Impacts of Energy Efficient Constant Output Heating on the Moisture Conditions of Unoccupied Summer Cottages in Finland

Citation
Vinha, J., Piironen, J., & Kiviste, M. (2018). Impacts of Energy Efficient Constant Output Heating on the Moisture Conditions of Unoccupied Summer Cottages in Finland. In *Cold Climate HVAC 2018: Sustainable Buildings in Cold Climates* (pp. 79-86). (Springer Proceedings in Energy). Springer. https://doi.org/10.1007/978-3-030-00662-4_7

Year
2018

Version
Peer reviewed version (post-print)

Link to publication
TUTCRIS Portal (http://www.tut.fi/tutcris)

Published in
Cold Climate HVAC 2018

DOI
10.1007/978-3-030-00662-4_7

Impacts of Energy Efficient Constant Output Heating on the Moisture Conditions of Unoccupied Summer Cottages in Finland

Juha Vinha[1[0000-0003-2426-4687]], Jarkko Piironen[1] and Mihkel Kiviste[1[0000-0001-8726-070X]]

[1] Tampere University of Technology, Korkeakoulunkatu 5, 33101 Tampere, Finland

Abstract. Finland has around half a million summer cottages. An increasing demand exist for using these cottages also in other seasons. The influence of constant output heating is studied for energy saving purposes while avoiding moisture damage in the cottages. The proposed type of heating requires only a fraction of amount of electrical energy in comparison with conventional heating.

Field measurements, which are presented in current paper, aim at indicating the actual moisture conditions in unoccupied Finnish summer cottages. Field measurements in seven non-insulated massive log walled cottages in Tampere region (Finland) have been performed during 2007-2009. Based on the values of indoor and outdoor RH (at one-hour interval) the monthly average differences between indoor and outdoor water vapour content were determined.

Prevailing conditions of moisture deficit were found in summer cottage case buildings during the measurement period. These results oppose to the usual conditions of moisture excess in Finnish residential buildings. Despite the difference in moisture conditions often the envelope structures in summer cottages and in residential buildings are often similar.

Keywords: Field measurements, Unoccupied summer cottage.

1 Introduction

Research have drawn out the advantages of development and application of energy-efficient heating, ventilation, and air conditioning (HVACs) systems [1, 2, 3, 4, 5, 6]. Finland has around half a million summer cottages. There exists a trend of constructing new cottages as well as renovating the building structures and replacing HVAC systems in existing ones. The objective of replacing heating systems in existing cottages is to avoid moisture damage with minimal costs, while the occupants are away [1, 7].

The purpose of typical electric heating is to maintain certain thermal conditions in summer cottages.. Maintaining constantly high indoor temperatures is very energy consuming. Current annual electricity consumption of free-time residences is clearly exceeding 500 GWh and due to the increasing rate of construction of new summer cottages it is expected reach 1000 GWh in the future, which is 10% of heating and domestic electricity consumption. Therefore, there lies considerable energy saving potential.

Studied constant output heating require only 5–15 W of electricity per floor square meter, which is rather marginal compared to conventional electric heating [1].

In heated and occupied residential buildings in Nordic climate the indoor air usually consists more water vapour than outdoor air. Therefore, there exists constant conditions of moisture excess. That is caused by residential moisture production of inhabitants and heated indoor air, which has naturally higher water vapour absorption capacity in comparison with outdoor air.

The moisture conditions in summer cottages are expected to be different since there exists less moisture production from inhabitants (used only occasionally) and also the indoor temperature is kept on lower level. However, the actual moisture conditions and their temporal change in summer cottages was not exactly known. Field measurements, which are presented in current paper, aim at indicating the actual moisture conditions in unoccupied Finnish summer cottages.

The study is a part of research project "Eco-efficient irregular heating" (EREL)" carried out in 2007-2009. This project studied free-time residences based on continuous energy and eco-efficiency in order to pursue finding and developing optional technologies, services and practices, which enable to increase the eco-efficiency of summer cottages.

2 Materials and methods

2.1 Case study buildings

Seven uninsulated massive log summer cottages in Tampere region, Finland (Fig. 1) were selected for the study. The field measurements consisted of temperature, relative humidity as well as air-tightness measurements of the log buildings. In five case buildings the temperature and relative humidity were measured for two consecutive years: 2007-2009. In two case buildings the measurements were performed for one year: in 2007-2008 and 2008-2009, respectively.

Fig. 1. Front and side view of two Finnish summer cottages.

The general information of the case study buildings is presented in Table 1. All the case buildings have natural ventilation through ventilation holes in external walls. The occupants have possibility to control the ventilation by opening or closing the ventilation holes. The information about ventilation openings (open, partially open or closed) is presented in table 1. The ceiling and floor structures in cottage no. 5 have been retrofitted during moving.

Table 1. General information of the case study buildings

No. of case building	1	2	3	4	5	6	7
Measurement period	07-08	07-09	07-09	07-09	07-09	07-09	08-09
Location	Tampere	Keuruu	Orivesi	Lavia	Lavia	Keuruu	Pälkäne
Year of construction	1989	2000	2007	1985*	2002	1993	1988
Indoor area [m^2]	53	24	75	17	66	27	28
Indoor volume [m^3]	135	68	182	40	181	78	69
Envelope weighed U-value [W/(m2·K)]	not calculated	0.66	0.45	0.60	0.51	0.60	0.63
Airtightness: air change rate, n_{50} [h^{-1}]	24.0	26.9	15.7	30.0	5.1	29.7	6.3
Ventilation holes	opened	partially opened	partially opened	partially opened	partially opened	closed	closed
Heating in winter 07-08	no	no	no	no	basic heating	constant 220 W	not included
Heating in winter 08-09	not included	constant 210 W	constant 780 W**	constant 110 W**	constant 800 W	constant 220 W	constant 140 W
Main direction of windows	west	east	west	east	east	east	east

Notes: * retrofits in 2000, ** part of the time unheated

2.2 Temperature and relative humidity measurements

Temperature and relative humidity dataloggers (Comark Diligence EV N2003) with battery power were applied for the measurements. The measuring range for relative humidity was 0…97% in a precondition that the humidity is not condensed. The accuracy for temperature is ± 0.5 °C and ± 3 % for relative humidity. Dataloggers were programmed for one hour measuring interval of temperature and relative humidity measurements. Due to limitations in memory capacity, the measuring data were collected in two stages: in spring 2008 and in spring 2009 (at the end of measurements). Four, five or six loggers were placed to each case building. One logger was recording the outdoor conditions while the rest were recording indoor conditions. The outdoor dataloggers were placed under the protection from rain and direct sunlight i.e. to the terrace or under the shelter. Same outdoor logger was placed for case buildings 4 and 5, since they were located at the same plot. The indoor loggers were placed to inner surface of external wall and window and so called cold surface, where conditions were expected to change more slowly compared to indoor air. If possible, windows in different directions were included to account also sun radiation. Fig. 2 shows the location of dataloggers in case building 5.

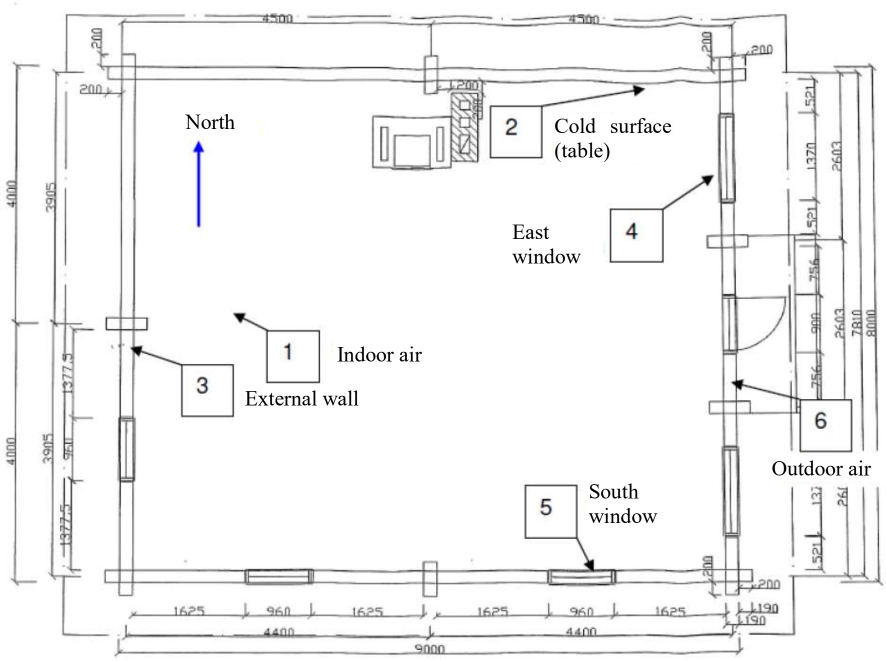

Fig. 2. Location of dataloggers in case building 5.

3 Results and discussion

The average daily conditions of different case buildings are presented in in Fig 3. Fig. 3 shows the the indoor air condition at the centre of each cottage (logger 1 in Fig. 2). Indoor and outdoor conditions of unheated case buildings from 1.12.07-23.2.08 are presented in left and constant output heated case buildings from 1.12.08-23.2.09 are presented in right column in Fig. 3. Upper figures show measured relative humidities, middle show measured temperatures and lower show water vapour concentrations, which was calculated from the measured temperature and relative humidity values. Since the indoor air conditions are measured in consecutive years, to enable better comparison, the outdoor air conditions in Fig. 3 are taken from the nearest weather station of Finnish Meteorological Institute (in Tampere, abbreviation TRE in Fig. 3).

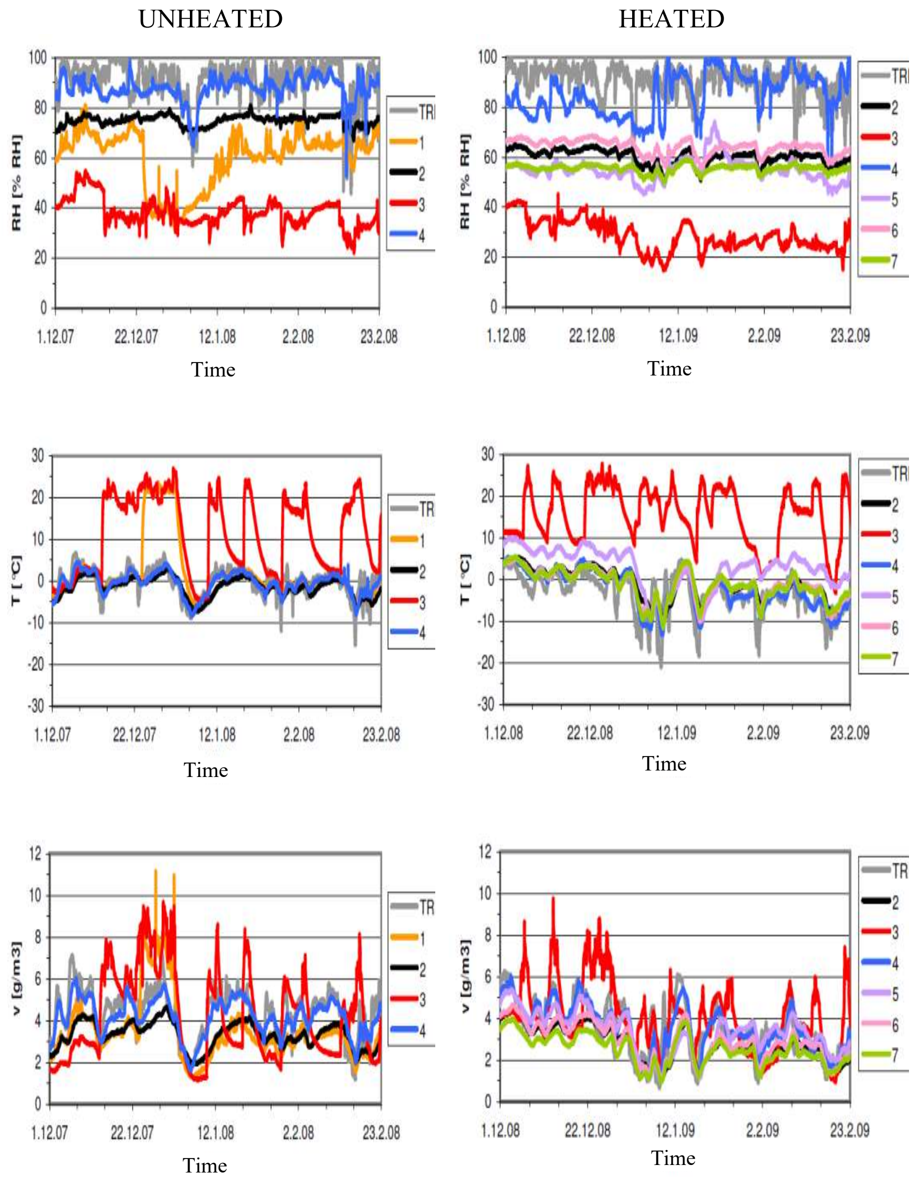

Fig. 3. Daily average indoor and outdoor conditions of unheated case buildings from 1.12.07-23.2.08 are presented in left and constant output heated case buildings from 1.12.08-23.2.09 are presented in right. Upper figures show relative humidities, middle show temperatures and lower show water vapour concentrations.

The following findings were made from the measurement results from unheated summer cottages (Fig. 3 left).

- The relative humidity of indoor air stays mainly under 80%, but could be occasionally 10-15 % higher on window surface making it the most susceptible place for condensation. However, usually condensation does not occur in unoccupied premises.

- Indoor temperature and humidity conditions mainly follow outdoor conditions. Indoor temperature and water vapour content follow outdoor changes with some hours delay. The surface of the materials also influences indoor air conditions.

- The thermal conductivity of envelope and ventilation have a major impact on the indoor temperature and water vapour content.

  - The indoor water vapour content is lower than that of outdoor water vapour content in most times. The opposite happens in spring and during the residence. The moisture absoption capacity of log surfaces in indoor air also affect the situation.

  - Winter visits dry the cottage. Drying is more significant the more the visits occur and last.

The following findings were made in constant output heated summer cottages (Fig. 3 right):

- The temperature increase (heating) +3 °C decreases about 10% relative humidity. Heating has lower impact on window surfaces than for indoor air conditions.

- Changing conventional heating to constant output heating does not affect indoor conditions significantly. Constant output heating could improve the conditions in autumn and spring.

- Similarly, outdoor conditions affect indoor conditions. However, indoor temperature stays a few degrees higher.

- Heating does not affect water vapour content, thus the difference between indoor and outdoor water vapour content is the same as in unheated summer cottages.

- Heating is not necessary in airtight cottage with nearly continuous residence. Heating could decrease the indoor relative humidity to aversely low levels.

- Decreasing ventilation could save heating power. The effect is greater in more airtight envelopes (Table 1). Closing ventilation in an airtight unoccupied cottages (cottages 6 and 7 in table 1) did not have adverse effect on the relative humidity or water vapour content even in spring (upper and lower figure in Fig. 3).

Based on indoor and outdoor RH logger measurements the monthly average differences between indoor and outdoor water vapour content were found (**Fig. 4**).

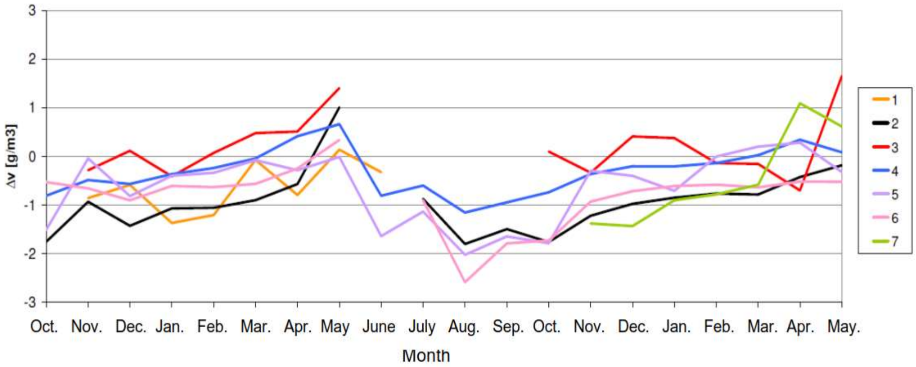

Fig. 4. The monthly average differences between the indoor and outdoor water vapour content of studied case buildings during 2007-2009.

Fig. 4 shows that indoor moisture deficit related to outdoor exist in case buildings during most times a year excluding spring. This situation is the opposite to the residential buildings in continuous use. The greatest indoor moisture deficit could be found in late summer and early autumn. Indoor moisture deficit decreases during winter and could turn to moisture excess in spring. In addition, occupant visits also produce moisture. It can be noticed from Fig. 4 that cottage 3 has higher indoor moisture related to outdoors in both studied winters, which was related to frequent winter use of the cottage.

It should be taken into account field measurements were performed only in uninsulated massive log cottages. The results might not be valid in e.g. timber-frame or inside insulated log cottages, because the water absorption capacity of inner surface of log wall could differ significantly. Conventional heating could be changed to constant output heating only, if the risks for possible freezing of home appliances and water systems are eliminated.

Additional research is needed in timber-frame summer cottages with different insulation materials in order to account the whole Finnish summer cottage building stock. Also, additional field measurements in roof, floor and foundations (with and without crawl spaces) to be performed for more reliable understanding of the performance of constant output heating. Additional research is necessary for the importance of ventilation, temporary breaks of heating and intermittent heating for possible heating optimization without increasing mould risks.

Conclusions

Current study presents the results of field measurements of indoor air conditions from seven unoccupied non-insulated massive log-walled cottages in Finland (Tampere region) during 2007-2009.

In general, changing conventional heating to constant output heating does not affect indoor air conditions significantly. Constant output heating could improve the conditions in autumn and spring. A temperature increase of 3 °C was found to decrease relative humidity about 10%.

The monthly average moisture content of indoor air was found to be lower than the average moisture content of outdoor air indicating an average moisture deficit of indoor air in unoccupied Finnish summer cottages. The indoor moisture deficit related to outdoor exist in case buildings during most times a year excluding spring in some cases. These results oppose to the usual moisture excess of full-time residential buildings in Finnish climate.

References

1. Jarkko Piironen, Juha Vinha, Mihkel Kiviste.: Modelling hygrothermal performance of roof and floor structures with an energy-efficient constant output heating. Energy Procedia (2017).
2. Burgett J., Chini A., Oppenheim P.: Specifying residential retrofit packages for 30% reductions in energy consumption in hot–humid climate zones. Energy Efficiency 6 (3), 523–543 (2013).
3. Mathews, E.H. C.P. Botha, D.C. Arndt, A. Malan.: HVAC control strategies to enhance comfort and minimise energy usage. Energy and Buildings 33 (8), 853–863 (2001).
4. Pérez-Lombard L., Ortiz, J. Coronel J.F., Maestre I.R.: A review of HVAC systems requirements in building energy regulations. Energy and Buildings 43, 255–268 (2011).
5. Meyers R.J., Williams E.D., Matthews H.S.. Scoping the potential of monitoring and control technologies to reduce energy use in homes. Energy and buildings 42, 563–569 (2010).
6. Ardehali, M.M. Smith. T.F.: Evaluation of variable volume and temperature HVAC system for commercial and residential buildings. Energy conversion and management 37 (9). 1469–1479 (1996).
7. Rytkönen A, Kirkkari A.: Eco-efficiency of holiday homes. The Finnish Environment 6/2010. Helsinki: Ministry of the Environment, Department of the Built Environment. 112 p. (in Finnish, 2010).
8. Piironen J, Vinha J.: Constant output heating and its effect on the hygrothermal performance of log summer houses. Research report no. 150. Tampere: Tampere University of Technology. 79 p. + app. 16 p. (in Finnish, 2010)