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To cite this article: A Gonzalez-Caceres and T A Vik 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **609** 032065

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Improving the Energy Performance Certificate recommendations accuracy for residential building through simple measurements of key inputs

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Abstract. The Energy Performance Certificate (EPC) allows building users to be informed and aware of the quality of the buildings in terms of energy needs. Additionally, the EPC includes a future for existing buildings, which is the incorporation of a Recommendation list of Measures (RLMs) to improve their energy performance in a cost-effective way. This has risen the question if this tool can provide trustful cost-effective recommendations due despite the use of standardized inputs. This study focuses on estimating the impact of using measured ventilation rate, heating set point and airtightness on the profitability of the recommendations. The study is based on a common dwelling in Norway, comparing results obtained with a Building Performance Simulation Software, following the Norwegian standard for energy certification and with the use of measured ventilation rate, airtightness and real heating set points. The results show that the performance gap can be reduced significantly just by adopting these inputs, increasing the confidence on the RLMs and reducing the uncertainty of the investment.

1. Introduction

One of the most important commitment made by the European Commission is to reduce by 20% of the energy by 2020 compared to the projected consumption in that year. Considering that, 40% of the total energy consumption in the EU are due to Buildings [1]. Actions to reduce their energy contribution are of great importance. One of the main policies to engage this issue was the introduction of the Energy Performance Certificate (EPC) as an information source of energy performance for both policy makers and building owners. However many aspects around this tool have not been fully studied [2]. The EPC quality it is strongly influence by the accuracy of its results, therefore the assessment methodology including their standardised inputs are central to achieved quality information [3]. These become critical for existing buildings, which are the ones that most energy inefficient sector. Several studies carried out in EU have reported inferior energy savings than expected in retrofit projects as well differences between assumed indoor temperatures and actually used [4]. Despite that the gap between simulation and actual energy saved, the EPC calculation are not comparable with the actual performance due to the use of standardised conditions and a number of loads that are not included in energy performance calculations [4]. These might be appropriate for the purposes of comparing buildings energy performance. However, when it comes to set energy efficiency recommendations for renovation purposes, standardised procedure might not be adequate, since the estimation of the energy savings and the accuracy of the measures for the renovation it requires an analysis based on real energy consumption.

Extensive research have been done around EPC and homeowners, however little investigations have been conducted on to support certifiers work. Certifiers have a central role to play in ensuring the



credibility of the EPC scheme, most of the issues reported focus on the cost of the EPC, highlighting the tension between the speed and the cost of the certifier's services one of the main issues. The quality of the energy recommendations c on the fees of the certifiers works, meaning that the more detailed recommendations more expensive the EPC it will be [5]. One of the main aspects that can improve the accuracy of the saving estimation and increase the usability of the list of the recommendation measure, is to review the method of how certificates are developed. Improving both the tools for calculation and the procedure carried out by the certifier.

Several attempts have been done to simplified measurements techniques to assess the building energy performance and many of them can be uses for housing inspections. Airtightness is one of the most important aspect in energy savings, however the blower door test can take a long time and it is very expensive. In Norway a blower door test for a typical wood-frame house can cost up to 1250 Euro, which is higher than the price of an EPC [6]. Nevertheless in literature it can be seen several method to estimate the airtightness [13], but the one that suits the most the inspection needs, it is the one based on the characteristic leakages. Despite that this method could lead to large deviations, this will depended on the quality and number of measurements used for the estimation of each leakage [7]. The U-values of the envelope in existing buildings without documentations are very common, the best source of information in that case is the uses of the regulation code of the time. Despite that in many cases that might not exist, it still a risky guess. The uses of Infrared Thermographic Images (IRT) has been used for this purposes and it can provided quick, affordable and acceptable level of accuracy [8], as well it can be useful to collect additional information, such as the indoor temperature to determinate heating set point when no thermostat is available. This become more relevant in dwelling since having several indoor set point temperature for different rooms can be a common practice [9].

The aim of this study is to show that valuable data can be taking from field inspections, through simple measurements without increasing the price of EPC, since it will not extended the duration time of the inspection and not highly costly equipment are needed. This data can be used as inputs to improve the recommendation and accuracy of the certificate produced by the certifier.

2. Methodology

As with many existing buildings, technical information on housing is non-existent, the main source commonly accepted for labelling purposes is the use of the building code of the time when the house was built. To overcome the use of standardised input and to reduce the uncertainties that these involve in the results and the energy recommendations. It is proposed a set of simple measurements to be undertaken during the one-hour field inspection. To test the usability of the proposed field inspection measurements, the study was divided into three steps. First, accurate data of the building performance was obtained through a calibration technique using hourly electrical consumption from the smart meter, additionally a blower door test was performed. Secondly, the dwelling was inspected in two forms, as a certifier and as an energy auditor. The certification procedure consist in a walkthrough inspection checking the original drawing of the building, maintenance and heating systems of the dwelling. Meanwhile the energy auditor inspection it was complemented with measurements such as IRT and mechanical ventilation airflow, and tailor checklist to detected typical air leakages and heating set points. Lastly, the collected data from the certification and audit procedure were used to calculate the energy performance of the dwelling into two separated models and compared against the calibrated model, all the simulations were done in Design Builder.

2.1. Study case

A typical Norwegian dwelling was selected to issue an energy performance certificate. The dwellings corresponds to a wooden terraced dwelling located in Oslo. The building was built in 1994 and consists of three levels, a basement and two upper floors. The data gathered from the smart meter and a near weather station weather both in hourly bases and from 2018.

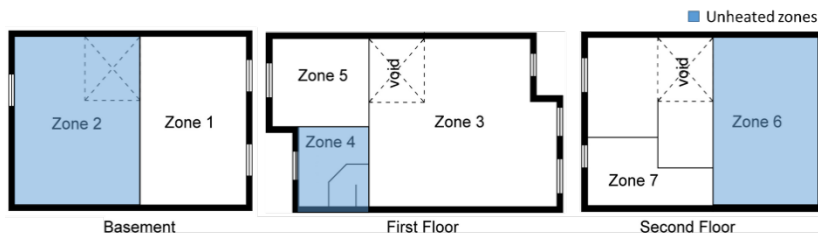


Figure 1. Floor plan of the dwelling.

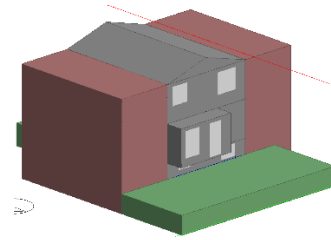


Figure 2. Simulation Model.

3. Results

The regular inspection of the house took 20 minutes. A checklist was used to confirm that all the items were covered. The measurements phase took 45 minutes, and most of the time was used to measure the airflow rate of the exhaust ventilation vent in each room with a Q-trak. The infrared thermal images were taken both inside and outside of the façades, and calibrated in-situ. An air leakage inspection checklist, where typical weak points were listed while inspecting the dwelling, was prepared before the inspection. The whole process took a little more than an hour, which is what one would expect from a certifier to spend on a dwelling. Each of these measurements and their subsequent use in the labelling are detailed below.

3.1. Calibration

In order to be able to assess the accuracy of the simple inspection measurements, a calibration process was performed to find the actual technical characteristic of the dwelling. For the purpose of minimizing computation time, a quick sensitivity analysis was performed. Ventilation airflow rate, airtightness, U-values and heating set points were found to be the most influential parameters regarding heating energy consumption. The calibrated model achieved a Root Mean Square Error variation of 0.36%. Figures 3 and 4 show the comparison between the smart meter data and the simulation. The resulting inputs can be seen in table 1.

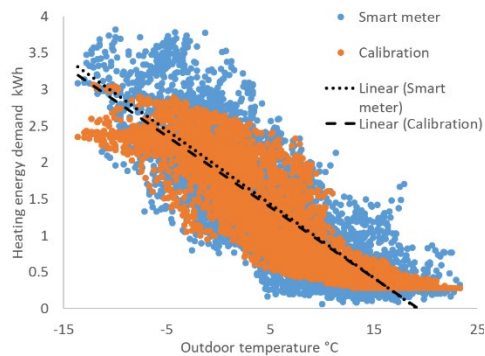


Figure 3. Scatter plot of hourly data during the heating season compared with the calibrated model.

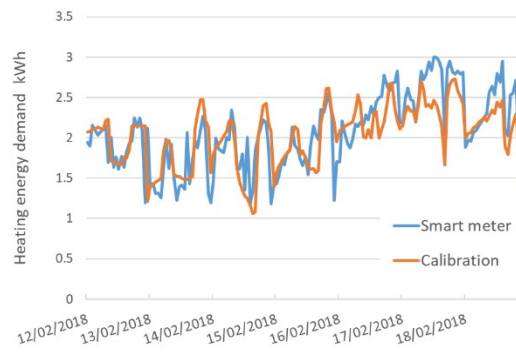


Figure 4. Hourly heating energy used during a week compared with the calibrated model.

Table 1. Input from the calibration.

U-value wall (W/m2K)	U-value floor (W/m2K)	U-value ceiling (W/m2K)	U value windows (W/m2K)	Airtightness (ACH)	Ventilation rate (m3/h)	Heating set point (°C)	Heating set back point (°C)
0.33	0.18	0.17	1.91	*6.1	75.2	19	16

*Value obtained from the blower door test

3.2. Measured ventilation airflow rate

The equipment used was the TSI 7575 Q-trak. The airflow rate was measured on each of the exhaust vents, except on the kitchen hood where the measurements were made in the duct. The result was used to update the building model, and can be seen in table 2.

Table 2. Ventilation air flow rate measurement.

	Kitchen	WC	Bathroom	Basement 1	Basement 2	Total
Airflow rate (m3/h)	36	18	15	18	5.2	92.2

3.3. U-value estimates

The IRT camera used was a FLIR E4. The purpose of using IRT images is to estimate the U-values for the wall by applying several formulas provided for this purpose. The camera was also useful to confirm the presence of air leakages and to room temperature. It is worth noticing that the house inspections was performed during winter, which it is the best conditions for IRT measurements. The results can be seen in table 3.

Table 3. Results from the U-values estimation using IRT.

Reference	Results	Formula	
[10]	$U = 0.46 \text{ W/m}^2\text{K}$	$U = \frac{4\varepsilon\sigma (T_s - T_{refl}) + h_c(T_s - T_{in})}{T_s - T_{out}}$	Eq. 1
[11]	$U = 0.43 \text{ W/m}^2\text{K}$	$U = \frac{\varepsilon_v\sigma (T_s^4 - T_{refl}^4) + 3.8054v(T_s - T_{out})}{T_{in} - T_{out}}$	Eq. 2
[12]	$U = 0.54 \text{ W/m}^2\text{K}$	$U = \frac{h_{out} (T_s - T_{out})}{T_{in} - T_{out}}$	Eq. 3

3.4. Air leakages detection

The checklist was prepared based on literature on typical air leakages in wooden residential buildings. The main characteristics listed were gaps between front/back door and floor, sealing around the window frames, sealing at the access door to the roof cavity, sealing of pipes or duct to the exterior, such as a wooden stove. The impact of the air leakages on the airtightness was based on tables gathered from literature. Only evident leakages were considered and the most conservative values for the airtightness were used. The total amount of leakages found was added to the maximum value accepted according to the construction code of the time. The results can be seen at table 4.

Table 4. Characteristics air leakages used for the Airtightness prediction [7, 13, 14].

Description	m3/h at 50Pa	Unit
Ventilation 100 mm	2.36	pcs
Unsealed electrical plumbing	0.93	pcs
Chimney with collar/flashing fastened with mastic	3.62	pcs
Door gap 3mm	0.405	pcs
Window frame	0.31	m

3.5. Comparison between results from standard values and from quick measurements

Three rounds of simulation were performed, in each round inputs from standard, field inspection and real values were evaluated. The first round consisted in simulation based on the minimum level of detail and a Single Zone (SZ), which is the most common procedure for labelling. In the second round, Multiple Zones (MZ) was applied to differentiate between heated and unheated zones, the zones can be seen in detail in figure 1. As figures 5 and 6 show, there are huge differences between the results of

these two simulation and even more when they are compared against the results from the calibrated model. However, the simulation with field inspection input have a better fit with the calibrated model, improving the accuracy around 33% for the SZ and 8.5% for the MZ in comparison with the standard model.

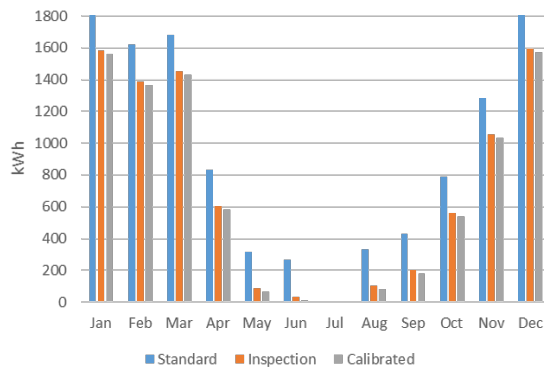


Figure 5. Single zone

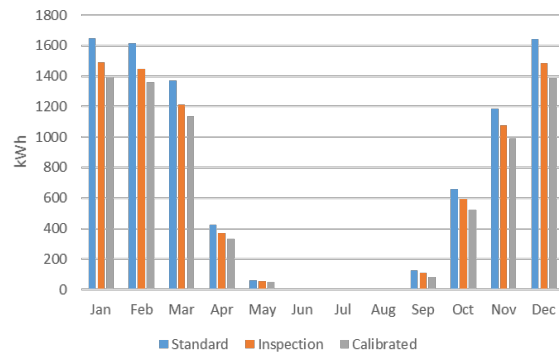


Figure 6. Multiple zones

The impact of each input in the simulation can be seen in table 5. As the result showed the ventilation rate has an impact of 33%, followed by 5% due to the wall U-value. It is worth noticing that heating set points shows a low impact. However that it is because the airtightness assumed in the simulation with standard input data is very low. By examining the hourly data it is noticed that the indoor temperature almost never reached the 16 degrees during night setback. Due to this, the impact of the night setback point is only reflected when the rest of the inputs from the inspection are used.

Table 5. Impact of using standardised inputs compared with simple measurement in the simulation.

Input	Standard	Inspection	Impact
U-Value wall (W/m ² K)	0.37	0.43	5.1%
Airtightness (ACH)	4	4,6	-6%
ventilation rate (m ³ /h)	199	98	33%
Heating set points (°C)	21-19	21-17	3%

4. Discussion and conclusion

The study case shows that simple measurements could significantly improve the accuracy of the simulation results for certification purposes, up to 32%. The relevance of these results is not on the labelling itself, but in the energy saving measures and their profitability estimation that are included in the EPC. Considering that standard inputs can be up to 50% higher than the calibrated inputs, unrealistic expectations of energy savings and profitability can be created if recommendations are based only on standardised calculations. The main conclusion of this work, is that double inputs should be used for the certification, one standardised for the labelling and a supplementary one to apply for the developing of energy saving measures. The incorporation of this method should not increase costs for the homeowner, as the necessary measurement equipment can be easily afforded by independent certifiers. However more research still needs to be done in order to have robust results. This is particularly the case for airtightness estimation, since this requires a large database to estimate the characteristic air leakage by each component more accurate. Also, the use of IRT to determinate the U-values should be further studied, since the methods applied did not provided enough precision. However, as in this case, they can be used to corroborate standardised U-values if an acceptable deviation is presented between the standardised and estimated U-values. As well, IRT can be used to register the heating set points in each room. The ventilation should be considered carefully in dwellings with mechanical ventilation, since infiltration and mechanical ventilation interact with each other.

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