

Accepted Manuscript

Title: Bayesian estimation of a building's base temperature for the calculation of heating degree-days

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PII: S0378-7788(16)31290-7
DOI: <http://dx.doi.org/doi:10.1016/j.enbuild.2016.10.038>
Reference: ENB 7097

To appear in: *ENB*

Received date: 18-2-2016
Revised date: 18-10-2016
Accepted date: 21-10-2016



Please cite this article as: David Lindelöf, Bayesian estimation of a building's base temperature for the calculation of heating degree-days, *Energy & Buildings* (2016), <http://dx.doi.org/10.1016/j.enbuild.2016.10.038>

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Bayesian estimation of a building's base temperature for the calculation of heating degree-days

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Abstract

Measuring the energy efficiency of a building requires adjusting for factors that affect the energy demand, such as the weather. When dealing with heating energy demand, this implies calculating heating degree-days for that building from climate data and the building's base temperature. This work describes a method for estimating a building's base temperature from periodic energy consumption records such as utility bills and weather data. This method derives not only the base temperature, but also the building's heat loss coefficient, base load, and daily heating variability. Unlike other techniques, this method uses Bayesian inference and provides exact confidence intervals. The theory is laid out before testing the method first on synthetic, "ideal" data, then on a set of real energy consumption data. The heating degree-days calculated from this estimated base temperature are almost perfectly proportional to the heating demand, unlike those obtained by the use of an officially recommended base temperature. The method is implemented in a freely available package in the R programming environment.

Keywords: Bayesian inference, heating degree-days, base temperature, balance point temperature, total heat loss coefficient, heating base load

1. Introduction

Measuring the energy efficiency of a building cannot be done without adjusting for all factors that affect the energy consumption, such as the weather. Variations in outdoor temperature explain most of the variance in the space heating demands, but the relationship is not linear. Each building has a characteristic outdoor temperature, the *base temperature*, above which the building's heating demands are covered by free and internal gains. Below this temperature, the building's heating demand rises linearly. No meaningful conclusions can be drawn about the heating energy efficiency of a building without an accurate knowledge of this base temperature; yet there is no consensus on how to estimate this key parameter.

Heating degree-days (HDD) are closely related to the concept of base temperature. Defined as the integral over time of the positive difference between the base temperature and the outdoor temperature, HDD measure how "colder" than the base temperature a given period has been. In steady state, the heating demand of a building during a period will be proportional to the HDD of that period—provided the HDD were calculated from the correct base temperature.

1.1. Base temperature estimation methods

Two techniques are commonly used for estimating the base temperature of a building: (1) the *energy signature method* and (2) the *performance line method*. The energy signature method consists in plotting daily energy consumption readouts against the mean daily outdoor temperature. This yields a typical "hockey-stick" pattern, and the base temperature is found at the knee of the stick [1, 2]. But because it

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