Cost responsive supply air temperature reset strategy

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Overview

Objective

- Develop and test a control strategy that identifies the optimal supply air temperature for an air handling unit

Approach

- No new hardware
- Minimize complexity so it can be implemented within building automation system software & hardware
- Test in a randomized controlled trial

Funding

- CEC PIER program
- CBE match funding

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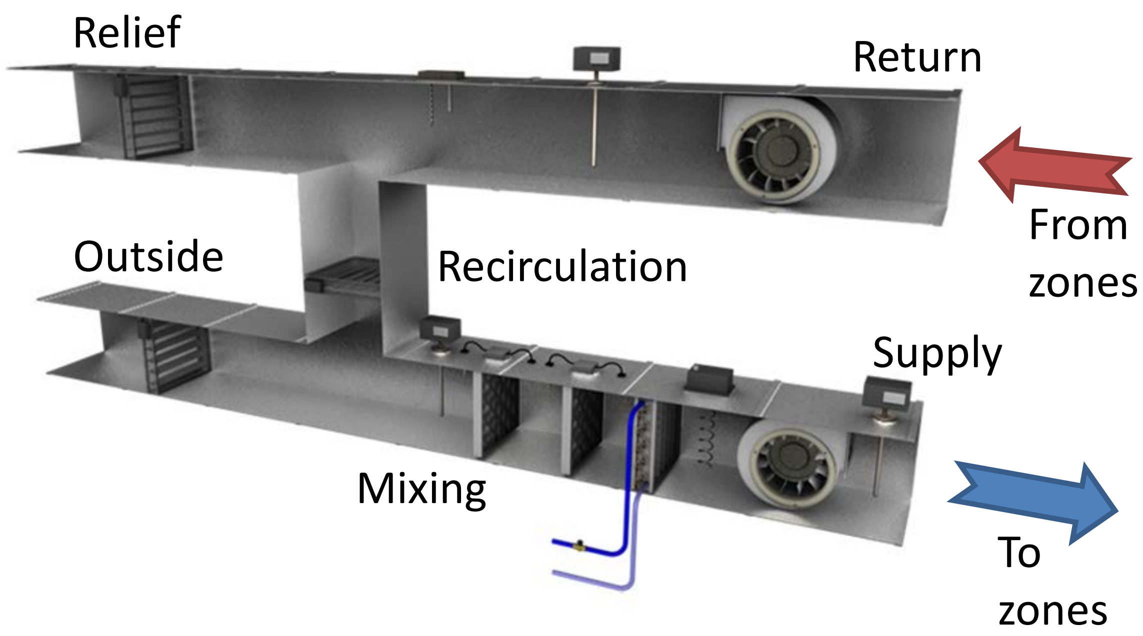
Background: Supply air temperature setpoint

Comfort constraint

- SAT should be low enough to cool the most demanding zone

Energy impact

- Lower SAT increases cooling and reheat, but decreases fan energy
- Optimal SAT varies based on weather, internal loads, and building conditions.



Air handling unit schematic

A brief history of best practice for SAT setpoint controls

Advent of DDC systems | Current best practice

Constant (manually adjusted) → **Based on outside air temperature** → **Warmest to satisfy most demanding zone** → **Warmest with outside air temperature based limits**

SAT is 58 °F (14°C), modified seasonally or as needed

↑ SAT when OAT ↓

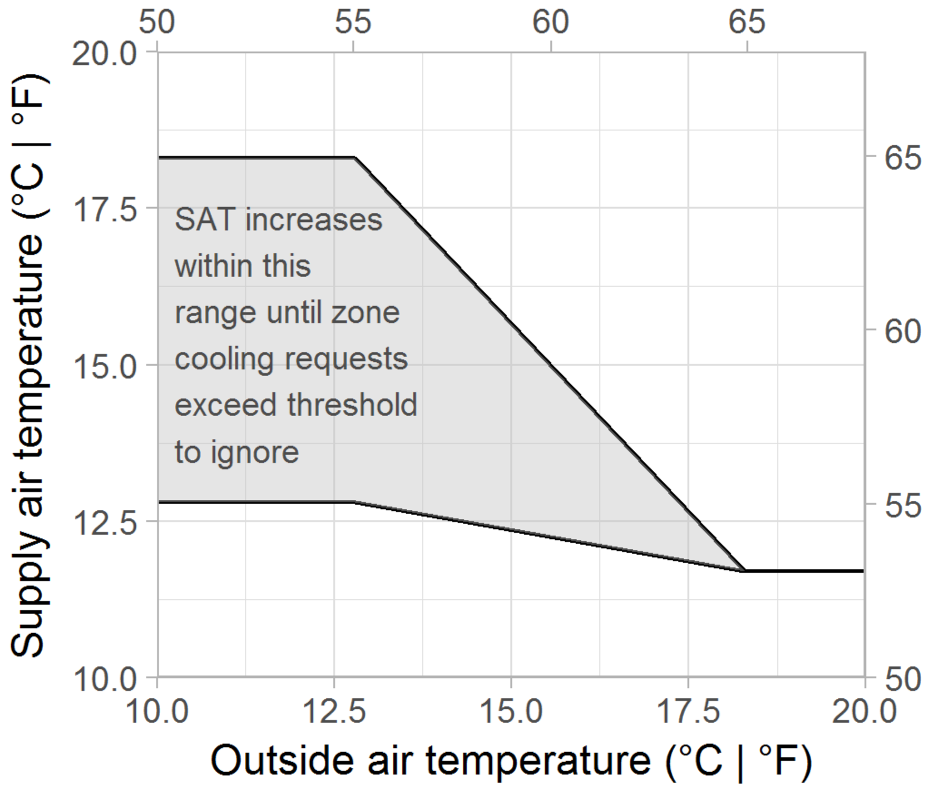
↑ SAT until one zone at max airflow

↑ SAT until one zone at max airflow - within limits that vary based on OAT

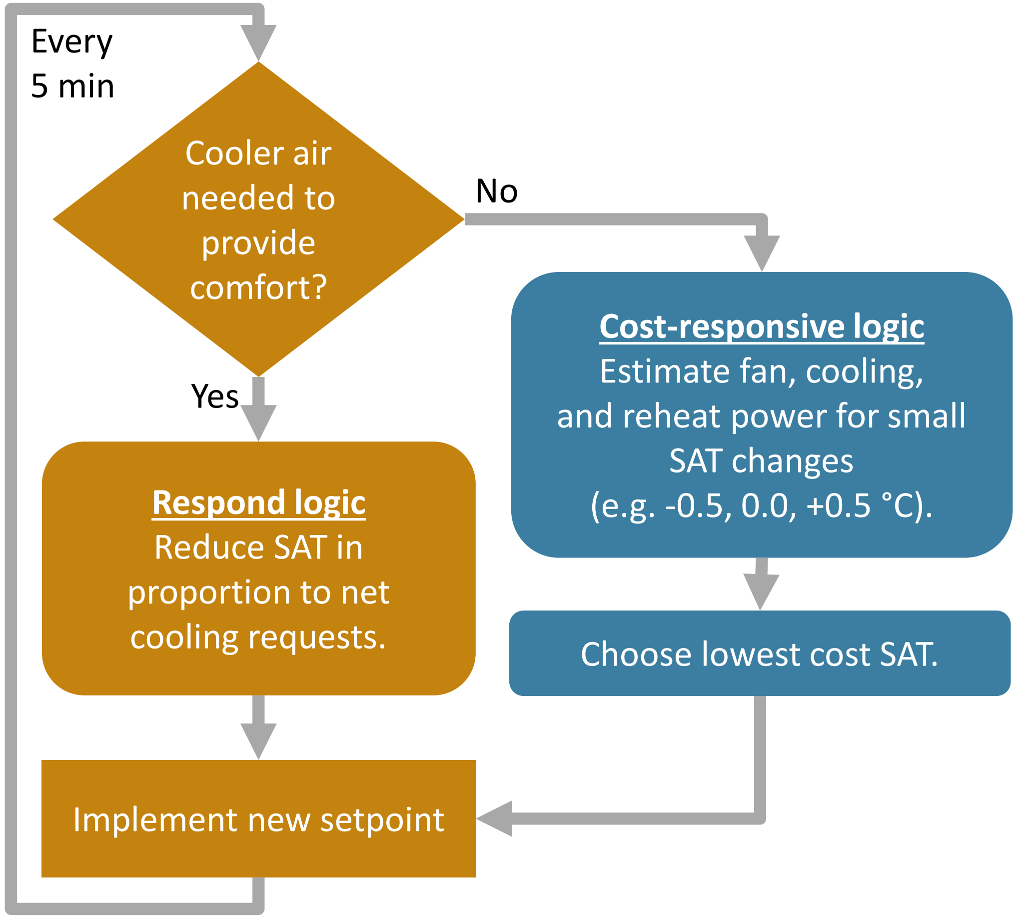
Current best practice vs. cost-responsive controls

Current best practice

- Warmest with outside air temperature based limits
- Trim & respond (or PID)



Cost-responsive



Control system inputs and calculations

Cost per unit energy

- Need common metric to compare fan, reheat, and cooling energy
- Use actual dollar cost from tariffs
- Change later as needed
- Alternatives
  - Site/source energy
  - Carbon

Fan power estimate

- Use VFD output and motor rating

Coil 'power' estimates

- Use sensible heat balance
- Cooling: mixing to supply air temperature.
- Reheat: supply to discharge air temperature.
- Apply temperature 'correction' to account for sensor error, fan/duct heat gain, passing valves, etc.
- Temperature correction is the long term average value when the valve is closed for ≥5 minutes

Estimating overall cost at different candidate SATs

Reheat

- For each reheat box with an open reheat valve, re-calculate reheat estimate at candidate SAT.

Airflow

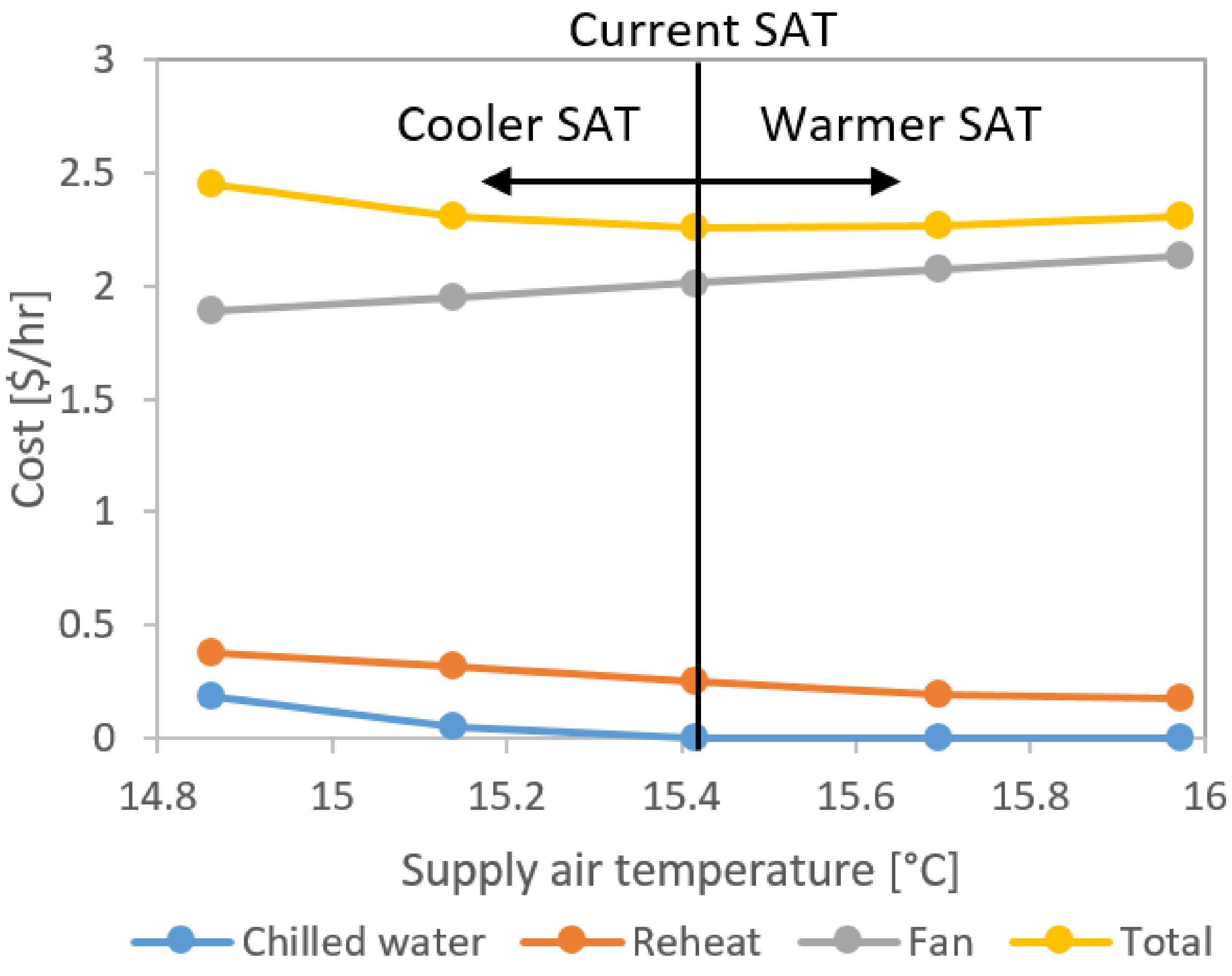
- For each VAV box in cooling mode, estimate new airflow at candidate SAT.

Fan

- Use total airflow estimate and fan affinity law to predict fan power at candidate SAT

Cooling

- Use new airflow estimate and re-calculate cooling estimate at candidate SAT.



Cost-responsive strategy in operation

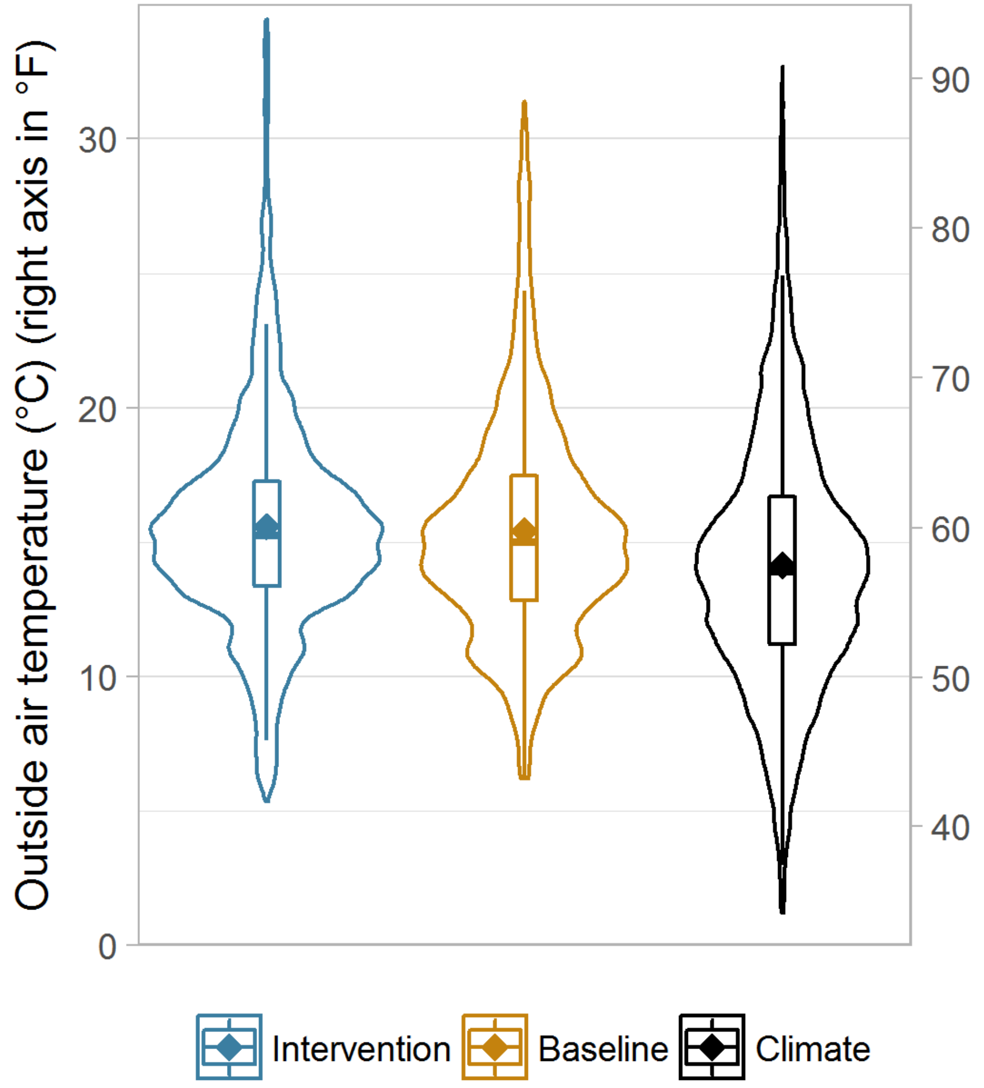
Case study in Sutardja Dai Hall

- Variable air volume system with hot water reheat
- 141,000 ft^2
- Offices, an auditorium, and cleanrooms
- Completed 2010
- Siemens Apogee system
- Implemented using sMAP and pybacnet

Sutardja Dai Hall. Source: Hathaway Dinwiddie

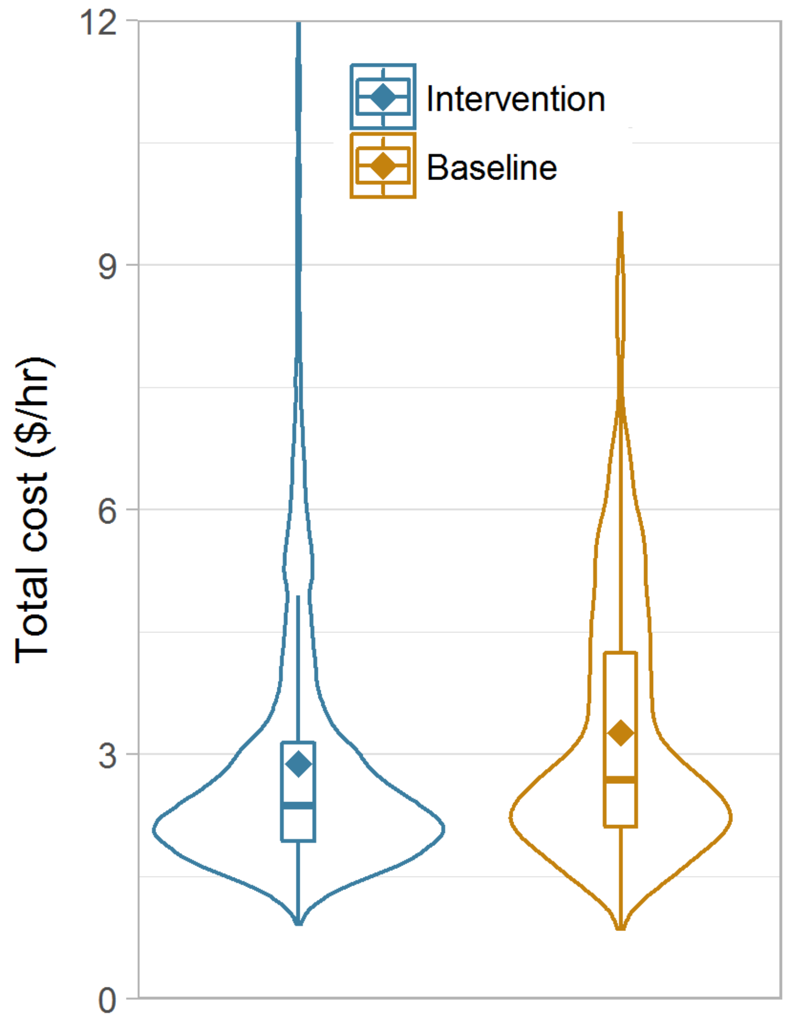
Method: Randomized controlled trial

- Randomly select control strategy every day at midnight between Sept 2016 and Feb 2017
- **Current best practice controls: 'Baseline' (77 days)**
- **Cost-responsive controls: 'Intervention' (68 days)**
- Minimizes the effect changes in weather, occupant behavior, operation of building and systems, have on results
- Overall savings potential adjusted to match typical annual climate

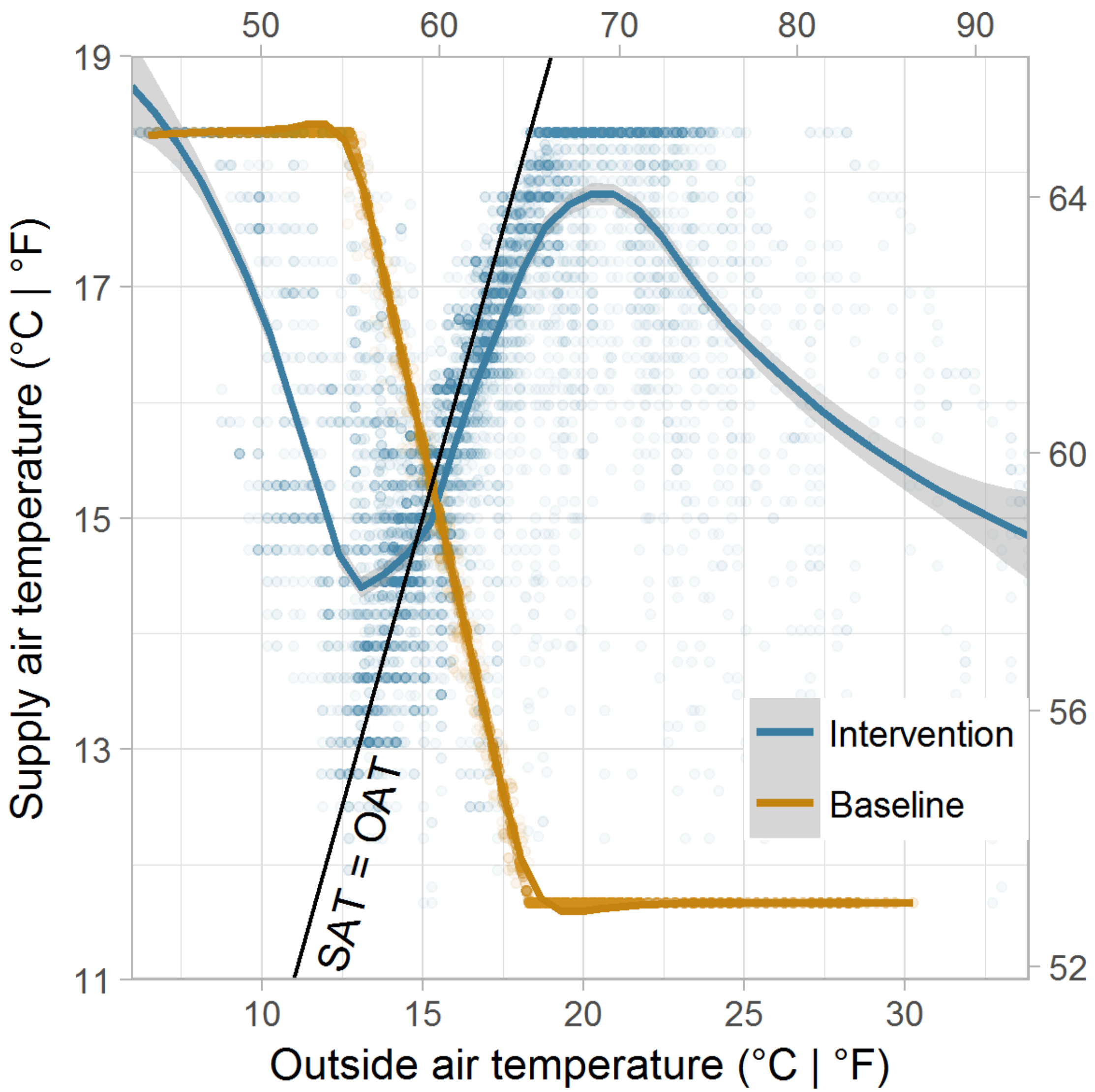


Results: Overall

- 17% total HVAC savings during randomized control trial (6 months)
- Savings occur at all outside air temperatures
- Savings highest between 16 °C (60 °F) to 24 °C (75 °F) outside air temperature
- 29% total HVAC savings when normalized to typical office hours (8am-6pm) in a typical meteorological year



Results: Detail



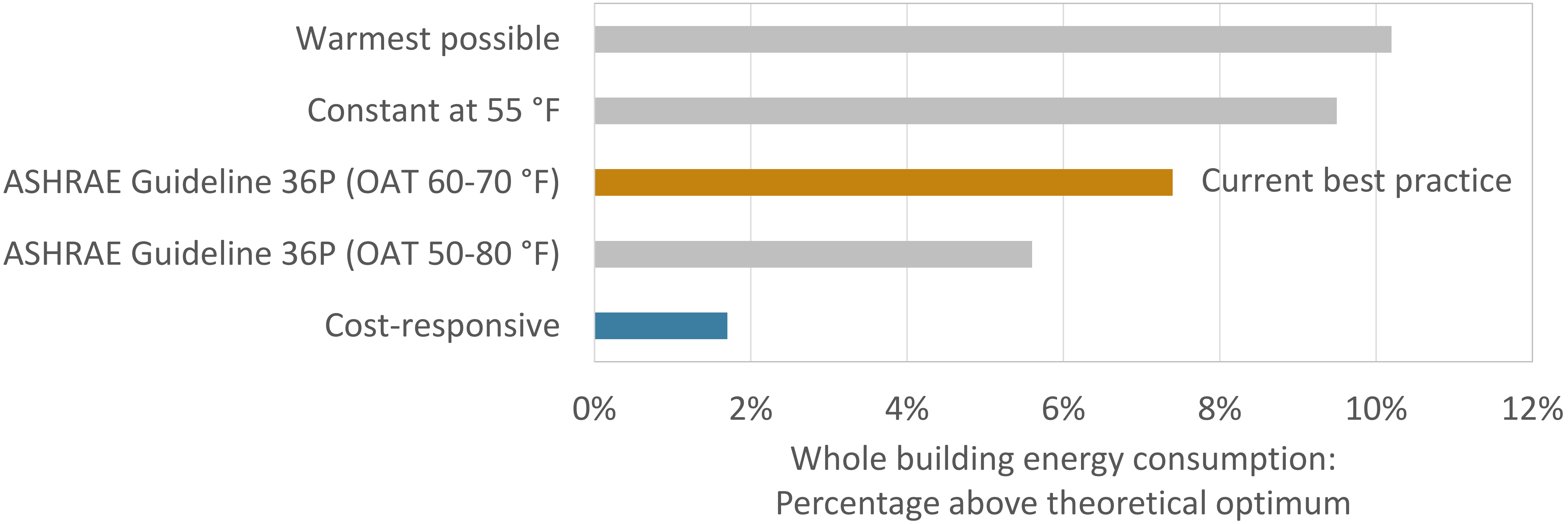
Results: Limitations of generalizing savings to other buildings

- Climate (Berkeley, cool summer Mediterranean climate, ASHRAE 3C)
- Size of the HVAC system relative to the actual building loads
- Relative cost of fan, cooling and reheat energy.
- Zone minimum airflows
- …

Mild Berkeley weather

Results: Parametric energy modeling

- Varied loads, zone airflow minimums, HVAC sizing, chiller efficiency, etc.
- Identified the theoretical optimum using a brute force approach
- Compared a range of different SAT reset strategies



Practicality

- Both approaches have the same number of required user inputs (4):
  - Current best practice: upper and lower limits for SAT at high and low OAT.
  - Cost-responsive: electricity & hot water prices, chiller plant efficiency, fan motor horse power.
- More complex to program… but hopefully can be implemented once, as standard 'block'
- Can be expressed as sequences of operation - Draft 4 page version available to share now.

Sutardja Dai Hall. Source: Hathaway Dinwiddie

Next steps

Publication

- Journal article submitted and under review

Open questions

- Test performance in other buildings
- Identify issues implementing in native building automation system hardware & software

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Q&A

Thank you for listening.

Questions?

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