Genie: A Longitudinal Study Comparing Physical and Software Thermostats in Office Buildings

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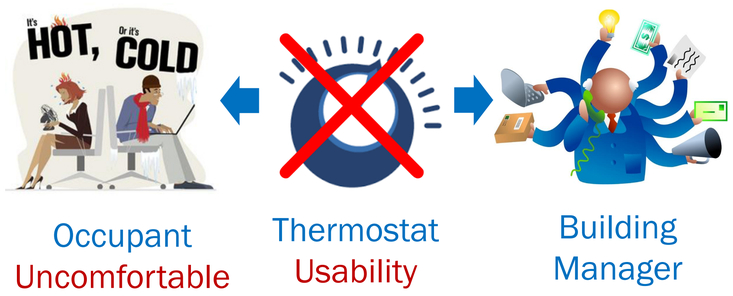
Can We Supplant Old Thermostats with Software Apps?



Occupant Uncomfortable

Thermostat Usability Problems

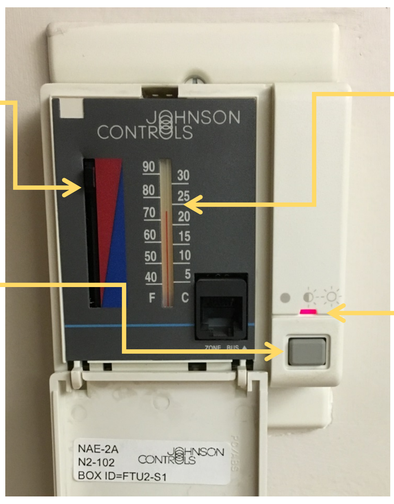
Building Manager Complaints!

Thermostat Unusability

- Occupant discomfort
- Energy inefficiency
- Complaints to building manager

Retrofitting is expensive

- Each thermostat replacement costs ~$1000



Slider to Adjust Temperature ± 1°F

Temporary Occupancy

Press for 2 hours of HVAC operation

Zone Temperature 60°F to 80°F

Status LED

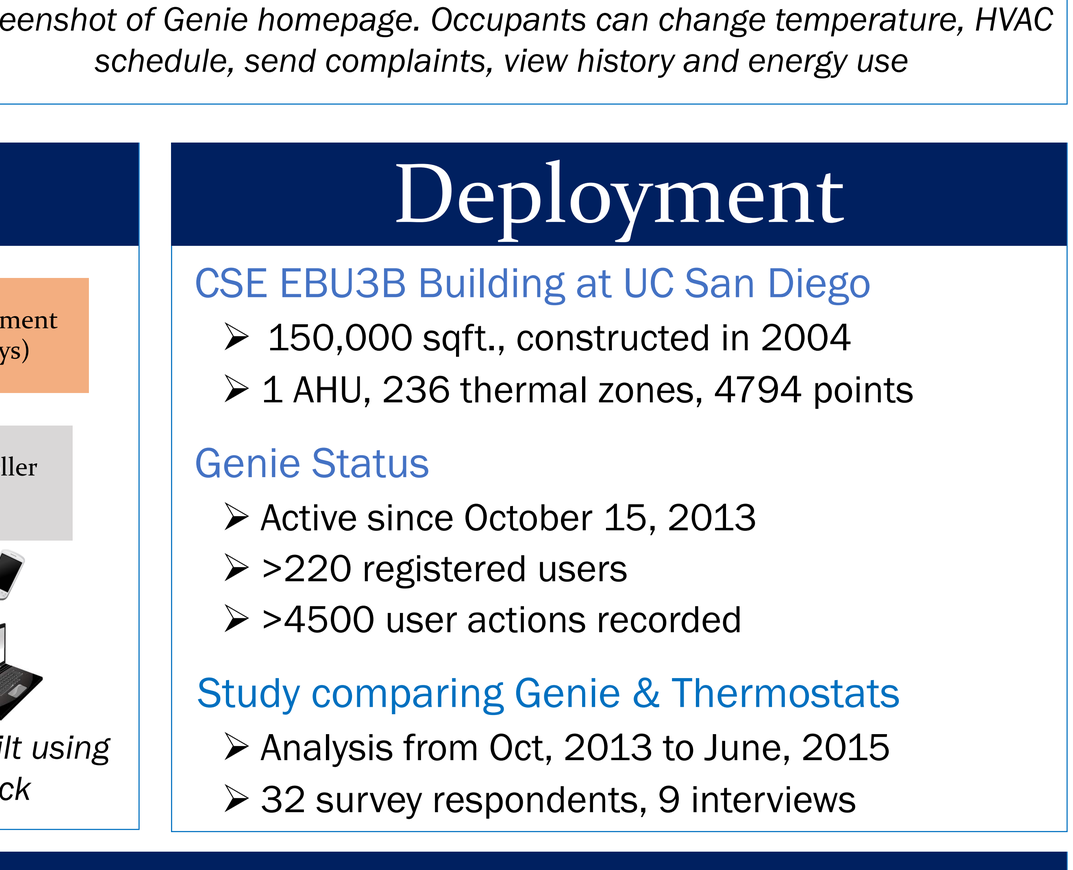
- On -> Occupied
- Blink -> Standby
- Off -> Unoccupied

Figure 1: Thermostat in a UC San Diego building

Thermostat Problems

- Slider doesn't provide temperature
- No access on weekends
- Accidental blocking of thermostat
- No feedback to building manager
- No energy information

Genie: Our Software Thermostat



Screenshot of Genie homepage. Occupants can change temperature, HVAC schedule, send complaints, view history and energy use

How does it work?

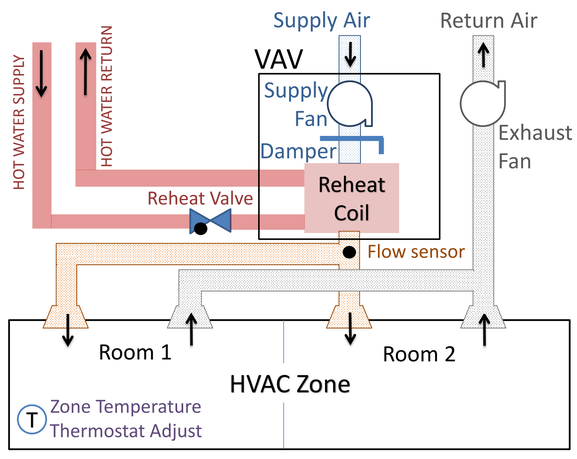
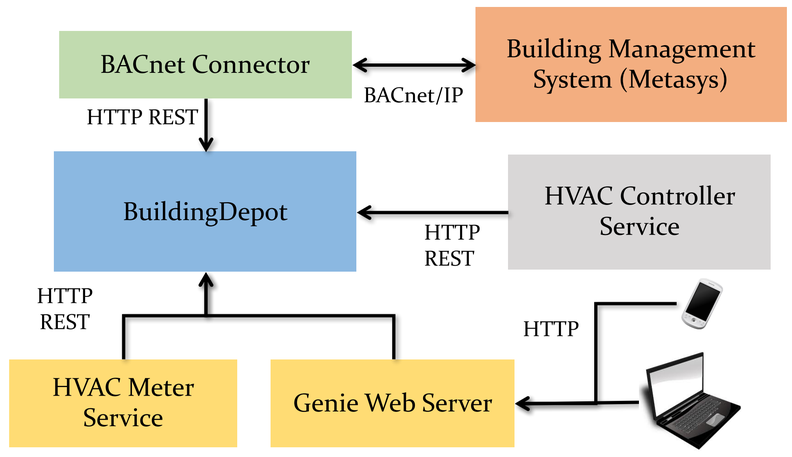


Figure 3: Building is divided into zones. VAV controls local temperature of a zone



Genie is based on RESTful Web Services. It is built using open source BuildingDepot and BACnet stack

Deployment

CSE EBU3B Building at UC San Diego

- 150,000 sqft., constructed in 2004
- 1 AHU, 236 thermal zones, 4794 points

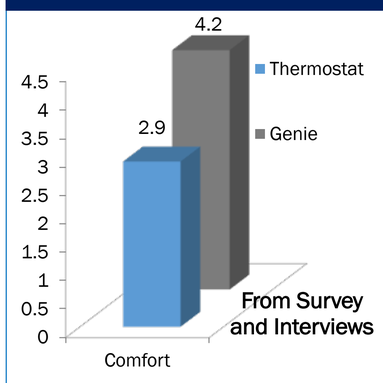
Genie Status

- Active since October 15, 2013
- >220 registered users
- >4500 user actions recorded

Study comparing Genie & Thermostats

- Analysis from Oct, 2013 to June, 2015
- 32 survey respondents, 9 interviews

Thermostats vs Genie



Users more comfortable

Thermostat

I was freezing to death. You can shut the door if that helps. I was freezing to death and I didn't know where the thermostat was…

Because it just blows down on me so forcefully that I actually went on top of my desk and I taped a manila folder to my ceiling

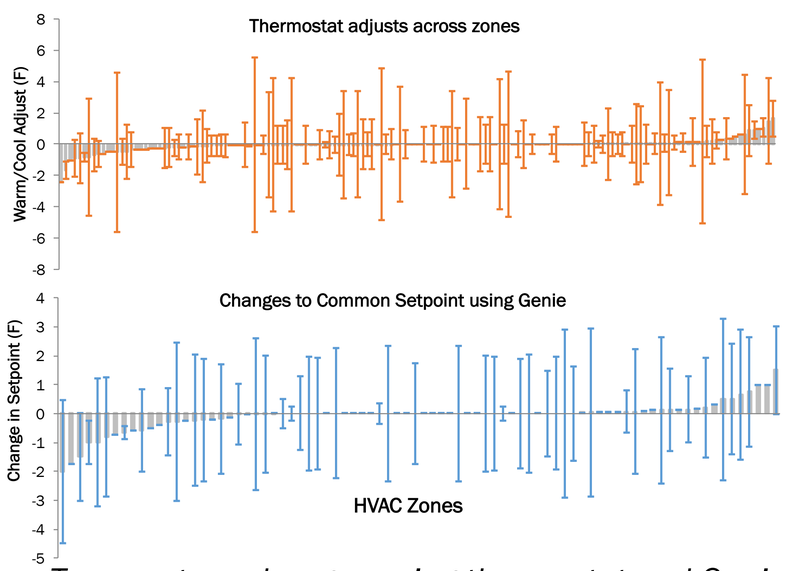
Genie

Digital control of the temperature is very, very useful. Moving the slider [on the thermostat] still leaves a lot of uncertainty as to what exactly will happen, and the temperature setting helps

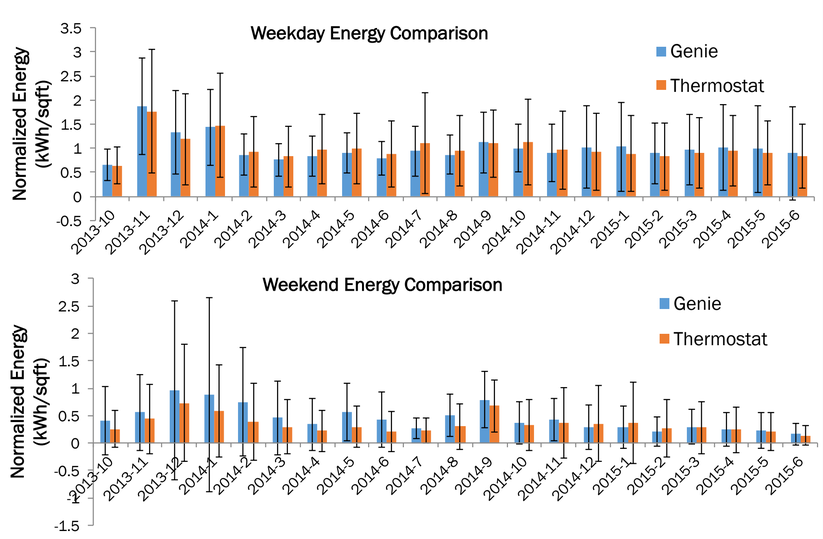
Table: User engagement with Genie over 21 months

User Types	One-time	Short-term	Sporadic	Consistent
% Users	24.6%	30.3%	23.8%	21.3%

45% of users actively engaged



Temperature changes using thermostat and Genie across all zones. Thermostats have an mean deviation of ±3.5F and Genie has ±2F.



Energy comparison between zones that use Genie and those that don't. Energy difference is statistically insignificant.

User Feedbacks Led to Fault Identification

- Thermostat blocked, heating malfunction
- 30 faults diagnosed from user input

Design Lessons for Software Thermostats

- Software should be in sync with thermostat
- Provide clear feedback and adequate control

UCSDCSE Computer Science and Engineering

MESL Microelectronic Embedded Systems Laboratory

synergy systems, networking and energy efficiency

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