Title

Controls and User Interface

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Publication Date
2004

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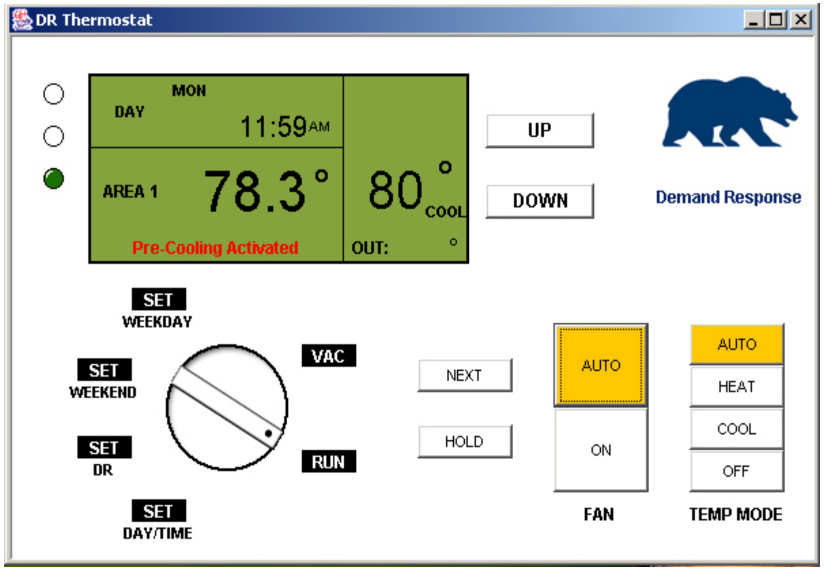

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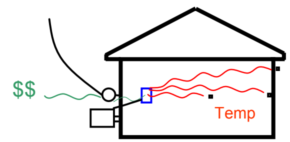
Thermostatic to 'Thermodynamic' Control

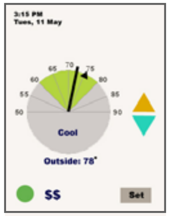
Electromechanical Thermostat

Digital Programmable Thermostat



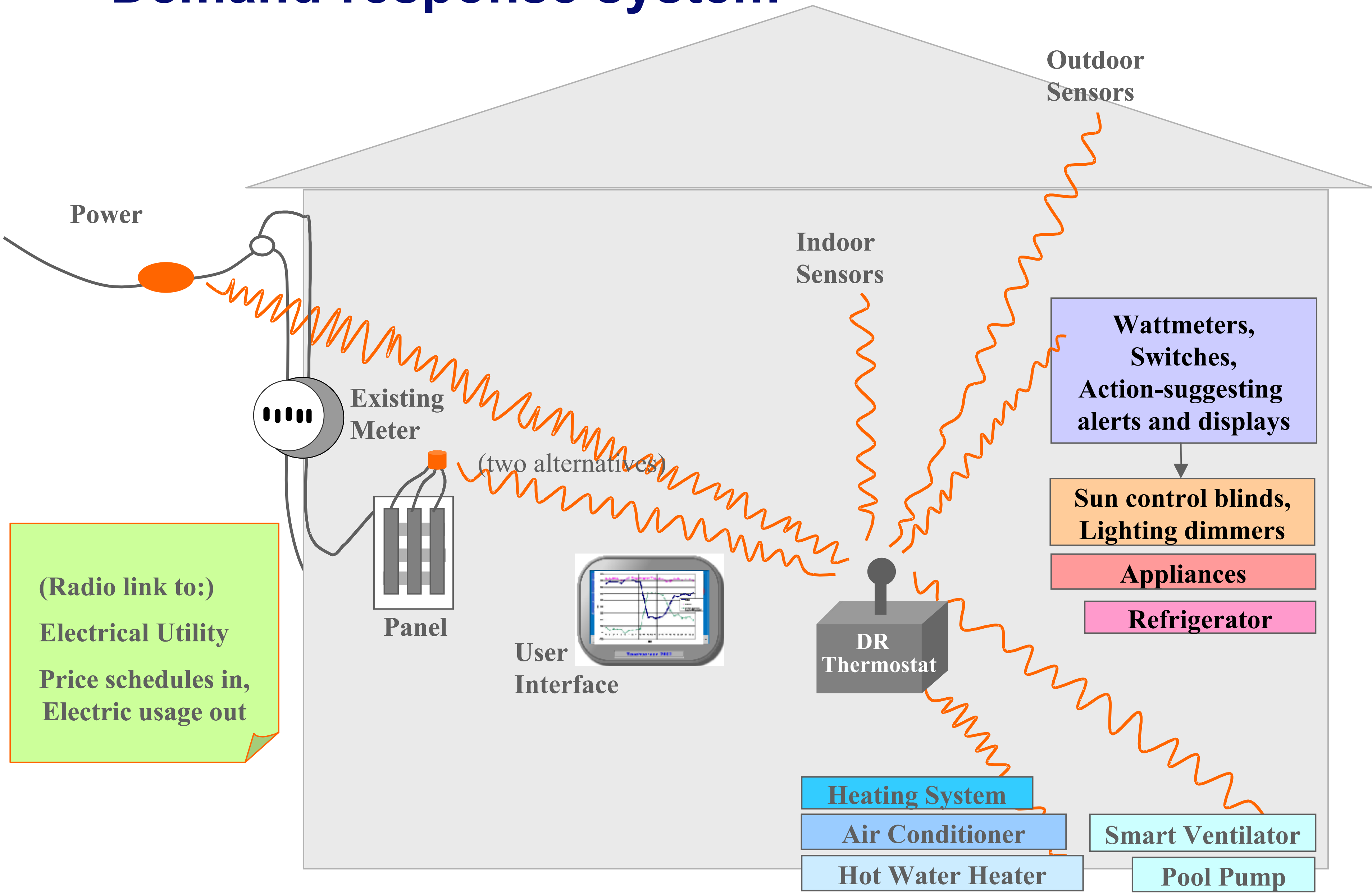
Demand Response House

Virtual DR Thermostat



Learning Mobile DR Thermostat

Demand-response system



Occupant interface concepts

Interface and Controls

Challenges:

- Interface that's easy to understand and intuitive to use—covering both comfort and cost.
- Algorithms that optimize energy savings and comfort as energy prices vary.
- Ability to manage environmental energy usage to a fixed user-selected monthly bill.
- Control strategies that can account for low network quality or complete network failure.

Thermostat: Simple to Install, Simple to Use

- As delivered, the thermostat must work adequately in any size or shape of house
- Installers should be responsible only for physical installation
- The thermostat must be able to set all of its internal parameters
- The users (occupants) express feelings (too cold) and preferences (too expensive) only
- The thermostat learns from the occupants to respond to environmental and price changes

Learning about the house

- As delivered, the thermostat must work adequately in any size or shape of house
- Even if the occupants never touch the thermostat, it will learn about house dynamics (how long it takes for changes to take effect), zonal differences (many sensors in the house even if there is only one actuation zone), etc.
- It will use this knowledge for appropriate setbacks, pre-conditioning, pre-cooling to reduce load in a peak (DR) period, matching conditions to desired cost, ...
- Diagnostics of sensors and actuators based on learned "normal" behavior

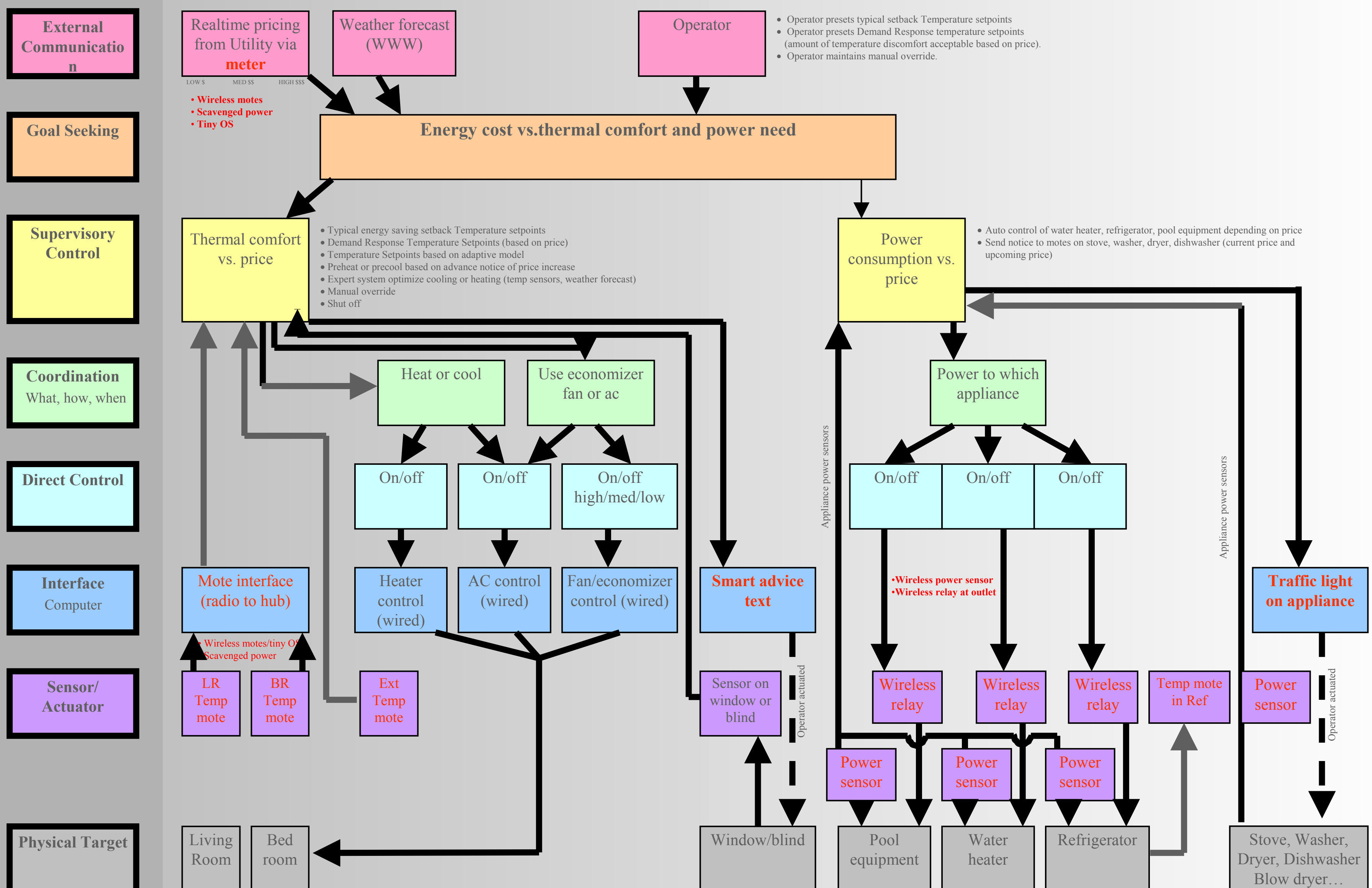
Learning about the occupants

- As delivered, the behavior should work for a significant portion of the population
- Even though it must be VERY easy to use, many users will not have to do anything
- Context-based interface - the user only sees a few items at a time (think ATM)
- Provide linguistic input wherever possible ("I'm very cold now") - temperatures can be used if desired, but not necessary
- Simple timelines for schedule changes
- Cost targets in accessible terms (monthly bill)
- Explanations for actions ("it's probably warmer than you'd like but it would be more expensive to make it cooler")

DR Thermostat (Controller) Design

- Built hierarchically for maximum flexibility
- Built from portable code (Java) so that the same controller can be used in:
  - Pure simulation on a workstation to develop concepts, study variability across very wide variety of houses, optimize algorithms, test abnormal operation (malfunctions)
  - Model house (see our demo!) to prove concepts in a near-real-world environment
  - Real house

Demand Response Thermostat Control Levels

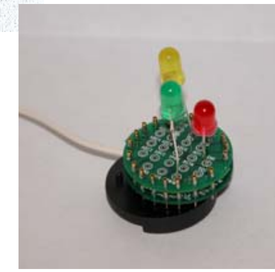


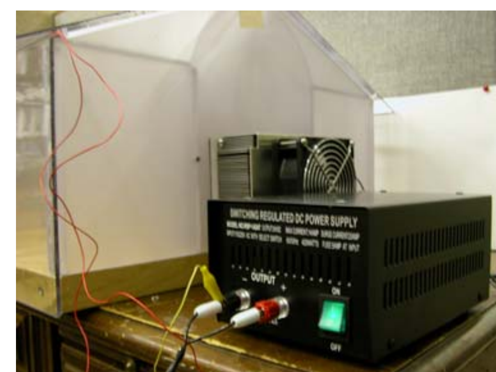
DR System Simulation and Control

Java code simulates:

- House thermal behavior
- DR control algorithms
- Wireless network communications
- Will actually control model and full-sized test houses via the wireless motes

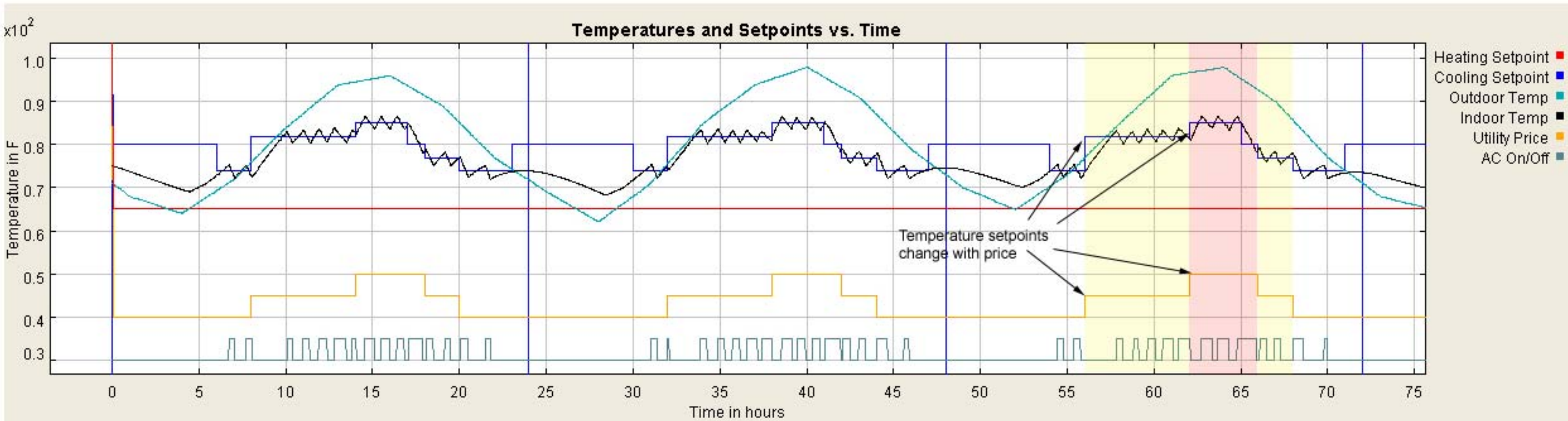
Model House with Sensor/actuator Motes



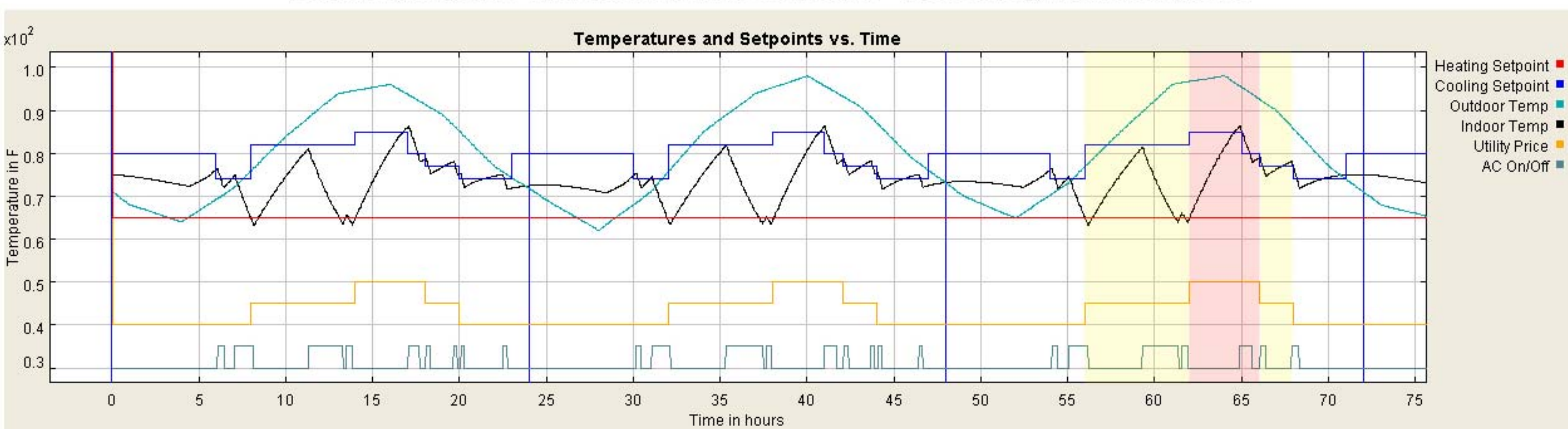


Simulated House Using Two DR Control Strategies

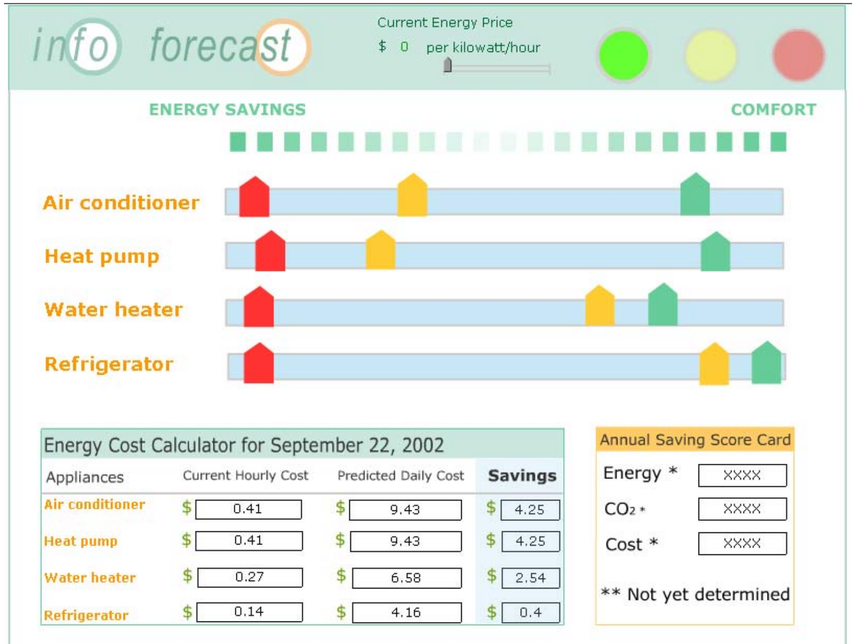
Demand Response Thermostat: Price Setpoints



Demand Response Thermostat: Price Setpoints + Precooling, Insulated house



Obtaining User Preferences



We have examined various versions of interface—the challenge is to balance energy cost and comfort.

Thermostat Prototyping

Working,interactive thermostat simulated on PC screen

Thermostat and signaling motes fabricated using rapid prototyping

Broader Context: Sensor Nets for Building Control