

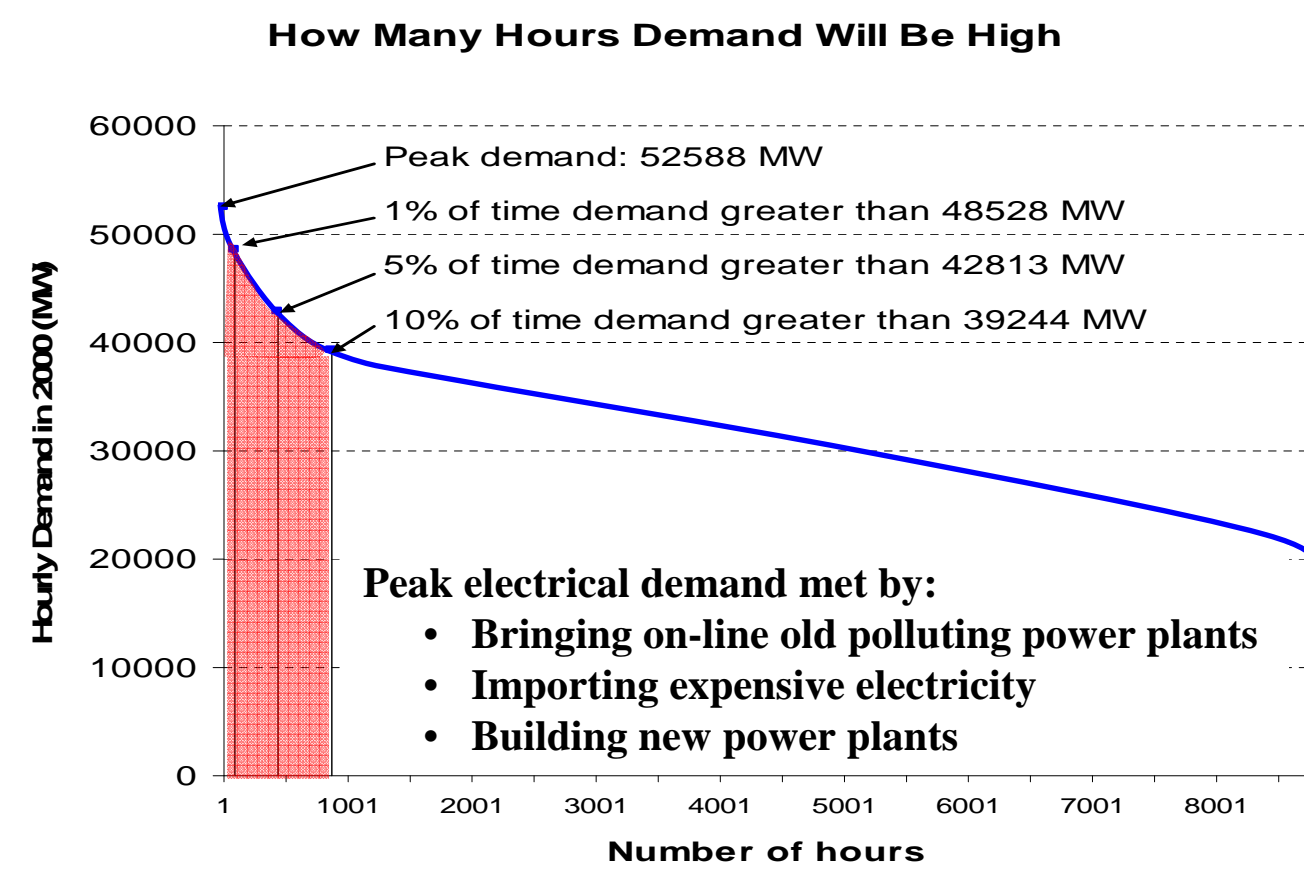
Smart Comfort at Home: Design of a residential thermostat to achieve thermal comfort, and save money and peak energy

Therese Peffer, PhD Candidate, Architecture, UCB
 Professor Edward Arens, Architecture, UCB
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Vision

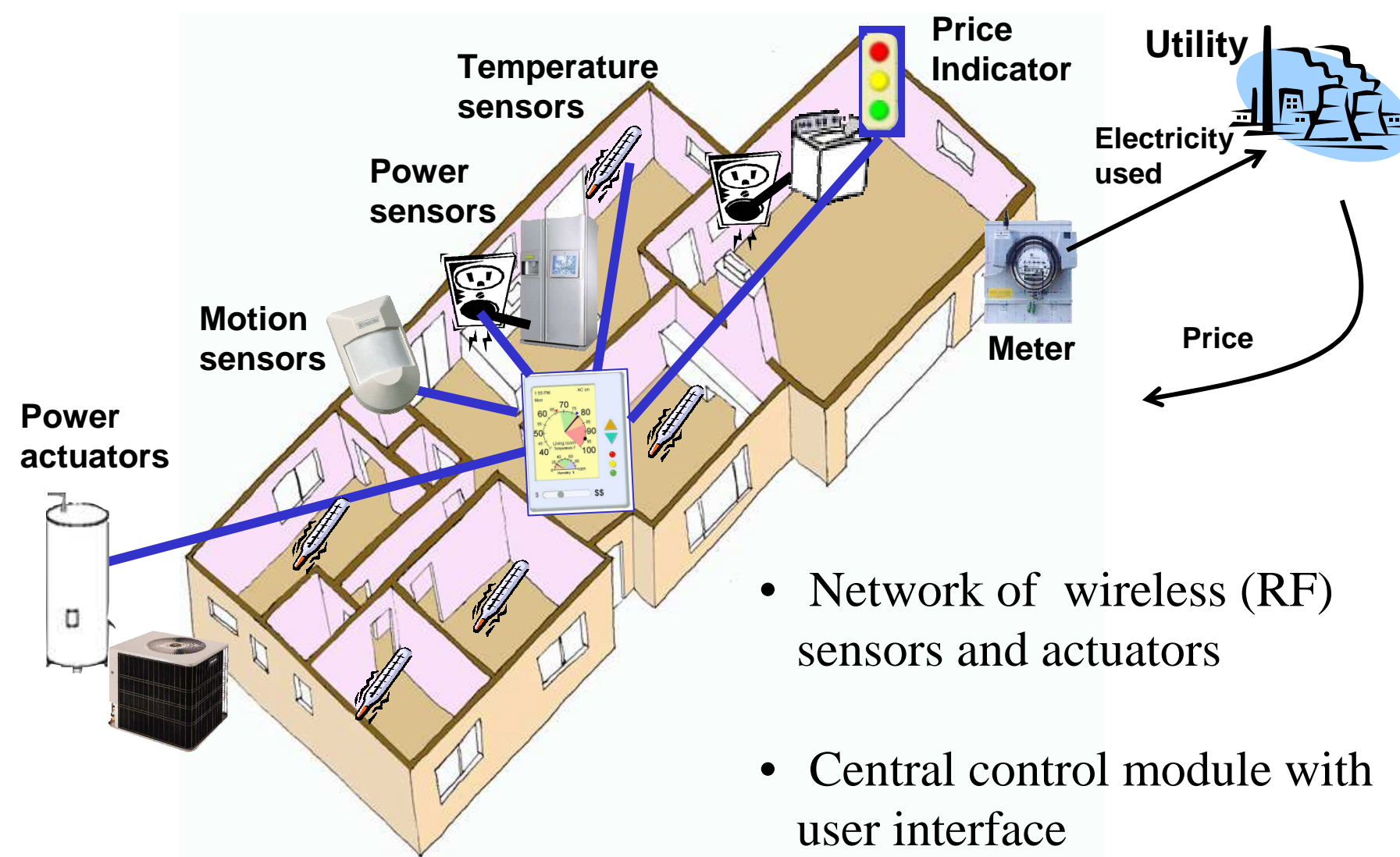
Problem: Peak electrical demand: only 1% of the time, California needs the equivalent of an additional 8 small power plants to meet electricity demand (usually air conditioning loads).

Goal: To develop technology that will enable residential customers to reduce electrical consumption during periods of peak demand (Demand Response or DR).



Design: the Demand Response Electrical Appliance Manager (DREAM):

- Receives price, reliability and emergency signals from the electrical utility.
- Responds with automatic measures (i.e., turn down thermostat/turn off pool pump).
- Responds with feedback and advice to occupant (i.e., delay clothes drying).



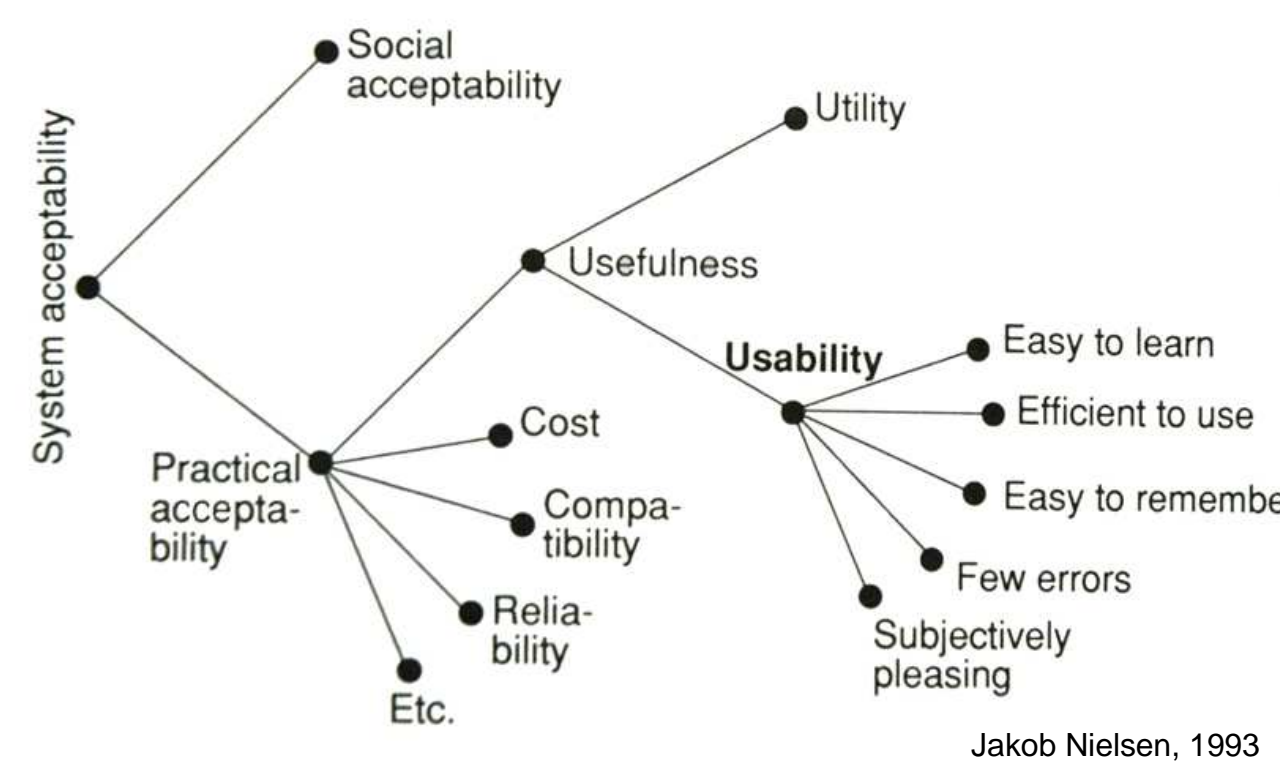
- Network of wireless (RF) sensors and actuators
- Central control module with user interface

Background

Consumer adoption:

The State of California is already assessing the inclusion of Programmable Communicating Thermostats (PCT) into the 2008 Title 24 energy code for new residential construction for Demand Response (DR) purposes.

While there are many residential DR programs across the country and have been for over 20 years, the vast majority are utility-controlled (i.e., ac-cycling, where the utility turns off the air conditioner during peak periods), and these are not widely accepted or adopted by consumers.



Manual Thermostat: Easy to use, but requires user to change often for energy savings.



Programmable Thermostat: Hard to use, and even when programmed, may not save energy



Design of Technology:

EPA's EnergyStar recently withdrew their endorsement of Programmable Thermostats because of lack of evidence that they save energy (thus, probably not a good model for the PCT).

Half of the households in California have Programmable Thermostats, and of these an estimated 65% use them as designed.

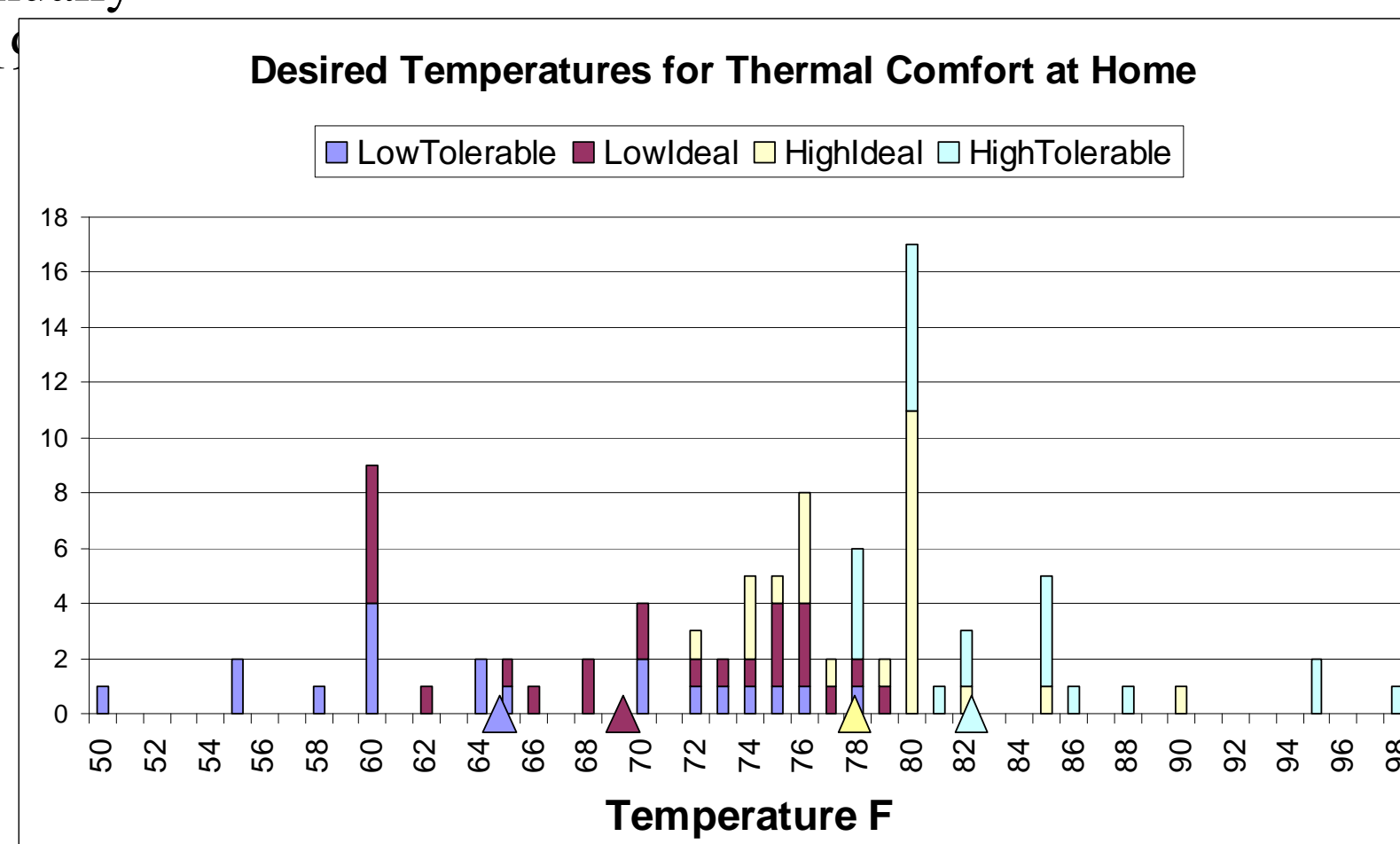
Research shows that having the perception of personal control in and of itself increases the range of thermal comfort temperatures. Kempton et al found that 75% of residents in a multi-family building did not use their thermostats but controlled cooling manually (Kempton, Feuermann, & McGarity, 1998).

Variability of Users:

Household energy consumption is highly stochastic: identical houses may vary 100% in energy consumption.

Comfortable temperature ranges in houses is highly variable.

One quarter of California's households use one-half of the residential electricity.



Hackett and McBride, 2001, Interviews with 30 people, Davis, California

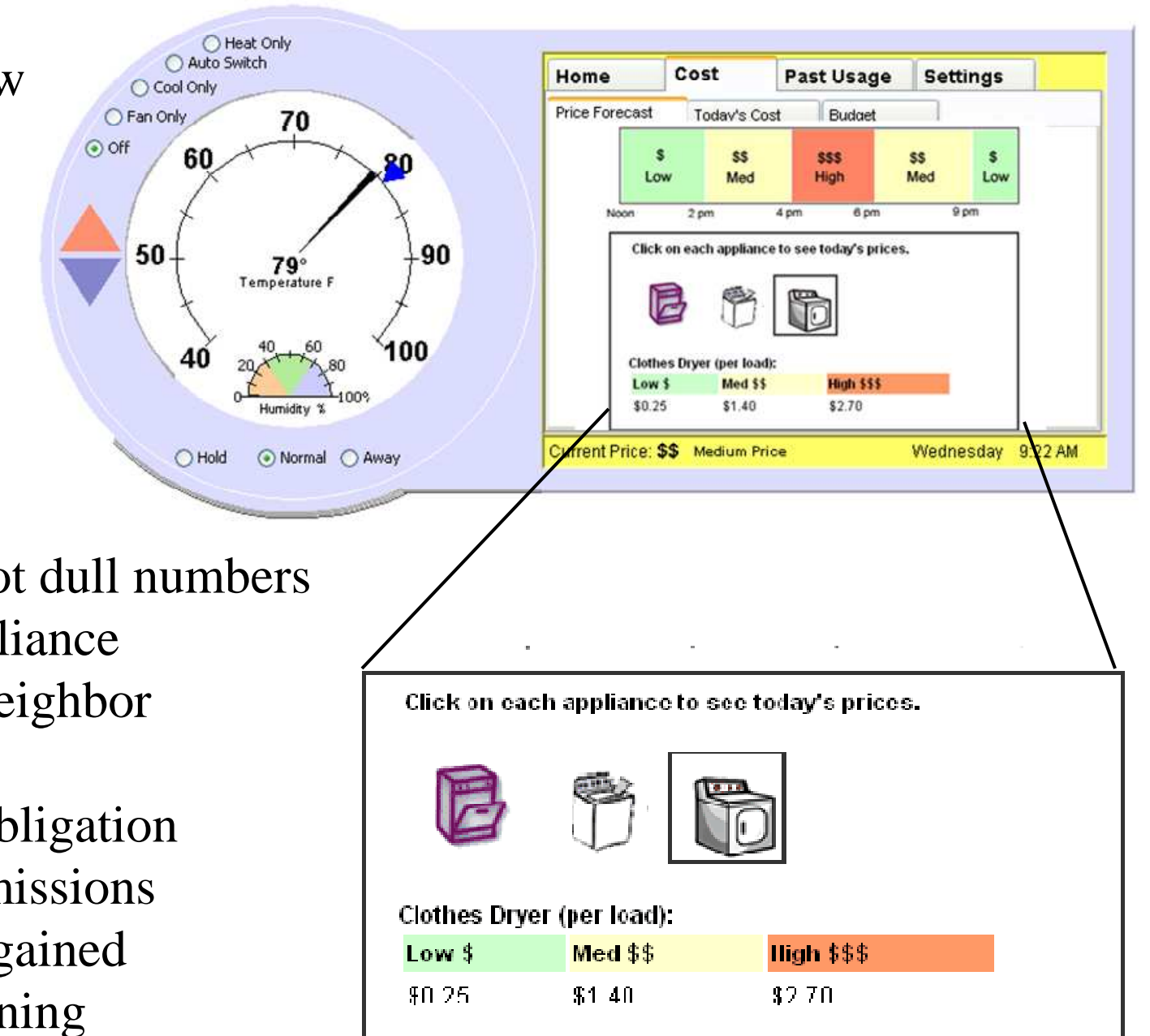
Methods

User empowerment for more successful adoption of technology:

David Wyon's 3-I's model includes providing insight (how does the device work, what is the need for it?), information (feedback, how is the system working), and influence (allow the user control).

Design of Interface:

- Allow the user to control
- Provide feedback
- feedback + advice is effective
- information should be humanized, not dull numbers
- provide energy consumption per appliance
- compare energy consumption with neighbor
- Incentives should include:
 - Social: imitative (role models) and obligation
 - Environmental: fewer greenhouse emissions
 - Financial: look at how much lost vs gained
- New devices require education and training

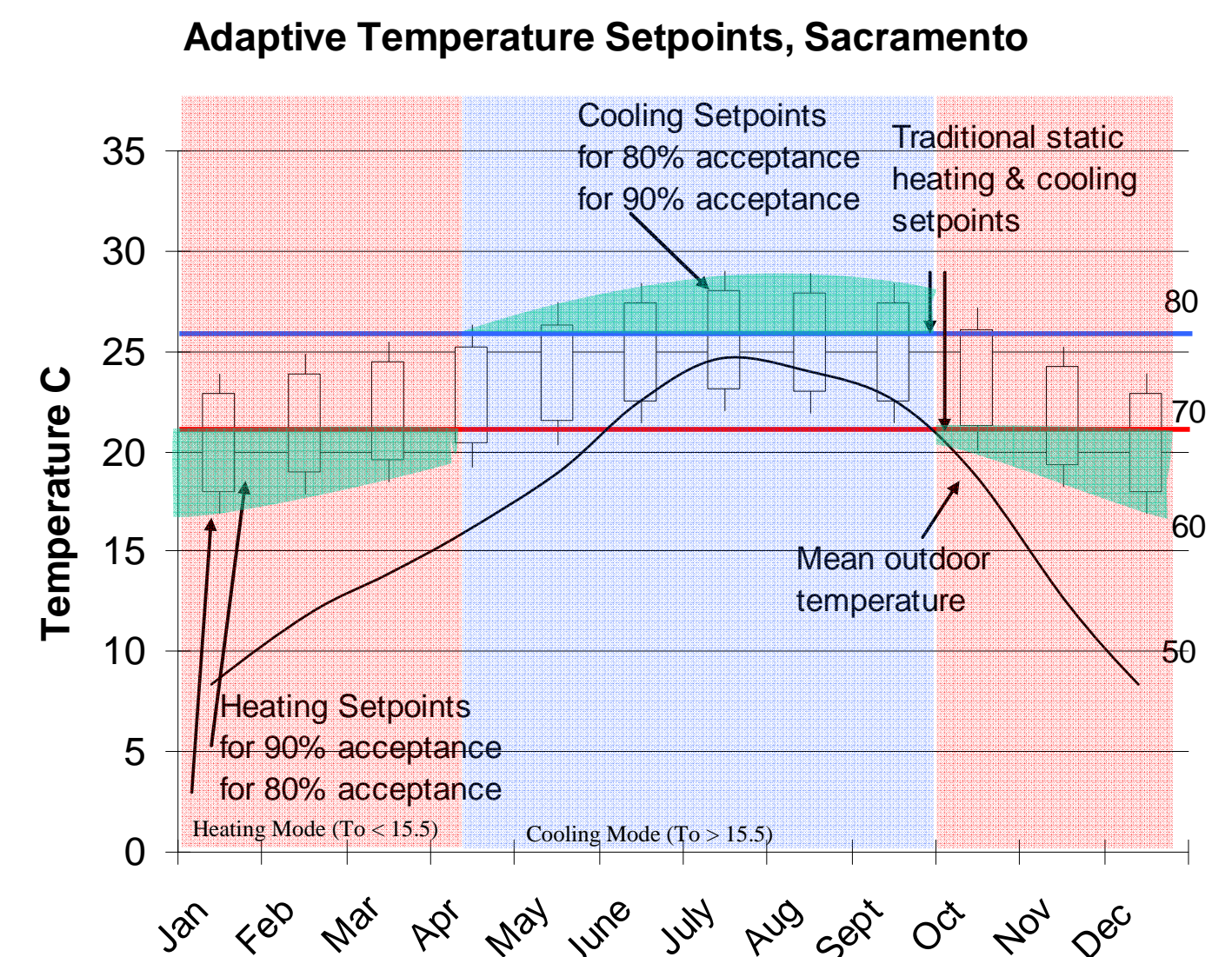


Dynamic temperature setpoints:

Studies show that people tend to change their thermostat settings based on the changes in season and outdoor temperature.

Seasonal and Daily Temperature Settings:

Following the Adaptive Comfort Standard, an algorithm was written to create temperature setpoints from a weighted running average of the outdoor temperature; these setpoints drifted also with the daily peak in temperature.

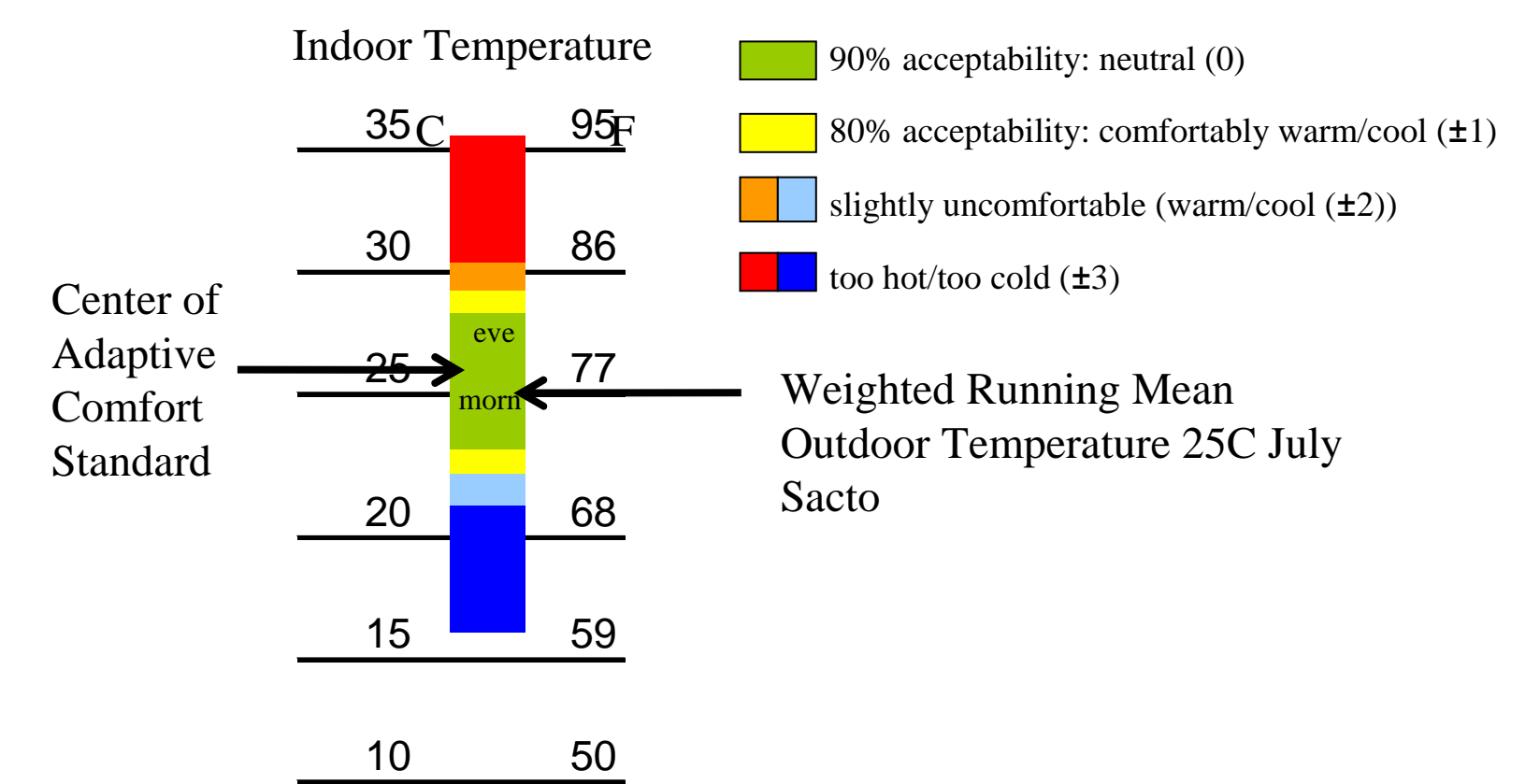


The graph to the right shows the energy savings possible (shaded areas) compared to the traditional static heating and cooling setpoints found in a programmable thermostat.

Provide feedback between comfort and cost for increased adoption.

Comfort Index:

The graphic to the right shows a comfort index of indoor temperatures based on the Adaptive Comfort Standard. The comfort zone changes with the seasons based on the outdoor temperature.

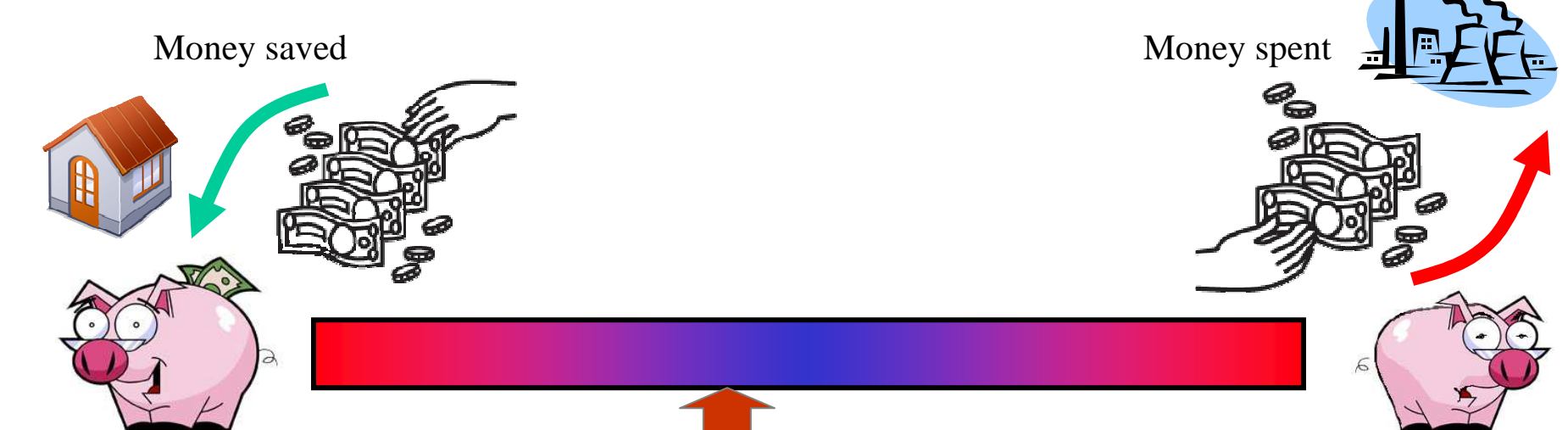


This comfort index allows us to place a value on comfort and give the occupant feedback as to how much comfort costs.

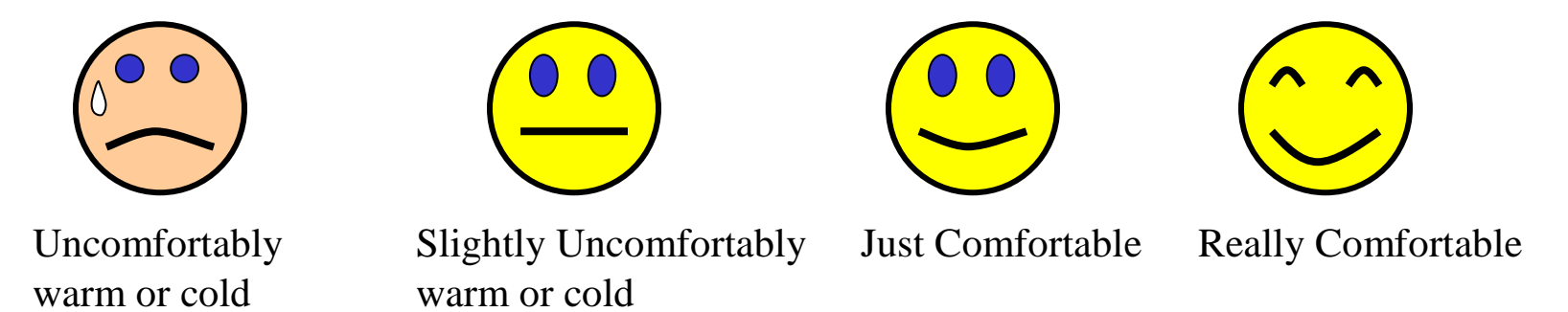
Economic and Comfort Index:

Combining the comfort index with a cost index created a slider bar in the user interface, where the user could set their economic and comfort preference. For example, a student may decide to bear some discomfort when the price of electricity rises during peak demand periods in order to save money. But if guests were coming over, the student might change the index to spend a little more money for better comfort. The interface would inform the student how much comfort or discomfort to expect for the cost as well as how much the cost might change based on the increased or decreased level of comfort desired.

Economic index



Comfort index



DRETD

Demand Response Enabling Technology Development

Therese Peffer therese.peffer@gmail.com

