Characterizing California Houses for DR Control

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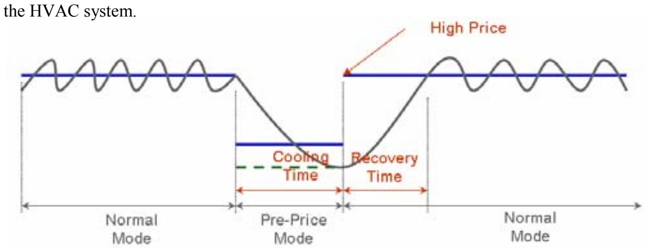
Introduction

As we develop a demand response enabled thermostat, we must also develop an environment in which to test it that represents the range of California housing stock where it will be deployed.

In preparation for testing the thermostat, control strategies and data-collection infrastructure in physical houses, we are testing the thermostat control strategies on a range of simulated houses. We are using MZEST (a multi-zone extension of the simulation code (California residential engine or CNE) used by CALRES, the energy simulation software distributed by the California Energy Commission used for demonstrating compliance with the state residential Title-24 energy standards) to test the ability of the thermostat's internal model to learn "out of the box" about the thermal characteristics of the house were it is installed in order to optimize the control of the air conditioner during peak electricity use.

The likely users of demand responsive control systems are considered to be homeowners rather than renters. Most owned housing units (88%) are single family dwellings, both attached and detached. This represents about two-thirds, or 64% of the 12.2 million housing units in California (US Census Bureau, 2000).

In order to predict how Demand Response-enabled thermostat will work in these residences, key characteristics that affect their thermal and electric loads (particularly during peak demand) must be identified. The solar orientation of the house, percentage of window area, foundation system, amount of insulation, window type, equipment efficiency, air infiltration, equipment sizing, house volume, the climate zone where the house is located, and the time of year all affect the thermal and electric load profile of a house. Further, the thermal mass of the house will affect the time between when a heat gain occurs and when it appears as a load on the HVAC system.



Cooling Time and Recovery time are dependent on 4 primary house parameters

Building envelope (conductance + infiltration)
Climate (solar + thermal gains)
Air conditioner (size and efficiency)
Thermal mass of the structure

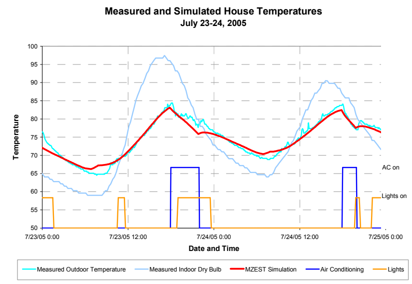
Methods

The Demand Response Electrical Appliance Manager (DREAM, our Java control engine for air conditioning control) can control an air conditioner in a simulated MZEST model the same way it will control an air conditioner in a real house. Because field testing the DREAM in a range of real California houses is not practical due to the need to instrument the houses and log data, the long periods of time required to run the tests, and the variability of weather conditions, we interfaced the simulation with DREAM with TCP/IP data transfer. MZEST writes outdoor temperature and zone temperatures directly to a file and DREAM reads those temperatures as if they came from sensors and, using its control strategies and our price simulation, determines how to condition the house. DREAM then dictates to MZEST, through the same file transfer method, whether to heat or cool the house.

Because we can simulate many different kinds of houses, we will be able to predict the effect of our demand response control strategies on the energy use profile of a range of house types located in any California climate zone. We can also test the smart thermostat's ability to learn about the thermal characteristics of its environment using this method.

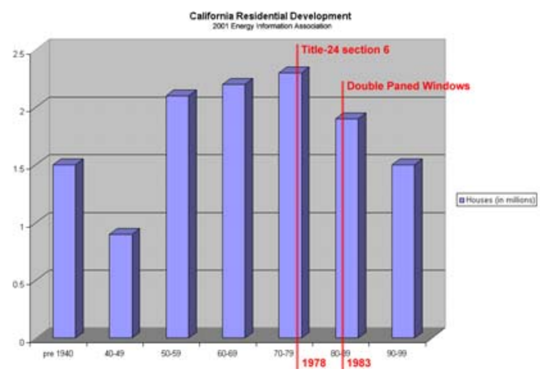
House Development

Moraga House



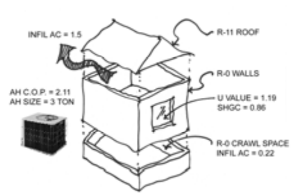
The initial MZEST model we created is a representation of a real single-story house in Moraga where simulation results were validated against measured indoor zone temperatures using identical outdoor weather conditions.

Because the thermal performance of the building envelope and air conditioner equipment have improved over time (due to more efficient window technologies, equipment efficiencies, and insulation values mandated by code) it is important to test the thermostat control strategies on houses with both low and high insulation values as well as with low and high SEER rated air conditioners. Further, because the heat storage capacity of slab-on-grade foundations has the potential to attenuate loads due to high heat gains, it is important to include houses with slab-on-grade foundations in our simulations.

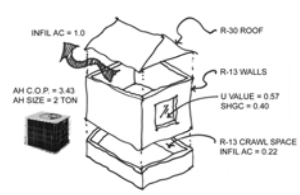


Because roughly half of the existing California housing stock was constructed before the first Title-24 energy standards took effect in 1978 a subsequent model were developed from the original to represent characteristics typical of a generic house built before the Title -24 energy efficiency standards were implemented. This house is assumed to be poorly insulated, with single-pane windows and equipment efficiencies typical of the 1970s.

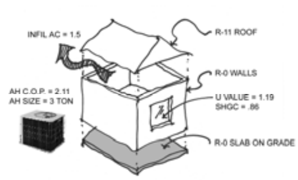
To represent the opposite extreme, yet still cover a large cross-section of California housing stock, a post-1992 model was developed representing a generic house with windows, insulation values and equipment efficiency meeting the minimum for Title-24 compliance. Further, because of the important role that thermal mass plays in the attenuation of heating loads, we modeled both a crawl-space model and a slab-on-grade version for each category (see below).



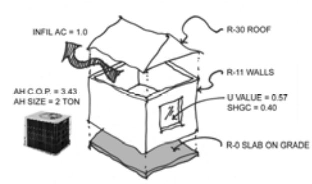
Pre **1978** Crawl Space Model



Post **1992** Crawl Space Model



Pre **1978** Slab on Grade Model



Post **1992** Slab on Grade Model