Normalisation of measured energy use in buildings – need for a review of the Swedish regulations

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Abstract. Normalisation of measured energy use in buildings is important in order to verify their performance in user phase. Two methods for normalisation have been presented in Sweden, static and dynamic normalisation. The static normalisation considers deviating hot water use, indoor temperature, internal loads and external climate. The dynamic normalisation is based on repeated simulation, meaning that the initial simulation, carried out during the design phase, is repeated with updated conditions regarding actual use of the building and exterior climate. The ratio between the first and second simulation is used as a factor for normalisation. A pre-study has been initiated in Sweden to enable further development of the two methods. This paper present the two methods, the initiated pre-study, and some early findings. The early findings show that there is need for further development of the methods presented.

Keywords: Normalisation, Energy use, Swedish regulations.

1 Introduction

While pushing boundaries of energy efficiency in buildings, it is of growing importance that predicted energy performance is actually achieved during user phase.

Performance gaps have been identified in earlier studies [1-15], showing that predicted energy use is often not achieved during user phase. Some of the studies show a very large performance gap [3-5, 11], some show a lower performance gap [6, 8].

One way to overcome and to identify actual performance gaps is to normalise the measured energy use. Indeed, in the cited works, a smaller performance gap is generally found when measured energy use is normalised.

Some studies normalise the measured energy use due to either internal or external deviating boundary conditions [6, 8], the latter being investigated and discussed in other studies [1, 2, 9, 14], which however do not attempt to normalise the measured energy use. A Swedish study investigated the uncertainty of different methods for normalizing energy use for deviating external boundary conditions and found that different methods may have a major impact. Furthermore, they concluded that the tested methods needs to be further developed, especially in order to be suitable for low-energy buildings [16].

However, none of the studies [1-16] attempts to normalise measured energy use for both internal and external deviating boundary conditions.

Normalisation of energy use allows comparison and verification of energy use in buildings, clarifying if a deviation is generated by different conditions of use or by an actual performance failure.

The Swedish Board of Housing, Building and Planning (Boverket) recently published regulations regarding verification of energy performance of buildings [17]. These regulations introduce two different methods for normalisation, where it is possible to choose one of these.

The first method is a static approach where the normalisation is carried out in four steps. The second method is a dynamic approach using a simulation tool. These methods have not been evaluated and may both have strengths and weaknesses.

To increase the knowledge on normalisation methods for the measured energy use in buildings a pre-study has been initiated, founded by the Swedish construction industry's organisation for research and development, SBUF [18].

It should be noted that the pre-study is still ongoing. The main purpose of this paper is to present the methods introduced by Boverket, the initiated pre-study, and some early findings.

Boverket has presented two methods to standardise normalisation of measured energy use. However, more work may be needed to improve the methods. The initiated pre-study may be an important first step.

2 Methods for normalisation from Boverket

2.1 Static normalisation

The static normalisation is carried out in four steps, including effect of hot water use, deviating indoor temperature, deviating internal loads and deviating external climate. The static normalisation is graphically summarised in Figure 1 and it follows Equation 1.

$$E_{norm} = E_{meas,DHW} - E_{corr,DHW} + \frac{E_{meas,SH} \cdot TAF + E_{meas,C} - E_{corr,IL}}{OCD} + E_{aux} \quad (1)$$

where E_{norm} is normalised energy performance based on static normalisation, $E_{meas,DHW}$ is the measured energy use for domestic hot water (excluding energy losses for hot water circulation), $E_{corr,DHW}$ is used to normalise energy use for domestic hot water (Equation 2), $E_{meas,SH}$ is measured energy use for space heating, TAF is used to normalise energy use due to deviating indoor temperature (Equation 4), $E_{meas,C}$ is the measured energy use for cooling, $E_{corr,IL}$ is used to normalise energy use due to deviating internal loads from plug loads and lighting (Equation 5), OCD is used to normalise energy use due to deviating outdoor climate (Equation 6), and E_{aux} is auxiliary energy used, e.g. fans, pumps, elevators [19].

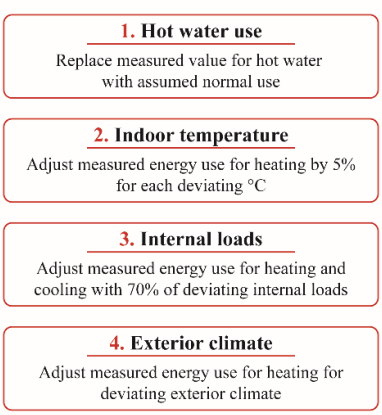

Fig. 1. Summary of static normalisation according to the Swedish national board of planning and housing (Boverket)

Hot water use

The first step of static normalisation is related to hot water use, see Equation 2.

$$E_{corr,DHW} = E_{\alpha,DHW} - E_{meas,DHW} \quad (2)$$

where $E_{\alpha,DHW}$ is the normal energy use for domestic hot water and $E_{meas,DHW}$ is the measured energy use for domestic hot water.

If $E_{meas,DHW}$ is measured including energy losses for hot water circulation, Boverket requires that 25% of the energy use for domestic hot water heating should be assumed to be energy losses due to hot water circulation. These energy losses are expected to heat the building and should therefore be included in space heating energy.

If domestic hot water is measured by volume; $E_{meas,DHW}$ may be calculated according to Equation 3.

$$E_{meas,DHW} = \frac{(V_{DHW} \times 55)}{SCOP_{DHW}} \quad (3)$$

where V_{DHW} is the measured annual volume of domestic hot water (m^3) and $SCOP_{DHW}$ is the seasonal coefficient of performance (SCOP) for the heat source. The equation is based on an assumption that incoming cold water from the municipality on average needs to be heated 47°C, from 8°C to 55°C.

Indoor temperature (Temperature Adjustment Factor)

The second step of static normalisation is related to indoor temperature, see Equation 4.

$$TAF = 1 + (T_\alpha - T_{meas}) \times 0.05 \quad (4)$$

Where T_α is the normal indoor temperature during heating season and T_{meas} is the measured indoor temperature during heating season.

Internal loads

The third step of static normalisation is related to internal loads, see Equation 5.

$$E_{corr,IL} = \frac{(E_{\alpha,IL} - E_{meas,IL}) \times I_h}{SCOP_{heating/cooling}} \quad (5)$$

where $E_{\alpha,IL}$ is the normal energy demand for plug loads and lighting, $E_{meas,IL}$ is the measured energy use for plug loads and lighting, I_h is the share of internal loads assumed to affect the heating or cooling and $SCOP_{heating/cooling}$ is the SCOP for space heating or cooling. According to Boverket, $E_{corr,IL}$ is applied/used if energy for plug loads and lighting deviates more than 3 kWh/m^{2}a. Furthermore, they recommend that I_h may be assumed to be 70 % when adjusting energy use for heating. No recommendation is given for adjustment of cooling.

Outdoor climate (Outdoor Climate Divisor)

The last and fourth step relates to deviating exterior climate. Boverket recommends normalisation by using the energy index [20] from SMHI [21]. The energy index, OCD_{EI} gives a weighted adjustment divisor based on outdoor temperature, solar radiation and wind.

$$OCD_{EI} = \frac{EI_{meas}}{EI_{\alpha}} \quad (6)$$

where EI_{meas} is the measured heating degree days adjusted for solar radiation and wind and EI_{α} is the normal heating degree days adjusted for solar radiation and wind.

2.2 Dynamic normalisation

It is also allowed to normalise the measured energy use based on repeated simulation. This means that the initial simulation, carried out during the design phase, is repeated with updated conditions regarding actual use of the building and exterior climate. The ratio between the first and second simulation is used as a factor for normalisation. Boverket states that the initial simulation and the repeated simulation has to be carried out in the same way. Furthermore, they clarify that technical parameters, such as quantities of insulation etc., must not be changed and this method of normalisation is only allowed when actual use (plug loads, lighting etc.) is verified.

3 The pre-study

The purpose of the pre-study is to create a knowledge basis for further work. This is done by examining different methods for normalisation and highlighting areas which could benefit from further development. The work is carried out in three phases, see Figure 2.

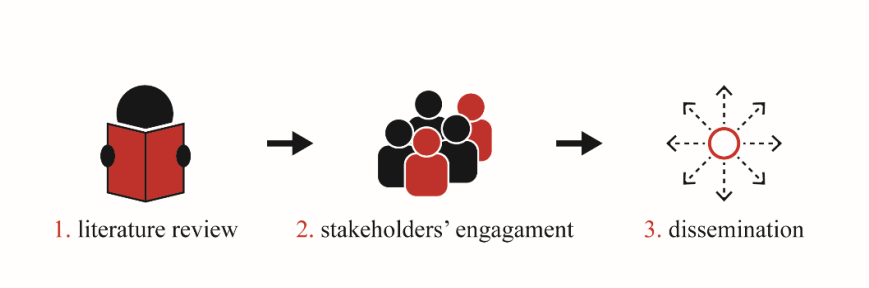

Fig. 2. Pre-study phases.

3.1 Literature review

The literature review will examine previous studies focusing on identification of important boundary conditions and parameters which may affect buildings' energy use during user phase and how deviating conditions may be accounted for by normalisation. If possible; the identified conditions/parameters will be ranked based on their impact on energy use.

3.2 Stakeholders' engagement

Public seminars will be carried out with consultants, practitioners and experts within the field. The purpose of the seminars is to gather input regarding important parameters which should be considered for normalisation of measured energy use.

3.3 Dissemination

The results from the literature review and seminars will be gathered in a report to highlight important areas for further work. The results will also be presented in a Swedish technical journal.

4 Early findings, review of methods for normalisation

4.1 Static normalisation

In Table 1, early findings regarding different energy use and aspects which are included/excluded in the static normalisation from Boverket are summarised. As can be seen, there is a large number of aspects influencing the energy use that are not included.

Based on Table 1, the static normalisation method by Boverket has the following limitations with respect to different use of energy:

- Heating; aspects such as deviating hot water use, increased/decreased ventilation, occupancy, and system losses are excluded.

- Cooling; aspects such as exterior climate, indoor temperature, hot water use, increased/decreased ventilation, occupancy presence and system losses are not included.
- Hot water; aspects such as system losses, indoor temperature and set points are not included in the normalisation.
- Ventilation, lighting, plug loads, auxiliary energy and renewable energy production; no aspects are included, there is no method for normalisation.

There are also examples where the factors used in the static normalisation lacks scientific basis. One example is the factor for deviating indoor temperature (5% per deviating °C). Previous studies have shown that deviating indoor temperature has a greater effect than the stipulated 5% per °C [5, 8, 14].

Table 1. Summary of early findings regarding energy use and aspects of normalisation which are included/excluded in the Boverket static method for normalisation.

Energy use	Aspects included in Swedish normalisation	Aspects excluded in Swedish normalisation
Heating	Exterior climate	Hot water
	Set points/Indoor temperature	Ventilation
	Plug loads	Auxiliary
	Lighting	Occupancy
		System losses
Cooling	Plug loads	Exterior climate
	Lighting	Set points/Indoor temperature
		Hot water
		Ventilation
		Auxiliary
		Occupancy
		System losses
Hot water	Hot water use	Set points/Indoor temperature
		System losses
Ventilation		Exterior climate
		Set points/Indoor temperature
		Plug loads
		Lighting
		Occupancy
Lighting		Exterior climate
		Occupancy
Plug loads		Occupancy
Auxiliary energy		Occupancy
Renewable energy		Exterior climate

4.2 Dynamic normalisation

Regarding dynamic normalisation there are no instructions regarding parameters which may be included or excluded when the initial "design simulation" should be repeated for the actual conditions regarding use of the building. E.g. is there a need to take into account relative humidity in outdoor air? – If so, it would also mean that it needs to be measured.

5 Discussion and conclusions

The static normalisation from Boverket tries, and succeeds to some extent, to include both deviating internal and external boundary conditions. The method is simple and straight forward but most likely at the expense of accuracy.

Many important aspects, such as occupancy, are not included in the normalisation. Furthermore, the terms and factors used need to be further developed and clarified. One example may be that the share of internal load that affects the heating or cooling most likely varies in relation to the energy-efficiency of the building. A second example is the normalisation due to deviating external climate; the energy index from SMHI may be applied using one divisor for a whole year, month by month or in a higher resolution, and Boverket does not stipulate which resolution should be used.

Regarding dynamic normalisation, there is much work needed to clarify this method. If the method is allowed to be vague, there is a big risk that different stakeholders will apply and use the method differently.

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