Impact of the Representation of Interior Loads on the Calibration of an eQuest Energy Model for a Case Study

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Abstract

This paper explores two different approaches for the representation of hourly interior loads for the calibration of an eQuest energy analysis model. Approach A uses the profiles of internal gains from the ASHRAE 1093-RP. Approach B uses a simplified step-change profile calculated based on derived measured cooling load profile for each thermal zone. The results show that the model is calibrated for all zones in terms of indoor air temperature, regardless of what approach is used for defining the internal loads. In terms of air flow rate, the model is calibrated for nine zones out of fifteen by using the approach A and eleven zones by using the approach B, when statistical indices are used for comparison. Only five zones are considered calibrated using approach A and six zones using approach B, when the statistical hypothesis testing is employed.

1 Introduction

In the calibration of an energy analysis program for an existing building, it is considered that the representation of internal loads plays an important role but challenging because of limited information available to the modeller about the occupants' energy related loads (e.g., peak loads and schedules of operation for lights and office equipment).

There is a discrepancy between the assumed internal loads used for calibrated models and the real, random interior loads in buildings, which might cause discrepancies between the measured and predicted energy use. Presently, there is not a common accepted method for defining the internal loads' schedules in the calibration studies of building energy models.

This study compares the computer predictions, when using two methods of defining the internal loads, with measured values in the Centre for Structural and Functional Genomics of Concordia University. One method assumes one profile of internal gains for all zones, based on the findings of the ASHRAE RP-1093, while the second uses a simplified step-change profile based on the derived profiles of cooling load for each of the zones.

2 Related work

There have been many studies conducted on calibration of building energy models, but only few of them talk about how the internal loads have been estimated and even fewer present the methodology used for deriving those internal gains.

Heidell et al. (1985) calibrated a building model by comparison with measured data. They recognized the importance of having a good estimate for the internal loads in large buildings; they compared the measured annual energy consumption with the results of three simulations, using three estimates of internal loads: i) based on power densities calculated from counting the fixtures and equipment and schedules based on building's operators' knowledge; ii) based on same power densities, but with default schedules from the DOE 2.1 B library and iii) based upon empirical data. The best results were obtained when using internal loads based on measured data; the difference between the simulated heating energy use and measured data was reduced from 78% to 42%, but the difference between predicted and measured cooling energy increased from 2% to 15%.

Bronson et al. (1992) have developed four different day types that were input in the simulation software as schedules, in order to calibrate the DOE-2 program to non-weather dependent measured loads. The four day types are as follows: i) the default profiles from the DOE-2 library; ii) based on occupancy and electric load factor measurements; iii) based on two-week auditor's data and iv) based on a statistical day-typing routine developed by Katipamula et al. (1991). The use of the default profiles from the DOE-2 library under estimated the energy use during the unoccupied hours, resulting in an annual difference of 25.6%. The second day typing improved the monthly estimates, leading to a total difference of 0.1% between measured and predicted energy use. The third day typing resulted in an increase in the annual difference between measured and predicted total energy use from 0.1% to 3.4%. The fourth day typing provided the best results; the shape of the hourly estimates fits better the measured data, and the difference in annual energy use is 0.7%.

Haberl et al. (1998) specified that site visits are crucial for developing an energy model, in order to count the lighting fixtures and obtain occupancy information from the building operators.

Pan et al. (2007) calibrated a model of a hotel by adjust the lighting, plug loads and occupancy loads densities based on hourly measurements; there is no information about the schedules of internal loads. They do acknowledge that the randomness of the operating schedule of the internal loads cannot be reproduced fully and could cause big discrepancies between measurements and simulation results.

Raftery et al. (2009) have developed a methodology to calibrate a building energy model to monitored energy use, in which the adjustment of internal loads was based on measured data from the Energy Management System. A day-typing technique was tried, but due to positioning issues of the measuring devices, the data did not present a daily pattern. Instead, the actual measured values were input on an hourly basis. The occupancy schedules were derived from occupant surveys and interviews with building operator. The same technique is presented in a later study by Raftery et al. (2011).

Love et al. (2013) calibrated a school energy model using hourly monitored data. They have used short-term continuous measurements from micro-loggers to verify the building's operator's estimates of lighting use schedules, and spot observations and measurements for luminaires type, office equipment and occupants.

3 Methodology

This study compares the simulation results of two different approaches for the representation of hourly internal loads for the calibration of an eQuest energy analysis model of a case study building.

The estimates of the hourly indoor air temperature and supply air flow rates, obtained from eQuest program under the approaches A and B, are compared with measured data available from the Building Automation System (BAS) of the Structural and Functional Genomics Centre. The authors had access to 305 measured data points, as part of a research program, from June 2012 until now. For this study, only measurements from June until August 2012 were used. The measured data cover thermodynamic properties of air and water in the HVAC system and zones. Only the existing sensors and BAS system were used for this purpose; no other sensors were installed. The calibration of the energy model lasted 3-4 months out of the entire research project, which included data collection, understanding of the HVAC system, literature review and development of the energy mode.

Previous studies on this building focussed on the bottom-up evidence-based methodology and calibration of the building energy model at the zone level and air handling unit level (Mihai et al. (2013 a), (2013 b)). We concluded that further investigation on the definition of internal loads in the energy analysis program was needed.

Three different methods are used to compare the hourly estimates with measurements: i) graphical representation; ii) statistical indices: root mean squared error (RMSE), the coefficient of variation of the root mean squared error (CV-RMSE) and normalized mean biased error (NMBE); and iii) paired difference statistical hypothesis testing.

Approach A uses the profiles of internal gains from the ASHRAE 1093-RP research project (Abushakra et al. (2001)), which was conducted to compile a library of schedules and diversity factors based on monitored electricity consumption data from 23 office buildings monitored by the Texas A&M Energy Systems Laboratory and information for 9 office buildings monitored by the Lawrence Berkeley National Laboratory, with the purpose of being used in energy simulations and to determine peak cooling loads in office buildings. The diversity factors and typical hourly load shapes were developed for weekdays and weekend days. The Genomic Research Centre of Concordia University, with an area of 3000 m^2, falls into the medium size buildings category of the project. For this category of buildings, the diversity factors are presented in Table 1.

The approach B uses a simplified step-change profile based on analysis of derived cooling loads profiles in each zone, therefore resulting in a separate internal loads profile for each zone. The cooling loads were calculated based on measurements of air temperatures in each zone, supply air temperature and supply air flow rates to each individual room. In a building with offices and laboratories for research, it is almost impossible to input a regular pattern of usage because of random hourly and daily schedules of utilization. Hence, we defined for each room an equivalent rectangular-shape daily schedule based on derived measured cooling load profile. An important factor in the difference of schedules from one zone to the other is the different types of spaces in the building: offices, conference rooms, laboratories, etc., which must be taken into consideration when simulating.

From the cooling load profile, the maximum value is registered as the maximum power of the combined internal loads and the diversity factors are calculated for each hour, by taking the ratio between the load and the maximum registered load. In order to change the shape of the internal load, the user must adjust the schedule; to increase or decrease the load, the maximum load or “maximum power”, as it is named in eQuest, must be increased or decreased. The profiles for one zone would be similar for the month of June, July and August, but they will differ from one zone to another. The diversity factors are presented in Table 2. For comparison purposes, the peak internal load values presented in Table 2 have been used for both approaches A and B.

The diversity factors of approaches A and B have been plotted for zones 1.6 NE (Figure 1) and 3.4 SW (Figure 2). For instance, in the case of zone 1.6 NE, the diversity factors of the approach A during unoccupied hours of weekdays are 30 to 40% higher than those of the approach B. For the occupied hours (between 10:00 and 18:00) the diversity factors during weekdays of the approach A are close with those of the approach B. In Figure 1 the diversity factor at time 7:00, for instance, indicate the value between 7:00 and 8:00.

Table 1: Combined lights and receptacles diversity factors for medium buildings used for simulation with approach A (1093-RP)

Hour	Diversity Factors	
	Weekdays	Weekend
1	0.46	0.4
2	0.44	0.39
3	0.44	0.39
4	0.44	0.39
5	0.44	0.39
6	0.46	0.39
7	0.57	0.4
8	0.76	0.46
9	0.87	0.51
10	0.92	0.54
11	0.94	0.55
12	0.93	0.56
13	0.92	0.56
14	0.92	0.55
15	0.92	0.56
16	0.92	0.55
17	0.88	0.53
18	0.73	0.5
19	0.63	0.47
20	0.6	0.46
21	0.59	0.43
22	0.53	0.4
23	0.48	0.39
24	0.46	0.39

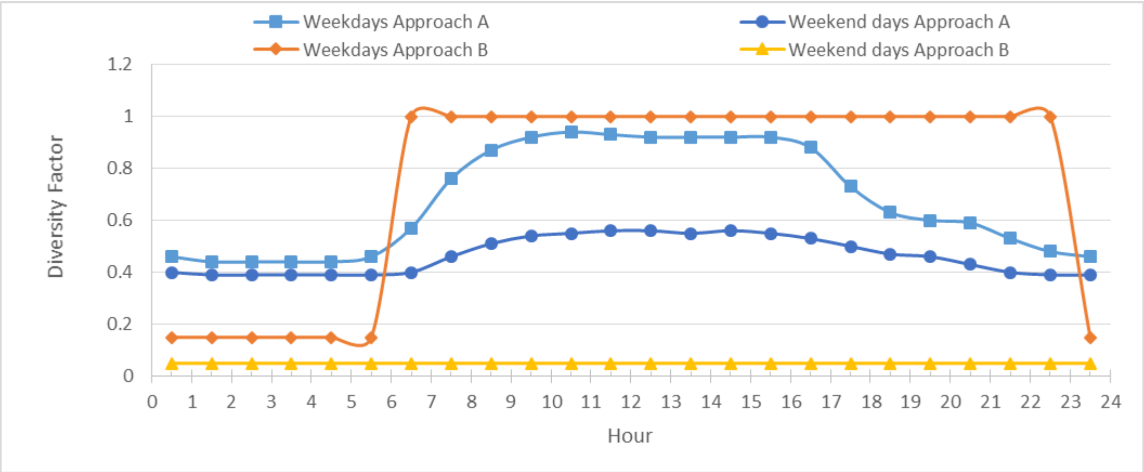

Figure 1: Diversity factors for weekdays and weekend days used for simulation of the zone 1.6 NE with approaches A and B

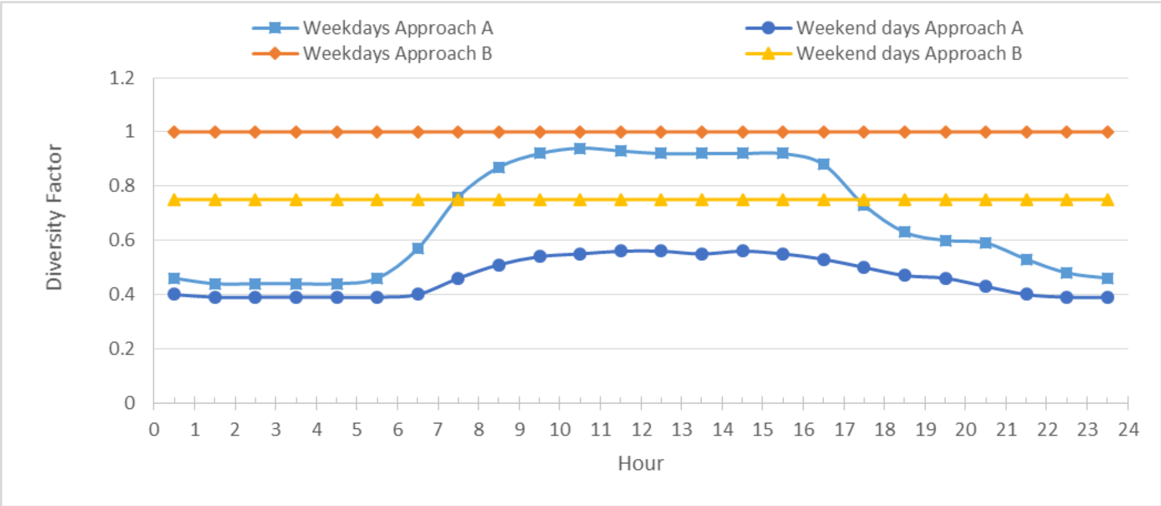

Figure 2: Diversity factors for weekdays and weekend days used for simulation of zone 3.4 SW with approaches A and B

In the case of the approach A, the same diversity factors are applied to all zones; while those of the approach B have been derived from the measured cooling load profiles in each zone; for example, for zone 3.4 SW, the measured cooling load indicated that a constant profile of 100% during week days and 75% during weekend periods is suitable for this particular zone. Therefore having a different profile for each zone reflects better the internal loads in the existing building.

The following sections present the comparison of hourly predicted indoor air temperature, supply air flow rate and cooling loads for each zone, by using both approaches A and B, with the measurements from the BAS.

Table 2: Peak internal loads and diversity factors of equivalent step-change diversity factors with approach B

Zone	Internal peak load [kW]	Diversity Factor					
		Weekdays			Weekend		
		Min	Max	Interval	Min	Max	Interval
1.3 NW	3	0.005	0.005	24 h	0.005	0.005	24h
1.4 SW	1.5	0	0.90	1am-5pm	0	0.1	1am-5pm
1.5 SE	8	0.50	1	5am-5pm	0.5	1	5am-5pm
1.6 NE	13	0.15	1	7am-11pm	0.05	0.05	24h
2.1 NE	8	0.35	1	6am-6pm	0.35	0.45	7am-5pm
2.3 NW	2	0	1	3am-7pm	0	1	3am-7pm
2.4 SW	5	0.7	1	5am-8pm	0.7	0.7	24h
2.5 SE	25	0.9	1	6am-10pm	0.9	0.9	24h
2.6 NE	6	0.7	1	5am-6pm	0.7	0.7	24h
3.1 NE	6	0.4	1	6am-6pm	0.3	0.3	24h
3.2 SW	4.5	0.15	1	3pm-8am	0.15	0.15	24h
3.3 NW	2.25	0	1	6am-8pm	0	1	6am-8pm
3.4 SW	4	1	1	24h	0.75	0.75	24h
3.5 SE	20	0.7	1	6am-7pm	0.6	0.6	24h
3.6 NE	5	0.75	0.9	6am-10pm	0.75	0.75	24h

4 Comparison of the indoor air temperature in each zone

The comparison is performed for the whole summer period, however, for graphical comparison we decided to present only three days with higher outdoor air temperature. As an example, Figures 3 and 4 present for the summer period, the measured vs. predicted indoor air temperature in zones 1.6 NE and 3.4 SW when using the equivalent step-change schedule (Approach B) and when using the RP-1093 schedule (Approach A). Between 5 am to 5 pm, the simulated values with both approaches are equal, while outside this interval, the values differ from the measurements by as much as 2ºC in zone 1.6 NE (Figure 3). For zone 3.4 SW, during unoccupied hours the approach B seems to agree better with the measurements.

The ASHRAE Guideline-14 (ASHRAE (2002)) requires the use of two different statistical indices to comply with the "Whole Building Calibrated Simulation" path: CV-RMSE and NMBE.

ASHRAE Guideline 14 (ASHRAE (2002)) indicated that a coefficient of variation (CV-RMSE) of 15% and normalized mean biased error (NMBE) of 5% on a monthly basis, or 30% and 10%, respectively, on an hourly basis should guarantee a calibrated model when the whole building energy use is compared. It is uncertain whether these values are based on experimental work or some statistical analysis. The same values are prescribed by the Federal Energy Management Program (FEMP) (DOE (2008)).

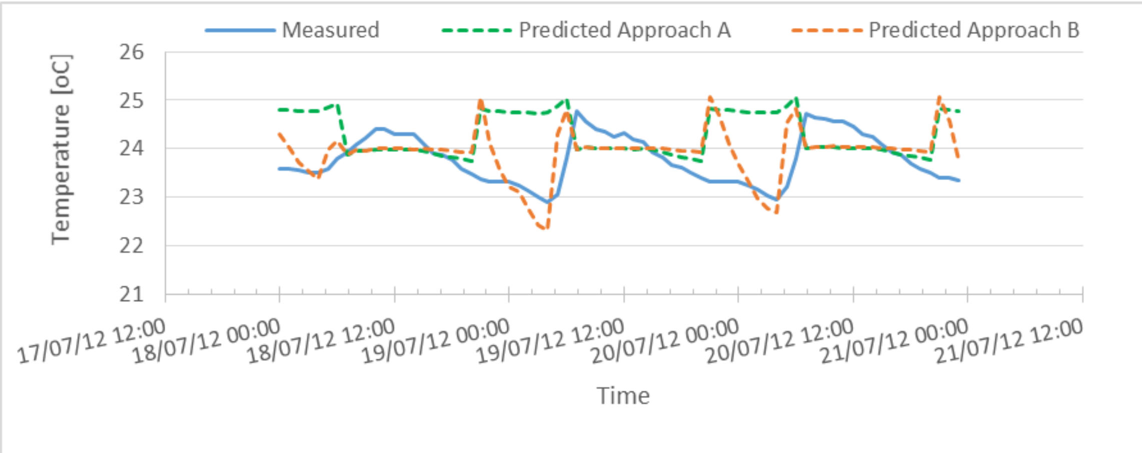

Figure 3: Measured vs. predicted indoor air temperature in zone 1.6 NE from 18th to 20th of July, when using approach A and B

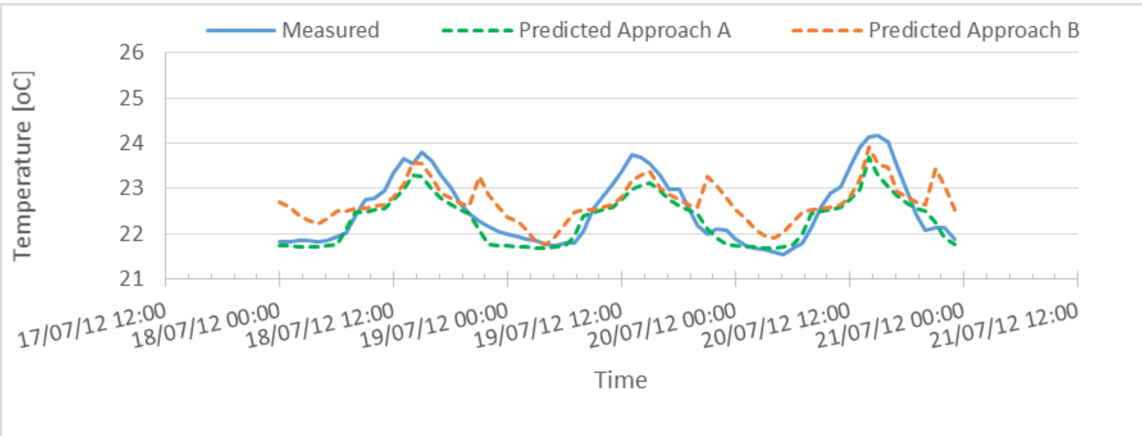

Figure 4: Measured vs. predicted indoor air temperature in zone 3.4 SW from 18th to 20th of July, using approaches A and B

The International Performance Measurement & Verification Protocol IPMVP-Committee (2002) suggested a CV-RMSE of either 5% on a monthly basis or 20% on an hourly basis for whole building energy use.

Raftery et al. (2011) recommended a reduction in the acceptable hourly CV-RMSE from 30% to 20%. Haberl et al. (1998) considered the calibration results as acceptable, with an hourly CV-RMSE of 23.1%.

It can be seen from Table 3 that for all zones, the CV is less than the 30% limit. Also, the NMBE should be less than 10% for hourly averaged values and for all the zones this condition is respected when comparing the measured and predicted indoor air temperature. The RMSE is less than the measurement uncertainty of 1ºC for all zones, except zone 1.4 SW. Both approaches A and B give similar results in terms of statistical indices of the calibration.

Another approach proposed in this study uses the statistical hypothesis testing. A paired difference hypothesis test (Reddy (2011)) is performed for two independent samples (measurements and predictions) to assess whether the difference between measured and predicted air flow rates is statistically significant. This is not a method about independent data points in the same sample. The null hypothesis H_0 states that the difference between measured and predicted air flow rate is equal to or smaller than the measurement uncertainty, therefore the difference is statistically insignificant; the alternative hypothesis H_1 states that the difference between measured and predicted values is significantly greater than the uncertainty. The significance level of the test is chosen to be $\alpha = 0.05$.

Equation (1) calculates the t-statistic (Reddy (2011):

$$\boldsymbol{t} = \frac{\boldsymbol{d}-\boldsymbol{u}}{\boldsymbol{SE}} \quad (1)$$

Formulas (2) and (3) are used to calculate the rest of the parameters (Reddy (2011)):

$$\boldsymbol{d} = \frac{\sum(\boldsymbol{M}-\boldsymbol{P})}{\boldsymbol{n}} \quad (2)$$

$$\boldsymbol{SE} = \frac{\boldsymbol{S_d}}{\sqrt{\boldsymbol{n}}} \quad (3)$$

Table 3: Hourly RMSE, CV-RMSE and NMBE for temperature difference between measurements and predictions with approaches A and B for the summer period

Zone	RMSE [C]		CV-RMSE [%]		NMBE [C]		Calibrated
	A	B	A	B	A	B	
1.3 NW	0.21	0.21	0.98	0.99	0.28	-0.27	A,B
1.4 SW	1.32	1.26	5.31	5.06	1.69	1.19	A,B
1.5 SE	0.85	0.57	3.64	2.42	-2.87	-1.05	A,B
1.6 NE	0.92	0.69	3.85	2.89	2.06	0.23	A,B
2.1 NE	0.57	0.48	2.54	2.16	1.43	1.01	A,B
2.3 NW	0.61	0.68	2.54	2.82	0.39	0.53	A,B
2.4 SW	0.62	0.64	2.72	2.81	-1.56	-0.23	A,B
2.5 SE	1.02	0.77	4.47	3.37	-4.39	-3.05	A,B
2.6 NE	0.69	0.84	3.04	3.70	-1.10	0.98	A,B
3.1 NE	0.63	0.71	2.66	3.02	-1.85	-1.95	A,B
3.2 SW	0.59	0.54	2.54	2.32	-1.43	-0.72	A,B
3.3 NW	0.66	0.72	2.78	3.06	-0.60	-0.86	A,B
3.4 SW	0.63	0.70	2.74	3.08	-1.69	0.42	A,B
3.5 SE	0.73	0.33	3.21	1.45	-2.66	-0.46	A,B
3.6 NE	0.71	0.83	3.13	3.65	-1.09	0.48	A,B

The null hypothesis H_0 is true only if the t-value is less than $t_{critical}$, therefore the difference is statistically insignificant; if t-value is greater than the $t_{critical}$, the null hypothesis is rejected and the alternative hypothesis is accepted, meaning that the difference between measurements and predictions is statistically significant. The t-critical value is found from t (Student) distribution (Reddy (2011)), based on the desired confidence level and the degrees of freedom. For α=0.05, a confidence level of 95%, and 1820 degrees of freedom, $t_{critical}$ is 1.645 for hourly values; for the case of 3 day period, using hourly values, $t_{critical}$ is 1.666, corresponding to a 95 % confidence interval and 70 degrees of freedom.

The hypothesis test with t-statistic is based on the assumption that the difference (d) between measured and predicted values is normally distributed or close to normality. Therefore, for each zone, a histogram was plotted to verify that the condition for normality holds. If the sample size is less than 30, then the condition of normality must be satisfied (Reddy (2011)), but since in this particular case we are dealing with a large population (>30), a graphical representation is enough to estimate if the distribution is normal or not.

The student t values of the difference between measured indoor air temperature for all zones and the predictions with approach A and B, are less than the critical t value of 1.645. Therefore the difference between measured and predicted indoor air temperature is statistically insignificant.

5 Comparison of the supply air flow rate in each zone

The same three methods are used to compare the measured supply air flow rate against predictions with approach A and approach B: graphical representation, statistical indices and hypothesis testing.

For zone 1.6 NE (Figure 5), approach B fits better with the measurements. For zone 3.4 SW (Figure 6), both approaches predict in the same way the supply air flow rate during the occupied hours, while approach A under predicts the supply air flow rate during the unoccupied hours. In conclusion, the approach B, using a step-change shape of internal loads, which was developed from measurements, gives better results than the use of a set of default diversity factors.

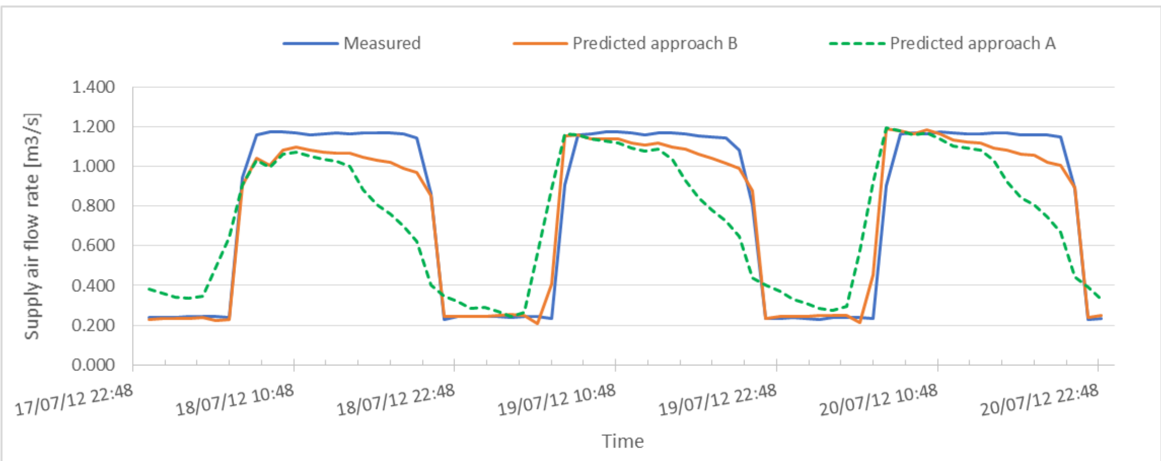

Figure 5: Measured hourly supply air flow rate vs. predictions with approach A and B for zone 1.6 NE from 18 to 20th of July

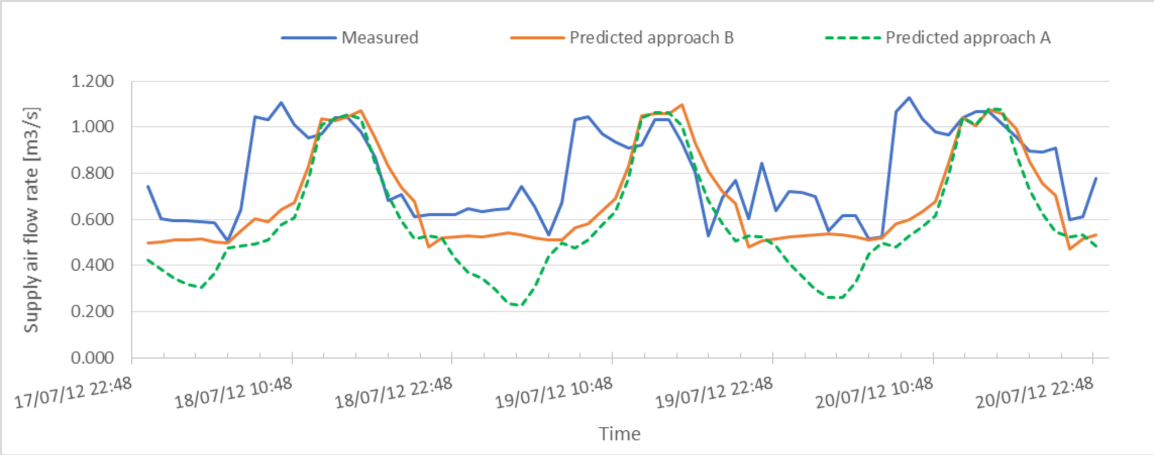

Figure 6: Measured hourly supply air flow rate vs. predictions with approach A and B for zone 3.4 SW from 18 to 20th of July

Table 4 presents statistical indices for all zones for the summer period, when using hourly values, for the difference between measured supply air flow rate and predictions with approaches A and B. With approach A, nine out of fifteen zones would be considered calibrated, since the CV-RMSE is less than 30% and the NMBE is less than 10% (ASHRAE (2002)). With approach B, a total of eleven zones would be calibrated according to the specifications of ASHRAE Guideline 14. Hence, approach B is preferred for estimating the internal loads of the building.

Table 4: Statistical indices for the difference between measured and predicted supply air flow rate using approaches A and B for all zones during summer

Zone	RMSE [m3/s]		CV- RMSE [%]		NMBE [m3/s]		Calibrated
	A	B	A	B	A	B	
1.3 NW	0.07	0.18	15.99	38.45	-0.25	-34.46	A
1.4 SW	0.21	0.20	107.73	103.42	-17.19	-20.52	-
1.5 SE	0.10	0.10	11.98	11.77	0.28	2.42	A,B
1.6 NE	0.29	0.13	46.04	20.78	12.16	2.91	B
2.1 NE	0.10	0.11	17.17	18.96	-2.29	-3.37	A,B
2.3 NW	0.07	0.07	95.19	92.97	-25.73	-8.03	-
2.4 SW	0.23	0.21	31.64	28.25	-13.54	-3.82	B
2.5 SE	0.55	0.31	19.71	11.27	-14.02	7.78	A,B
2.6 NE	0.12	0.10	20.34	17.25	-2.79	8.71	A,B
3.1 NE	0.08	0.08	19.25	19.75	0.93	3.19	A,B
3.2 SW	0.09	0.09	21.20	20.96	-8.44	-10.25	A,B
3.3 NW	0.06	0.07	51.26	55.13	10.22	15.56	-
3.4 SW	0.23	0.18	32.97	27.00	-18.57	-8.36	B
3.5 SE	0.28	0.18	13.74	8.97	-7.97	0.23	A,B
3.6 NE	0.13	0.10	23.81	18.89	-4.19	7.27	A,B

The statistical indices have been also developed for the shorter periods of three days of each month. For the three days with the highest outdoor air temperature during the month of July (Table 5), approach A leads to nine zones being considered calibrated, while approach B suggests that ten zones are calibrated. We also concluded that eleven zones are calibrated for three selected days in August, using approaches A and B.

In conclusion, the use of periods of three days leads to similar results with the comparison over the entire summer period, when using hourly value. For all cases, approach B gives slightly better calibration results.

The statistical hypothesis testing suggests that when using approach A, five out of nine zones are calibrated, as the difference between measurements and predictions is not statistically significant. When using approach B, six zones are calibrated. Therefore the approach B is slightly better, as more zones are calibrated.

Hence, the use of the equivalent step-change of interior loads is compared favourably with the use of one set of default diversity factors for all zones. Method B also takes into consideration the fact that the zones have different purposes (office, laboratory, conference room).

When using hourly values over the set of three days in July, the t student values are less than the critical one (t critical = 1.666) for ten zones, both when using approach A and B. Therefore in this case, both methods give the same results.

When using hourly values over three days in August, approach A results in having seven calibrated zones and approach B leads to eight zones to be calibrated.

Table 5: Statistical indices for the difference between measured supply air flow rate and predictions using approaches A and B for all zones, from 18 to 20th July

Zone	RMSE [m3/s]		CV [%]		NMBE [m3/s]		Calibrated
	A	B	A	B	A	B	
1.3 NW	0.08	0.19	16.49	41.50	1.15	-38.49	A
1.4 SW	0.26	0.25	108.43	104.43	-14.99	-18.02	-
1.5 SE	0.10	0.10	12.51	11.56	-1.19	1.55	A,B
1.6 NE	0.26	0.09	32.38	11.42	-6.96	-3.88	
2.1 NE	0.12	0.12	17.82	18.15	-9.59	-9.89	B
2.3 NW	0.05	0.04	66.18	63.39	-7.98	-0.50	A,B
2.4 SW	0.29	0.26	35.19	31.61	-18.92	-7.80	-
2.5 SE	0.52	0.27	18.48	9.41	-12.67	6.28	-
2.6 NE	0.14	0.10	21.65	15.26	-9.55	6.05	A,B
3.1 NE	0.08	0.08	17.47	16.59	-5.30	-2.67	A,B
3.2 SW	0.11	0.10	25.98	23.55	-5.60	-8.21	A,B
3.3 NW	0.05	0.05	39.04	39.04	15.40	16.89	A,B
3.4 SW	0.28	0.21	35.29	25.78	-26.17	-14.64	B
3.5 SE	0.29	0.15	13.81	6.95	-10.66	-1.47	A,B
3.6 NE	0.16	0.11	28.06	19.74	-7.13	6.75	A,B

6 Comparison of the cooling load in each zone

The graphs are very similar to the ones presenting the air flow rate therefore the same conclusions can be drawn here: for zone 1.6 NE, simulation with approach A over estimates the cooling load at night, while approach B seems to present results that agree better with the measurements (Figure 7). For zone 3.4 SW, approach A underestimates the cooling load for the unoccupied periods, while the results of the simulation using approach B seem to conform better with the measurements (Figure 8). For some zones, approach A seems to be a better fit, while for others approach B gives better results.

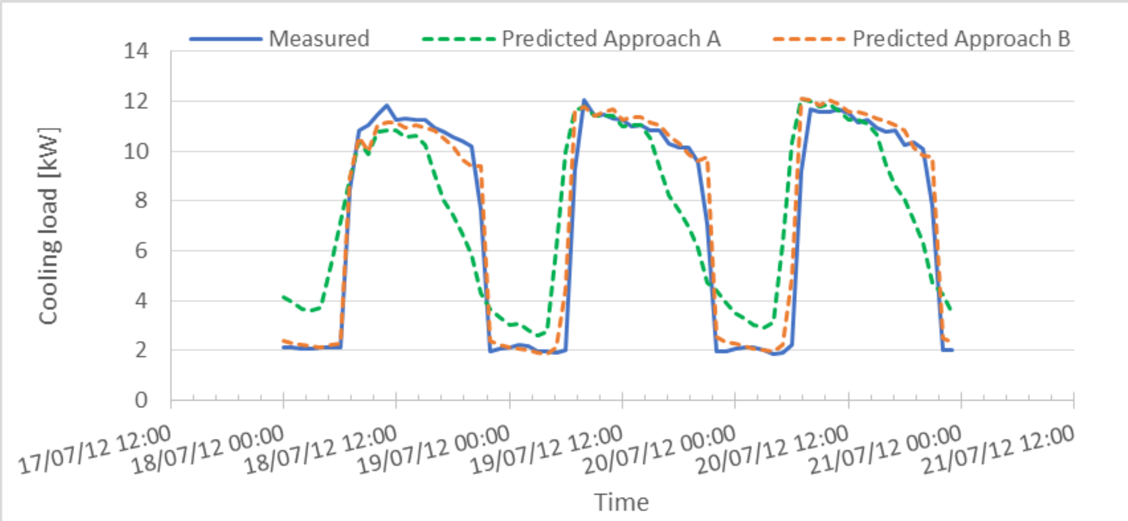

Figure 7: Measured cooling load vs. predictions using approach A and B, for zone 1.6 NE, from 18 to 20th of July

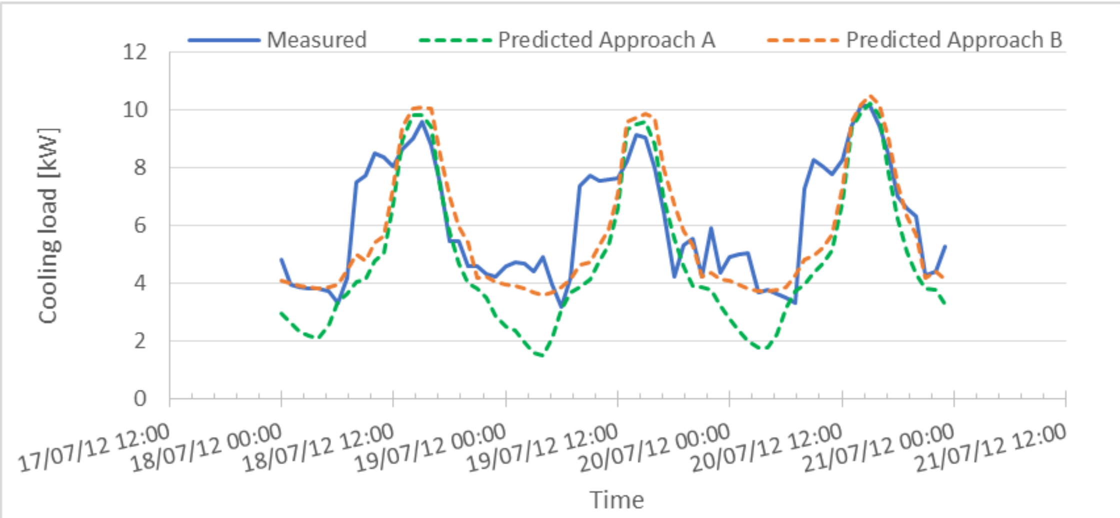

Figure 8: Measured cooling load vs. predictions using approach A and B, for zone 3.4 SW, from 18 to 20th of July

Table 6 presents the statistical indicators of the difference between measured and predicted zone cooling load based on hourly values, for the entire summer. The CV-RMSE is less than 30% and the NMBE is less than 10% for seven zones when approach A is used, and for six zones when approach B is used. Even though the results are similar with both approaches, it seems that in this case approach A gives slightly better results.

The conclusions from the student t values based on hourly average values for the entire summer and for all zones in the building are similar to the conclusions from using statistical indicators: seven out of the fifteen zones can be considered calibrated when either approach A or B is used.

Table 6: Hourly statistical indices for the difference between measured cooling load and predictions using approaches A and B for the entire summer

Zone	RMSE [kW]		CV-RMSE [%]		NMBE [kW]		Calibrated
	A	B	A	B	A	B	
1.3 NW	0.72	0.96	25.51	33.98	12.48	-27.68	-
1.4 SW	2.01	1.89	108.80	102.57	-1.38	-5.89	-
1.5 SE	1.01	1.13	14.22	15.86	-1.98	6.38	A,B
1.6 NE	3.20	1.58	54.13	26.70	25.15	11.39	-
2.1 NE	1.04	1.11	23.69	25.35	10.76	8.43	B
2.3 NW	0.64	0.66	92.72	95.52	-15.24	6.80	-
2.4 SW	1.81	1.74	31.24	30.13	-10.58	2.86	-
2.5 SE	5.80	2.48	26.33	11.27	-19.72	4.67	A,B
2.6 NE	1.17	1.39	25.35	30.25	1.96	20.17	A
3.1 NE	0.69	0.78	19.32	21.70	2.97	5.20	A,B
3.2 SW	0.94	0.78	26.47	22.09	-5.09	-5.12	A,B
3.3 NW	0.59	0.65	55.28	60.63	18.00	23.99	-
3.4 SW	1.72	1.50	31.15	27.20	-15.10	0.67	-
3.5 SE	2.61	2.30	16.19	14.31	-8.45	7.29	A,B
3.6 NE	1.19	1.30	27.64	30.22	1.29	17.61	A

7 Conclusions

This article explored the impact of using two different methods of defining the internal loads for the calibration of a building energy model of an existing building: i) approach A which uses schedules from the ASHRAE project RP-1093 and ii) approach B which uses an equivalent simplified step-change profile derived from the cooling load which is based on measurements of indoor air temperature in each zone, supply air temperature to each zone and supply air flow rate. The findings are not very consistent; for some zones the predictions by using the approach B agree better with the measurements, while for others the approach A gives better agreement with measurements. Overall, approaches B and A lead to about the same number of zones to be calibrated, with a slight advantage for the approach B. The approach B is easier to apply and is based on measurements from BAS, taking into consideration the profiles of different types of zones in the building.

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9 Nomenclature

d= mean of difference between measured and predicted variables [unit of variable];
M= Measured variable [unit of variable];
n= sample size;
P= predicted variable [unit of variable];
RMSE= root mean squared error [units of variable];
Sd= standard deviation of the difference between measured and predicted variables [%];
SE= standard error [%];
S_x= standard deviation of the random component [%];

u= uncertainty of measurement of the variable [units of variable].

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