting period. It does not give the same R^2=0.78 value as the baseline period, only R^2=0.70, that increases the uncertainty in the calculations.

$$y = 151{,}5x + 301{,}03 \qquad (2)$$
$$R^2 = 0.7031$$

3.2 Savings

The results of the normalisation are translated into financial gains and CO_2 emissions to evaluate the environmental effect and pay-back time of the ECM.

Table 1 shows the normalised electricity consumption, CO_2 emissions and the energy costs in the Baseline period and the Reporting period in summer. Accordingly, the savings of the ECM of the summer period, considering only the energy used by the chillers is 877 €, which is equal to 5%.

Table 1 Chiller energy consumption

Period	Chiller	Emission	Cost
Baseline	127900 kWh	39 tCO2	19.326 €
Report	122098 kWh	37 tCO2	18.449 €
Saving	5802 kWh	2 tCO2	877 €

Table 2 shows an approximation of possible savings after the implementation of the Energy Conservation Measure. The same percentage of summer savings (5%) is assumed to be saved in the winter period

Table 2 Boiler energy consumption

	Natural gas	Emission	Cost
Baseline	306462 kWh	56 tCO2	12.136 €
Report	291139 kWh	53 tCO2	11.529 €
Saving	30646 kWh	6 tCO2	1.214 €

3.3 START-UP PRODUCT 1 results

The algorithm realized the energy consumption tendencies in the buildings. In the two office buildings, in ICAEN and AV. Roma, the weekly pattern is clearly visible. There is significant energy consumption on weekdays, while on weekends energy use is limited to some basic appliances like the security or telecommunication system. Besides the weekly pattern, the daily start-up times are also assumed properly by the algorithm.

The maximum energy needs forecasted are different in many days. The error of the forecasted values compared to the real values is 20.3% in Av. Roma and 30.4% in ICAEN on an hourly basis, while 13.3% and 11.9%

respectively on a daily basis. Considering the sum of these values for the month, the error is 5% in Av. Roma and 1.8% at the ICAEN building.

Besides the total electric energy consumption, the HVAC energy consumption is forecasted in the ICAEN building. The forecast of HVAC energy consumption is following the weekly trend; however the hourly energy forecast has an average error close to 400% and 42% to the daily values. Considering the error of the monthly energy use, it is 3.6%, which is a significantly lower value compared to the hourly and daily error.

Table 3 Errors in energy forecast of PRODUCT 1

	Av. Roma	ICAEN	Waalw.	Gentbr.
Hourly	20.3%	30.4%	-	-
Daily	13.3%	11.9%	-	-
Monthly	5%	1.8%	-	-

There is a lack of energy consumption data in De Lijn Gentbrugge from mid-September. The communication between the START-UP servers and the data logger does not work for several weeks. However, the data logger is being changed by the company responsible, the results cannot be evaluated.

In addition to De Lijn Gentbrugge, the results in NH Waalwijk cannot be evaluated either. Due to the failure of the data logger, the energy use data between the 2nd and the 15th of September is missing. The company responsible for maintenance restarted the electricity meter on the 15th of September. The START-UP PRODUCT 1 started forecasting on the 22nd September again. The summary of results are shown on Table 4.

3.4 Business plan

It is visible on Figure 4 that the sales are forecasted following the stages of product life cycle. The Partner is assumed to have 5 customers, based on the assumption of Comsa Service, the first potential Partner of START-UP. In 2017 more than 44000 € profit is expected. Then, until the fourth year a rapid increase in revenues are expected. This rapid increase in sales is due to the supposed growth stage in the product life cycle. It is clearly visible, that after 2021 the sales are slowing down, but still more than 300000 € profit is expected.

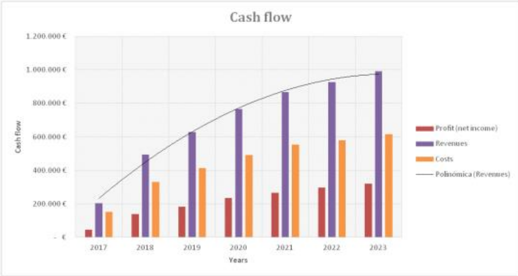

Figure 4 Cash flow of a Partner's sales of START-UP products

4 Conclusions

In this thesis, the energy savings reached and the results of the energy forecasts of a Building Energy Management System were evaluated. The energy savings were calculated into money and CO_2 savings, while the accuracy of the forecasted energy values was analyzed. The following conclusions were made:

The regression analysis only considers one independent variable, the ambient temperature and provides an R^2=0.78 and R^2=0.70 in the baseline and the reporting period respectively. According to the IPMVP the suggested minimum R^2 value is 0.75. It means that ambient temperature is not strictly correlated to the energy consumption in this building.

The calculated energy saving is 5% compared to the last year's energy consumption in the summer. This means 877 € and 2 tCO_2 savings. Assuming the same percent for the whole year, the energy saving is equal to 2090 € and 7 tCO_2. However the pay-back time is more than 20 years, it is not an aspect to take into account at this pilot project.

The energy forecasts provided by the software have an error on the total energy use of 30.4% and 20.3% on hourly basis, 11.9% and 13.3% on a daily basis and 1.8% and 5.0% on a monthly basis. This means, that the START-UP PRODUCT 1 app needs further testing and development to improve the outputs and to be a successful product.

The global market for BEMS was worth $3 472 million in 2014 and a 12% of growth is expected between 2015 and 2020. This means that the development of the product is reasonable and the potential market is present.

References

[1] European Commission, “EU-wide headline targets for economic growth,” 2015. [Online]. Available: http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/targets/index_en.htm#top. [Accessed 05 April 2016].

[2] Intelligent Energy Europe, “Energy Efficiency Trends and Policies in the Household and Tertiary Sectors, An Analysis Based on the ODYSSEE and MURE Databases,” European Union, Brussels, 2015.

[3] Efficiency Valuation Organization, “International Performance Measurement and Verification Protocol,” Efficiency Valuation Organization , Toronto, 2012.

[4] “Wunderground,” [Online]. Available: www.wunderground.com. [Accessed 3 October 2016].