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Regression analysis of the energy consumption of tertiary buildings

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Abstract

Energy signature methods are applied over three tertiary buildings in the UK, Sweden and Spain, based on both simulations and experimental data, for pre- and post-retrofit scenarios. Variations in their energy profiles relate to differences in climate severity, usage pattern (continuous/discontinuous) and HVAC scheduling. This study discusses the impact of such particularities for obtaining a steady-state linear regression model of the dependence of heating energy load against climate data. The choices of dataset and time step have important implications for the results obtained.

Keywords: energy signature; linear regression; tertiary buildings

1. Introduction

Energy signature models estimate the energy consumption of a building as a function of external climate data. They are typically presented as a plot of total energy consumption versus ambient air temperature [1]. However, the static nature of such methods does not consider variations induced by dynamic effects. Furthermore, use patterns and user behavior are known to have a critical impact on energy consumption. The use of daily intervals can provide additional insight into unusual energy demands compared to monthly or weekly signatures [2]. Finally, additional

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challenges are posed by the application of energy signature methods to non-residential buildings and air conditioning systems, as assumptions that hold for heating systems of residential buildings do not necessarily apply [3].

This paper discusses the suitability of different time intervals, resampling and aggregation techniques for obtaining a steady-state energy signature model of non-residential buildings. Three buildings of tertiary use are considered as case studies, assessing the impact of climate severity, usage pattern and HVAC operation on their characterization through linear regression methods.

Fig. 1. (a) University Building in the United Kingdom; (b) Secondary School in Sweden; (c) Hospital Building in Spain.

These three buildings have different uses and occupancy schedules, and cover a range of European climates (oceanic, continental/subarctic and Mediterranean).

The University Building (Fig. 1a), which houses a faculty located within an educational campus in the United Kingdom, was originally built in the 1970s. The Secondary School (Fig. 1b) is an aggregation of buildings constructed over many years, located in a Swedish city. Finally, the Hospital Building (Fig. 1c) is a facility located in the outskirts of a large city in the Mediterranean coast of Spain.

All three buildings underwent retrofit interventions to improve their energy efficiency and reduce consumption. For each of the case studies, there is available data for the original building prior to interventions (up to March 2015) as well as for the retrofitted state (from April 2016).

2. Method

Data sourced from simulations and monitoring campaigns have been compared, for both pre- and post-retrofit periods.

For both simulations and measurements, regression analysis has been performed in order to obtain the dependence of heating energy load against climate data. The mathematical identification of this dependence has been expressed as a simple linear regression, relating the rate of energy consumption Q (in kW) to external ambient temperature T (in °C), as follows: $Q \sim C_0 + C_1 \cdot T$

In order to assess the potential impact of different climate- and usage-induced patterns on the regression analysis, three different resolutions have been considered, with hourly, daily and monthly intervals. In this context, the use of energy consumption rate and temperature in the equation above (instead of energy consumption and degree-days) allows for a direct comparison of average performance among time intervals of differing length (e.g. hour to day, or January to February). It also allows the resampling of experimental measurements including missing values to coarser time intervals, as the resampling is carried out by averaging rather than by aggregation.