Temperature Analytics

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Introduction

This poster presents how temperature data analytics can be used to characterize residential homes. A full energy audit can be expensive and invasive, but new analytical techniques using smart meter data, weather data, and indoor temperature can provide information about heat transfer through the envelope of the building. The envelope includes the entire outer surface of the structure, including walls, roof, windows, basement, etc.

As connected devices like smart thermostats proliferate in homes, their data can be used to improve building energy efficiency. Analysis can indicate which parts of the building are energy inefficient, and therefore suitable for a retrofit. Additional data, such as indoor humidity or temperature in multiple rooms, enables more detailed information on the building envelope.

Many benefits can be realized by this type of analysis:

- Energy saving incentives can be targeted more effectively
- The approach scales better than energy audits, so larger samples can be assessed
- Reduced number of expensive/invasive full energy audits

Methodology

In collaboration with the Sacramento Municipal Utility District (SMUD), a sample of homes was equipped with interior temperature sensors as part of an investigation into temperature analytics techniques. ADM simulated thousands of homes with various building characteristics in Sacramento using EnergyPlus software and R analysis tools. We designed a large parametric study of residential buildings, and then applied several algorithms to match the data from the real home sample to the simulated population.

We applied three models for envelope characterization:

1. Delta enthalpy regression coefficients. If indoor humidity data is available, then an analysis of the change in enthalpy between indoor and outdoor air is possible. Physically, an energy analysis using enthalpy is more effective because it captures energy associated with condensing or evaporating water, which can be very significant in humid areas.
2. Differential equation coefficients. Time constants are calculated from time series data for the building transient response, and used in envelope characterization.
3. Delta temperature regression coefficients. A regression equation describing the energy consumption of each building is completed utilizing the change in temperature.

Coefficients from all three approaches were used to match the sample buildings to units in the simulation population. The statistical method used is the K Nearest Neighbor (KNN) algorithm to find the most similar simulated home.

Conclusions

The best results were found modeling the building envelope as a function of the change in enthalpy. The coefficients were the most physically accurate given that it captures energy used to change the moisture content of the air. If humidity information is not available, indoor temperature information can be used to gain information about the effectiveness of the building envelope, especially in a dry climate.

Using the transient response time constants proved less effective than the other two methods for characterizing buildings using this approach. The reason is that there are limited conditions during which the effects are distinct enough to detect above the noise; time constants are most apparent when the HVAC system is not being used, but the change of temperature from indoors to outdoors is high.

Modern commercial building energy management software can trend a plethora of data, including temperatures in various zones, HVAC and fan operation status, economizer position, and others. If that much information was available in residential homes, analytical approaches could easily yield information about the building envelope or energy saving opportunities. Currently, most residential homes do not have indoor temperature data available to the utility or an energy evaluator. However, home automation trends, digital assistants, smart thermostats and smart meters are all growing in popularity, and each can provide new opportunities for new energy evaluation approaches.