DTU Library

Better building operation, maintenance and well-being in apartments with smart indoor climate meters

Gunnarsen, Lars; Andersen, Rune Korsholm; Wilke, Göran

Published in:
Healthy Buildings 2021 – Europe

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Gunnarsen, L., Andersen, R. K., & Wilke, G. (2021). Better building operation, maintenance and well-being in apartments with smart indoor climate meters. In Healthy Buildings 2021 – Europe: Proceedings of the 17th International Healthy Buildings Conference (Vol. 9, pp. 78-82). SINTEF Academic Press.

Better building operation, maintenance and well-being in apartments with smart indoor climate meters

Lars GUNNARSEN *[1], Rune Korsholm ANDERSEN[2] and Göran WILKE[3]

[1] Department of the Built Environment, Aalborg University, Copenhagen, Denmark
[2] Department of Civil Engineering, Danish Technical University, Lyngby, Denmark
[3] IC-Meter aps, Copenhagen, Denmark
* *Corresponding author: lbg@build.aau.dk*

ABSTRACT

The justification of energy consumption in dwellings is to maintain comfortable and healthy indoor climate. Sufficient air exchange and comfortable temperatures protect building structures against mould growth caused by high relative humidity and improve comfort and health among occupants.

This project investigated a new way of heat accounting based on indoor climate meters logging temperature, humidity and CO_2 concentrations in apartments every 5 minutes. The logged values permitted calculation of payments according to ability to maintain an indoor climate with moderate temperatures, low CO_2 concentrations and low relative humidity of the indoor air.

The results show less variation in payments between dwellings than for the traditional heat consumption based billing. In addition, an apparent increased interest in maintaining temperatures, humidity and carbon dioxide concentrations at recommended levels was noted among tenants.

INTRODUCTION

Average people spend around 2/3 of their time at home. The old, the females and the very young spend relatively more time at home (Farrow et al. 1997). A good indoor climate in the home is a prerequisite for healthy, productive and long lives. Typical indoor climate problems in homes comprise moisture related problems (Gunnarsen and Keiding 2009, Hägerhed-Engman et al. 2009). House dust mites and mould growth is the results of high humidity indoors. Also high concentrations of human bio-effluents measured as high carbon dioxide concentrations are known to cause annoyance, symptoms and reduced productivity among occupants (Laverge et al. 2015). High humidity indoors may also result in costs in relation to renovation of apartments with adverse mould growth. The typical indoor climate problems in dwellings may have costs in relation to loss of health and productivity among occupants but also costs in relation to building maintenance and renovation.

In blocks of flats with billing for energy use in relation to individually metered consumption it is economically attractive for tenants to keep their indoor temperatures low - in particular, to keep their temperatures lower than temperatures in neighbouring apartments. Savings can become very big when temperatures are slightly lower than in surrounding flats because the walls and floors between flats are typically more important for the heat loss from an individual apartment than the building envelope. Since tenants have no influence over temperatures among neighbours the heat billing based on the typical temperature loggers on radiator surfaces may include some random and for the individual not predictable aspects that may reduce the interest in maintaining a good indoor climate with moderate temperatures. Traditionally the interest in healthy and sustainable temperatures, humidity and carbon dioxide levels may also be diffused by only once per year meter based cost modification.

The purpose of this paper is to examine the differences in indoor climate quality and heating expenditures between rental apartments in the same tenement before and after the introduction of smart indoor climate meters.

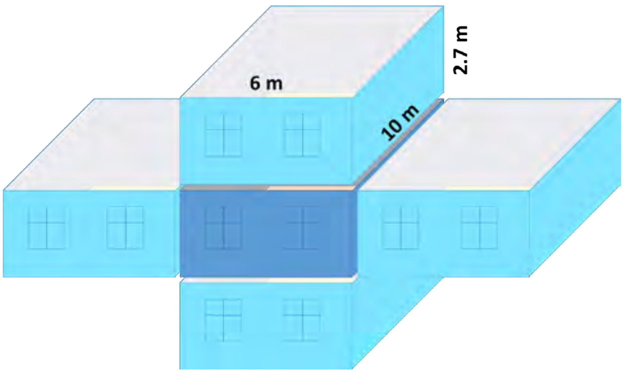

Figure 1. Visualisation of the large area towards neighbours compared to areas facing outside

In order to acknowledge the need not only for reduced environmental impact trough reduced use of energy for heating but also for better protection of building envelope trough reduced indoor humidity and better health among tenants through reduced CO_2

concentration the concept Dynamic Heat Accounts have been devised.

METHODS

The concept Dynamic Heat Accounts was experimentally introduced in 237 apartments in the same estate. In the year 2019 heat accounting was based on cloud upload, visualisation of measured values and monthly calculation of payments for energy use based on the logged values during one full year.

Figure 2 shows heat consumption in relation to different temperatures in neighbouring apartments. It is based on values in table 1, an assumed average outdoor temperature of 8 ºC, temperature in model apartment of 20 ºC and formula (1) below It is seen that when neighbours have slightly more than 4 ºC above the 20 ºC of the model apartment then heat consumption becomes negligible.

Table 1. Heat transmission coefficients or U values, areas, air change and volume used as basis of simplified heat consumption calculation

Transmission losses		
	U	Area
	W/m² ºC	m²
Windows	2.00	6.0
Facade	1.46	26.4
Wall neighbours	1.89	54.0
Floor/ceiling	0.93	120.0

Ventilation losses	
Air change	Volume
h^{-1}	m^3
0.5	162

Heat consumption: Q
Heat transmission coefficient: U
Area building part: A
Temperature: T
Volume based heat capacity of air: C
Outside air supply: v
(Suffix i: inside, n: neighbour and o: outside)

$$Q = \Sigma (T_i - T_o) A_o U_o + \Sigma (T_i - T_n) A_n U_n + v C (T_i - T_o) \quad (1)$$

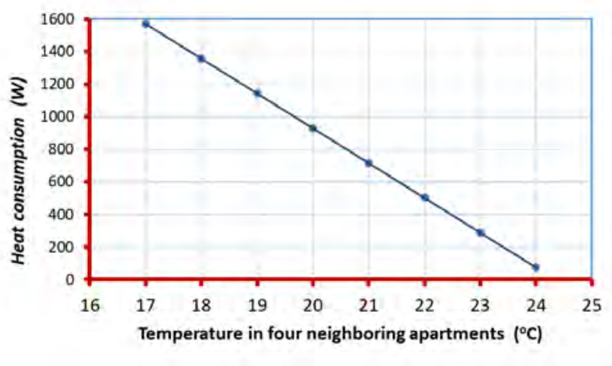

Figure 2. Rough calculation of heat consumption in simplified apartment visualized in figure 1. In relation to temperature in neighboring apartments - all assumed same.

Figure 3, 4 and 5 show the applied borders between payment zones for temperature, relative humidity and carbon dioxide.

Extra payments required to compensate for extra expenditures in relation deviations from the optimal green zones in relation to relative humidity and carbon dioxide is not directly quantifiable in economic terms in spite they are big in particular in relation to building maintenance and health and productivity of occupants. It was therefore decided to calculate extra payments in relation to assumed extra heat consumption in relation to excess temperatures disregarding impact of neighbouring apartments and presuppose same extra expenditures in relation to deviations in relation to humidity and carbon dioxide.

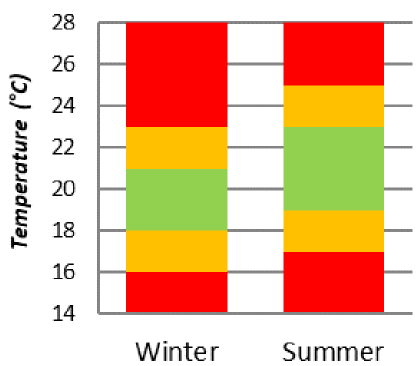

Figure 3. Limits for baseline payment, added payment and extra-added payment for temperature

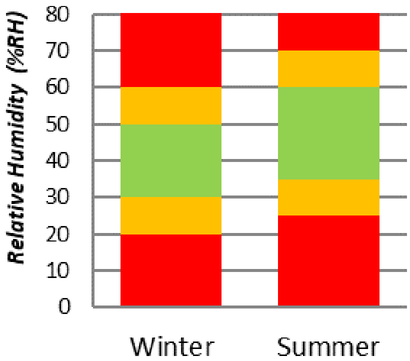

Figure 4. Limits for baseline payment, added payment and extra-added payment for relative humidity

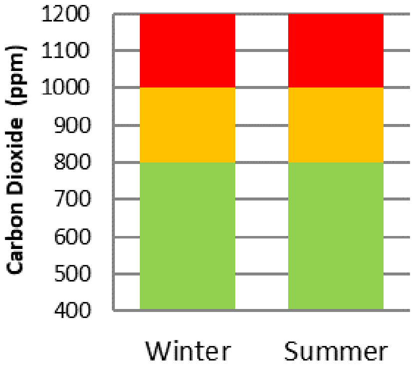

Figure 5. Limits for baseline payment, added payment and extra-added payment for carbon dioxide

The increased heat consumption that may be attributed to a temperature of 20.5 °C instead of 19.5 °C may be calculated according to this in a simplified manner for outside conditions in Denmark.

$$Q_{rel} = \Delta T \; / \; (19.5\ {}^{o}C - Q_{add} - T_{out}) * 100\ \%$$

Where

Q_{rel} : Relative increase in heat consumption per 1 °C deviation from actual room temperature.

Q_{add} : Increase in room temperature from sunshine and other energy gains. Here assumed to be 3 °C.

T_{out} : Average outside temperature in heating season. Here assumed to be 5 °C.

The increased heat consumption at a temperature of 20.5 instead of 19.5 °C is then calculated as

$$Q_{rel} = 1\ {}^{o}C \; / \; (19{,}5 - 3 - 5)\ {}^{o}C * 100\ \% = 8{,}7\ \%$$

Figure 6 show such calculations for a wider span of temperatures

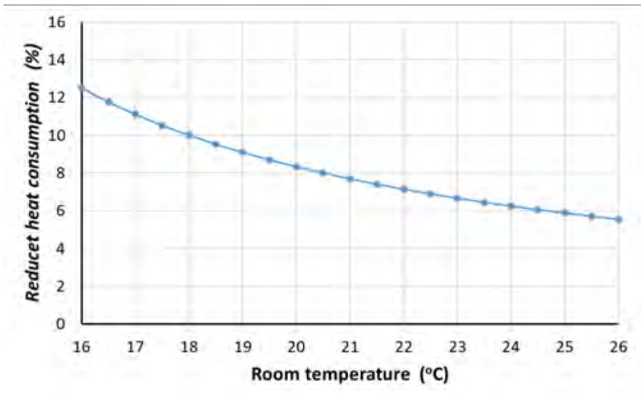

Figure 6. Reduced heat consumption at 1 °C less than indicated room temperatures only accounting for heat loss to the outside

For simplification the extra payments shifting from green to yellow was suggested by building operation staff in collaboration with the authors of this paper to be 22 % or the result of 2,5 °C (temperature difference between middle of green temperature interval and yellow temperature interval) times 8,7 %/°C. The extra payment for red zone was then suggested to be the double or 44 %.

Expenditures in relation to building maintenance and loss of health normally by far exceeds the expenditures in relation to energy consumption. But similar calculations are as mentioned not possible for carbon dioxide and relative humidity. The same penalties as for temperature for these parameters was applied.

However based on the reluctance of tenants to keep accepting high differences in heat expenditures they decided to base extra payments only on one third of the calculated and argued extra expenditures for the first year.

We analysed heating accounts from 237 apartments in one tenements. The apartments was equipped with equipment logging temperature, relative humidity and CO_2.

RESULTS

Figure 7 show energy use before introduction of indoor climate meters. It shows more than a factor 10 difference between 10 % apartments with minimum payments and 10 % maximum payments in apartments with similar characteristics.

Furthermore, preliminary results indicate that these differences in energy consumption does not correlate directly with the measured differences in indoor temperature, humidity and carbon dioxide.

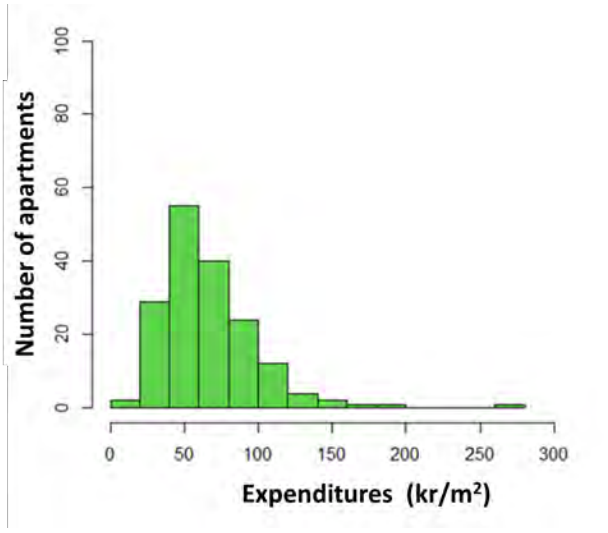

Figure 7. Spread of billing according to traditional heat accounting

Figure 8 show the much reduced spread of payments during the first year of dynamic heat accounting.

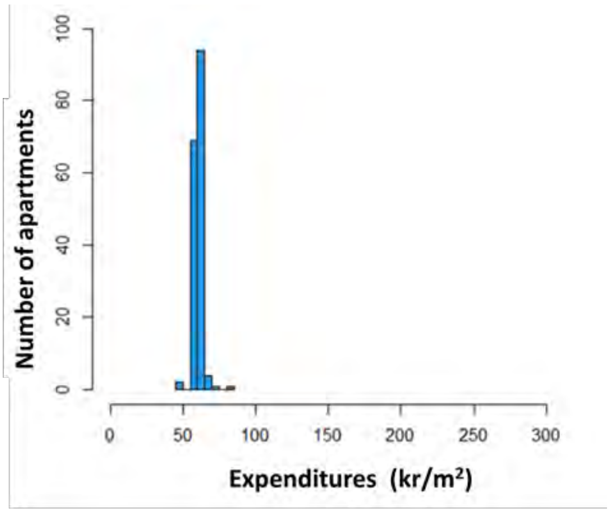

Figure 8. Spread of billing according to dynamic heat accounting

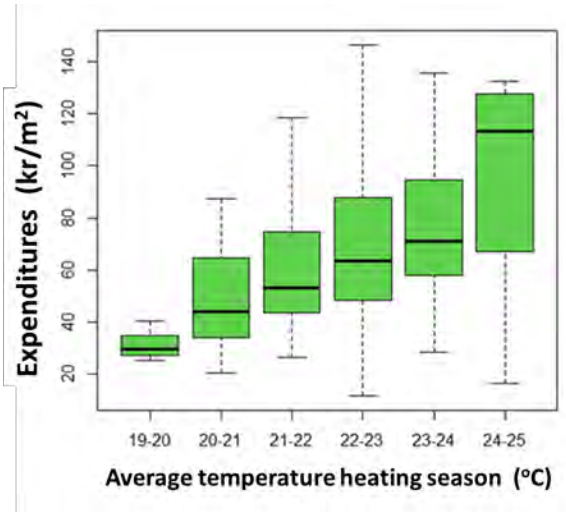

Figure 9. Expenditures in relation to average temperature for traditional accounting

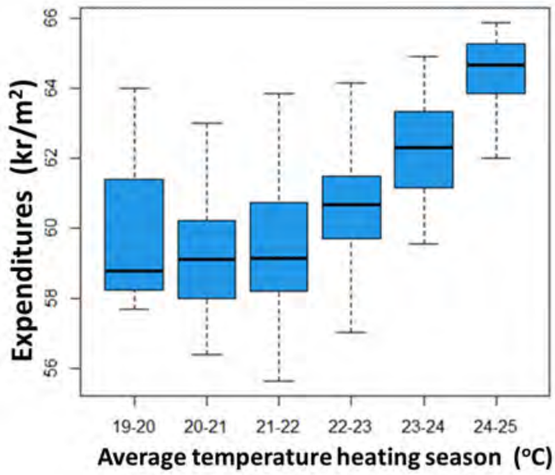

Figure 10 . Expenditures in relation to average temperature for Dynamic heat accounting

DISCUSSION

The experiment indicate some promises for a future where heat accounting benefit from the technological progresses including cheaper more reliable indoor climate measurements, cheaper and more widely available cloud connections and better visualisation of time course of indoor climate quality for tenants.

Results also indicate some indications of a need for revision of the common recommendations regarding the preservation of energy to give a more sustainable set of guidelines, especially in apartment buildings where temperature competition between tenants potentially can damage the whole building.

Tenants voted in favour of very small differences in payments for their first year of the new heat billing system. Their argumentation was related to insecurity regarding the new concept and a wish for reduced differences in payments. In the first year the average expenditures in the actual average temperature range 19 - 25 °C as shown in figure 10 varied between 59 DKK/m² and 64 DKK/m². This was far less than would have been the reality with the accounting they previously used. This is shown in figure 9 and would have resulted in the range 32 - 110 DKK/m². The incentive to maintain good conditions in relation to room temperature, relative humidity and carbon dioxide concentrations was increased by tenants who as recommended voted in favour of 3 times higher redistribution of expenditures outside the green zone in the second year.

CONCLUSIONS

The experimenting is still ongoing.

The shift to dynamic heat accounting improved the awareness of the responsibility to maintain a good indoor climate at all times among tenants. This was achieved apparently without a significant increase in energy consumption.

Preliminary results indicate a need for bigger payment differences in relation to measured values.

The transition from traditional billing to dynamic heat billing is not straight forward in regards to tenant acceptance and understanding of the more complex available readings from their apartment

ACKNOWLEDGMENTS

National Building Foundation, Denmark (Landsbyggefonden) has financially supported the research.

REFERENCES

Farrow A, Taylor H and Golding J. (1997). "Time Spent in the Home by Different Family Members". *Environmental Technology*, 18(6), 605-613. https://doi.org/10.1080/09593331808616578.

Gunnarsen L and Keiding L. (2003). "Magnitude of the mould and moisture problem in Danish homes". *Proceedings of the 7th International Healthy Buildings Conference,* National University of Singapore, 3, 677-682. https://www.aivc.org/resource/magnitude-mould-and-moisture-problem-danish-homes.

Hägerhed-Engman L, Bornehag CG and Sundell J. (2009). "Building characteristics associated with moisture related problems in 8,918 Swedish dwellings". *International Journal of Environmental Health Research*, 19:4, 251-265. https://doi.org/10.1080/09603120802527653.

Laverge J, Delghust M and Janssens A. (2015). "Carbon Dioxide Concentrations and Humidity Levels Measured in Belgian Standard and Low Energy Dwellings with Common Ventilation Strategies". *International Journal of Ventilation*, 14:2, 165-180. https://doi.org/10.1080/14733315.2015.11684078.