Demand Response Enabled Thermostat

Control Strategies and Simulations

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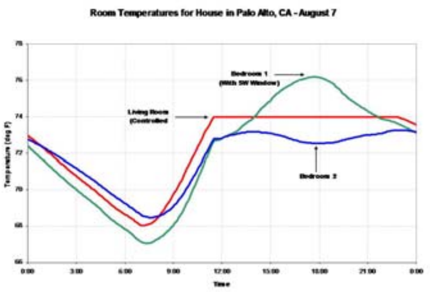
Simulation Engine

We use the Multi-Zone Energy Simulation Tool (MZEST) to simulate the energy use of houses. MZEST is a multizone extension of the simulation code used by CALRES, the energy simulation software distributed by the California Energy Commission used for demonstrating compliance with state residential Title 24 energy standards. We chose MZEST because it can predict the temperature in several thermal zones and because we had access to the source code.



We interface the simulation directly with DREAM (Demand Response Electrical Appliance Manager), our Java control engine for all air conditioning and electrical loads. This will enable us 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.

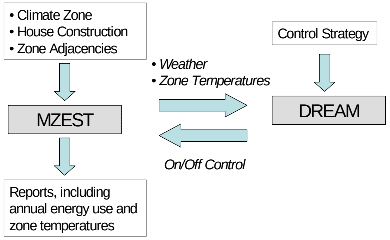
The tool uses 5-minute steps, which will allow us to use an external controller to control MZEST in the same way that the controller would control a real house.

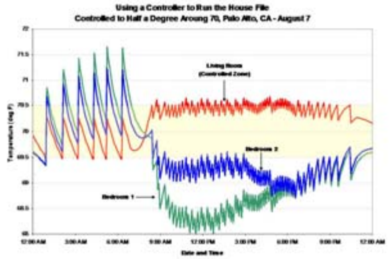
Currently, MZEST heats or cools the modeled house to meet the needs of only one zone (the control zone). The other zones are conditioned, but will generally not exactly meet the setpoint, especially if there are large internal gains (see chart to the left) or some other influence on the temperature of the zones.

External Controller

The controller (DREAM) can run MZEST the way a thermostat runs a house. Using outdoor temperature and room temperatures, the controller dictates to MZEST whether the heating or cooling is on or off (see chart below left). MZEST then computes the new room and outdoor temperatures and provides feedback to the controller. The controller will be able to learn the behavior of the house and preferences of the occupants and tailor its conditioning strategy accordingly. The controller will also incorporate the price of electricity into its control strategy.

The chart to the right shows the room temperatures of the Palo Alto test house when the living room is being controlled to within a degree around 70°F by a simple controller running MZEST.





Test House – Palo Alto, CA

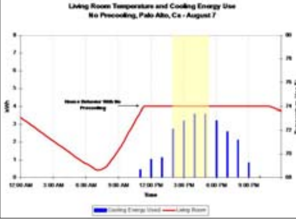
We modeled an existing detached single family residence in Palo Alto, California. This 985 square foot house has two bedrooms, two bathrooms, and a great room combining with living room, dining room and kitchen. We tested various cooling control strategies using this model. Control strategies include no setback, setback, demand response setback, and demand response setback with precooling.

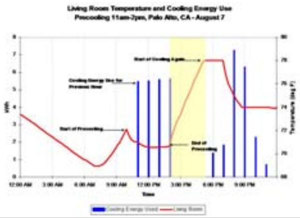
Precooling

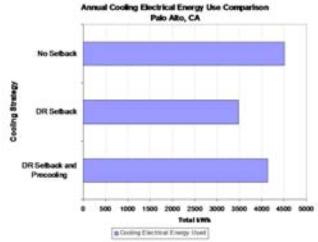
Precooling is a strategy used to reduce energy consumption during peak energy demand periods. The air conditioning is turned on before the peak energy demand period. During peak hours, the setpoint is raised to reduce air conditioning use and the temperature slowly rises in the house.

The graphs below show the temperature of the test house living room when controlled to a single cooling setpoint during the day (left) and when precooling is implemented between 11 am and 2 pm (right). The graphs also show hourly cooling energy use.

While precooling uses more total energy for cooling than setpoint setbacks, the energy is not used during peak demand period between 2 pm and 5:30 pm (see below). Certain precooling strategies use less energy for cooling annually than not using any setbacks.



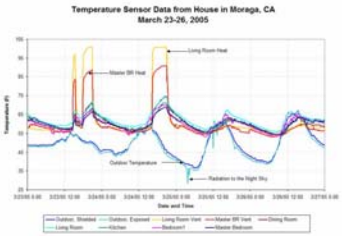


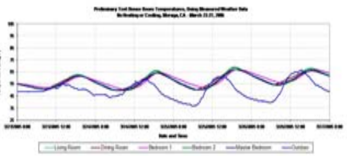


Test House – Moraga, CA

We are also modeling this existing detached single family house located in Moraga, California. This 1800 square foot house has three bedrooms, two bathrooms, bar, living, dining, kitchen and den.

We have modeled the house in MZEST and will be using DREAM to control both the simulation and the actual house.





Monitoring the House

We are monitoring the weather and house temperatures of the existing house in order to check that our simulations are accurate. Room temperatures and the outdoor temperature are measured with dataloggers and will be measured with Telos radio motes at 1-minute intervals for the DREAM controller. The recorded weather data are used to create weather files for the simulation so that behaviors of the house and the simulation can be compared under the same weather conditions.

The use of the airhandler for both heating and cooling is also recorded, so that conditioning behavior can be scheduled into the simulation to ensure that the house room and surface temperatures are accurate. Recent measured weather data, room temperatures, and conditioning activity are shown in the chart to the upper left.

Simulating the House

The preliminary simulation results of room temperatures are shown in the lower left chart, with the house in float mode. This simulation uses a weather file created with temperature data recorded by the dataloggers. The living room has been designated the control zone.

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