Practical Applications and Case Study of Temperature Smart Ventilation Controls

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BA-PIRC Building America Partnership for Improved Residential Construction

PARR The Partnership for Advanced Residential Retrofit

Energy Program

Washington State University

Learning Objectives

- Describe the concept of temperature-based ventilation control
- Discuss the magnitude of costs and savings of temperature-based ventilation control

Acknowledgments

- Florida Solar Energy Center (FSEC)
- Lawrence Berkeley National Lab (LBNL)
- Panasonic USA
- The Energy Conservatory (TEC)
- Google/Nest Labs

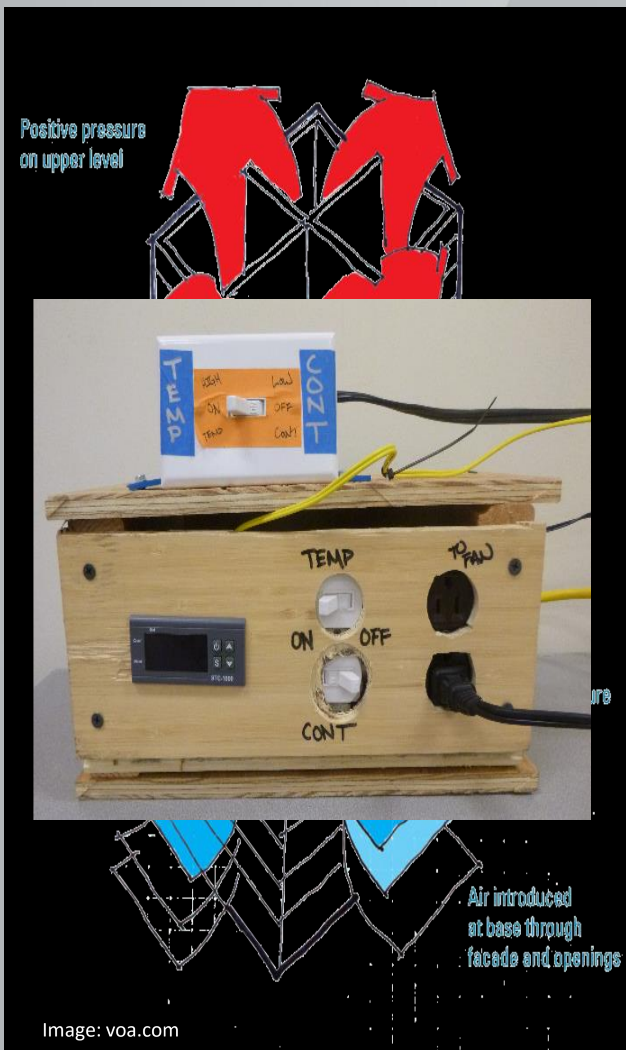
Motivation

Energy Efficiency

Smart Ventilation Control

Indoor Air Quality

Theory



- Large ΔT
  - Strong stack effect
  - High natural infiltration
  - Substantial energy to condition incoming air
  - Highest utility rates

Funding

"Smart Ventilation Technology Solutions that deliver adequate outside air for general pollution dilution and odor control, while optimizing the delivery to minimize energy associated costs."

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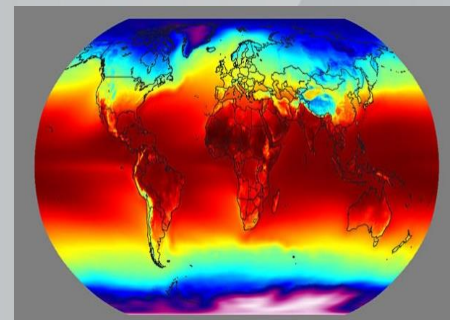
Smart Ventilation Control (SVC)

Temperature Smart Ventilation Control (TSVC)



Real Time of Use Smart Ventilation Control (RTSVC)

Image: picamemag.com

Combo!

Intermittent Exhaust Smart Ventilation Control (IESVC or RIVEC)

Occupancy Smart Ventilation Control (OSVC)

Authority

ASHRAE 62.2-2013 Section 4.6

- "Same or lower annual exposure"
  - 62.2-2016 Appendix C (Variable Ventilation)
    - Limits peak (short-term) exposure to 5x annual average
    - Provides equations
- Real-time ventilation controller
  - Reduce ventilation rates when doing so benefits the occupants

Extreme weather

Poor outdoor air quality

Elevated energy prices

TSVC Execution

Two-house case study

Champaign, IL	Location	Olympia, WA
Cold (zone 5)	Climate	Marine (zone 4)
1 story, 900 ft^2	Size	2 stories, 1,640 ft^2
Forced air furnace	HVAC	Ductless HP
No	Weatherized?	Deep (20 → 5)
9	ACH_{50}	5
30	62.2-2013 rate (CFM)	40
80	TSVC rate (CFM)	90
55	TSVC shutoff (°F)	57

Modeling

REGCAP & EGUSA simulation tools:

- Mass-balance ventilation, heat transfer, HVAC equipment, moisture
- EGUSA hourly annual simulation
- Tightness matters
  - Too tight (<1.5 ACH_{50}) → unacceptable short-term levels
  - Too loose (>10 ACH_{50}) → fan has minimal impact on total ventilation
  - Biggest savings with 5-7 ACH_{50}

Champaign, IL	Location	Olympia, WA
$7.30/year	Projected savings	$23.00/year
11 years	Payback period (*)	4 years
9	ACH_{50}	5

(*) Assumes installed cost of $80 as part of a web-connected "smart" thermostat, useful life?

www.cosasqmepasan.com http://www.gracefox.com/

Logistics

- Weekly flip-flop tests
  - 1 week 62.2 continuous rates
    - Low flow
  - 1 week TSVC
    - High flow, on ~ >56°F
- No manual override
  - No local demand ventilation for showers
- Temp sensor location
  - IL: attic vent
  - WA: shielded outdoor location

Monitoring

- Recorded
  - Indoor temp/RH, CO_2 levels
  - Outdoor temp (WA only)
  - HVAC operation
    - Ductless HP electricity consumption (WA)
    - Furnace air handler state (IL)

Results –
Carbon Dioxide in Main Living Area

Champaign, IL	Location	Olympia, WA
1600	Peak CO_2	2200
868	Ave. CO_2 (Cont.)	666
966	Ave. CO_2 (TSVC)	748
+ 11%	% Difference	+ 12%

Year 1 results: concentration are in PPM, CO_2 higher at lower outside temperatures.

Two-sample T-test: suggests average CO_2 higher in TSVC mode at 95% confidence interval, where:
WA case $p=0.0025$, IL case $p=0.0038$

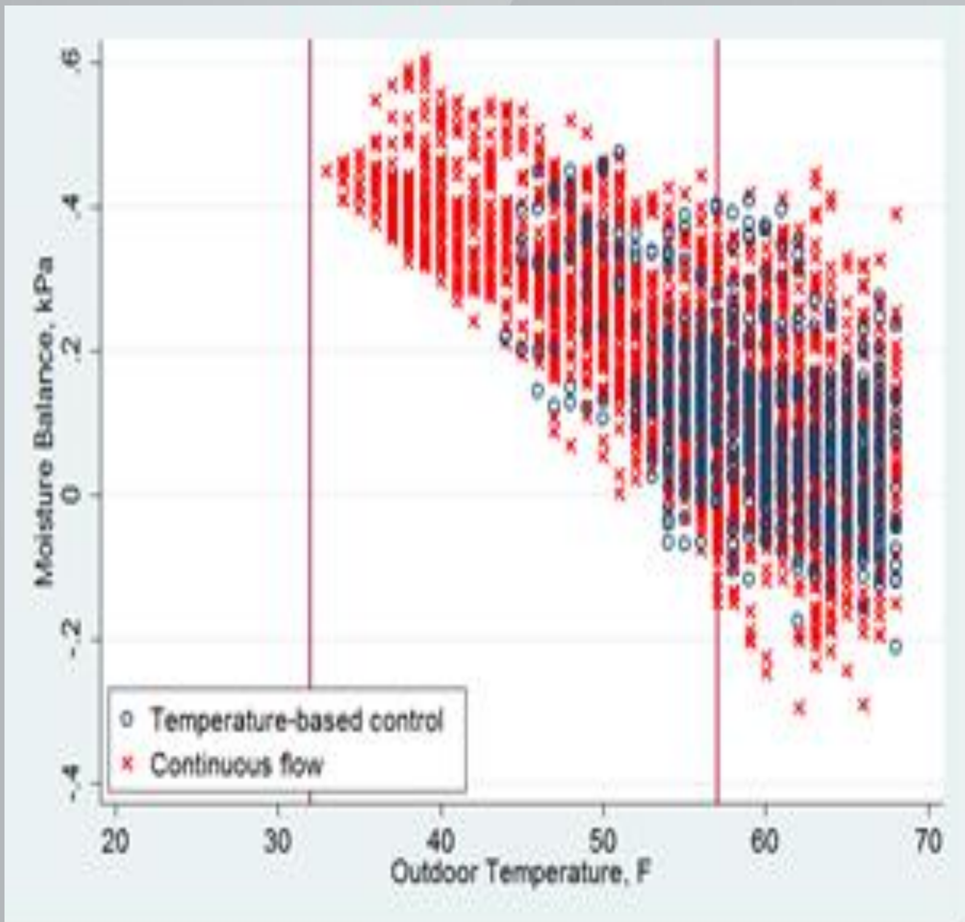
Results-
Relative Humidity Data Analysis

- Employed a Moisture Balance Technique (Francisco and Rose, 2008) used by IEA in Annex 41 for ISO 13788 (IEA, 2004).
- Technique compares the vapor pressure indoors “temperature-independent” to the vapor pressure outdoors over a range of outdoor temperatures.
- Linear regression of data between 68°F (20°C) and 32°F (0°C) and forcing the regression though zero PA at 68°F.
- The value at 32°F (0°C) intercept is the vapor pressure excess value used to characterize the home moisture balance.

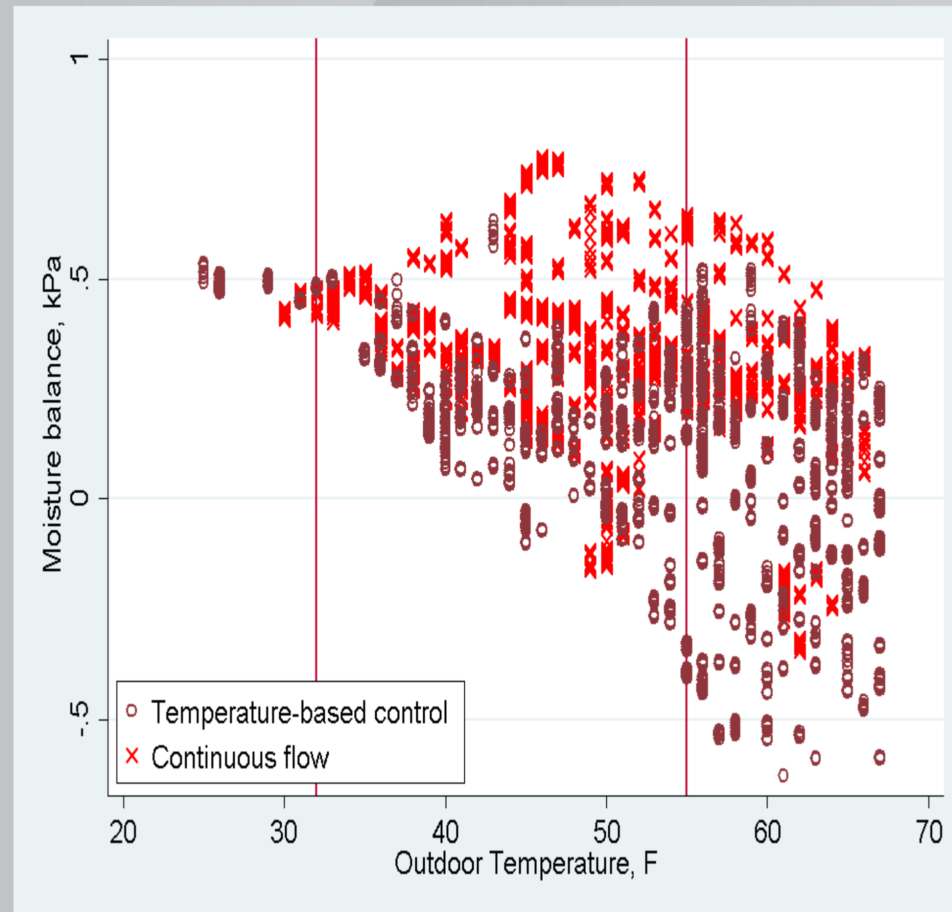
Results-
Relative Humidity Data Analysis

- **WA Case Study**
  - Vapor pressure excess was 616 Pa for SVC and 472 for continuous ventilation.
  - Differences not statistically significant at 95%, direction of change as expected.
- **IL Case Study**
  - Vapor pressure excess was 234 Pa for SVC and 586 Pa for continuous ventilation
  - Differences are statistically significant at 95%, counter to expectations; attributable to 44°F to 54°F (7°C to 12°C) range, possibly occupant effects or short term outdoor conditions.

Moisture Balance vs. Outside Temperature



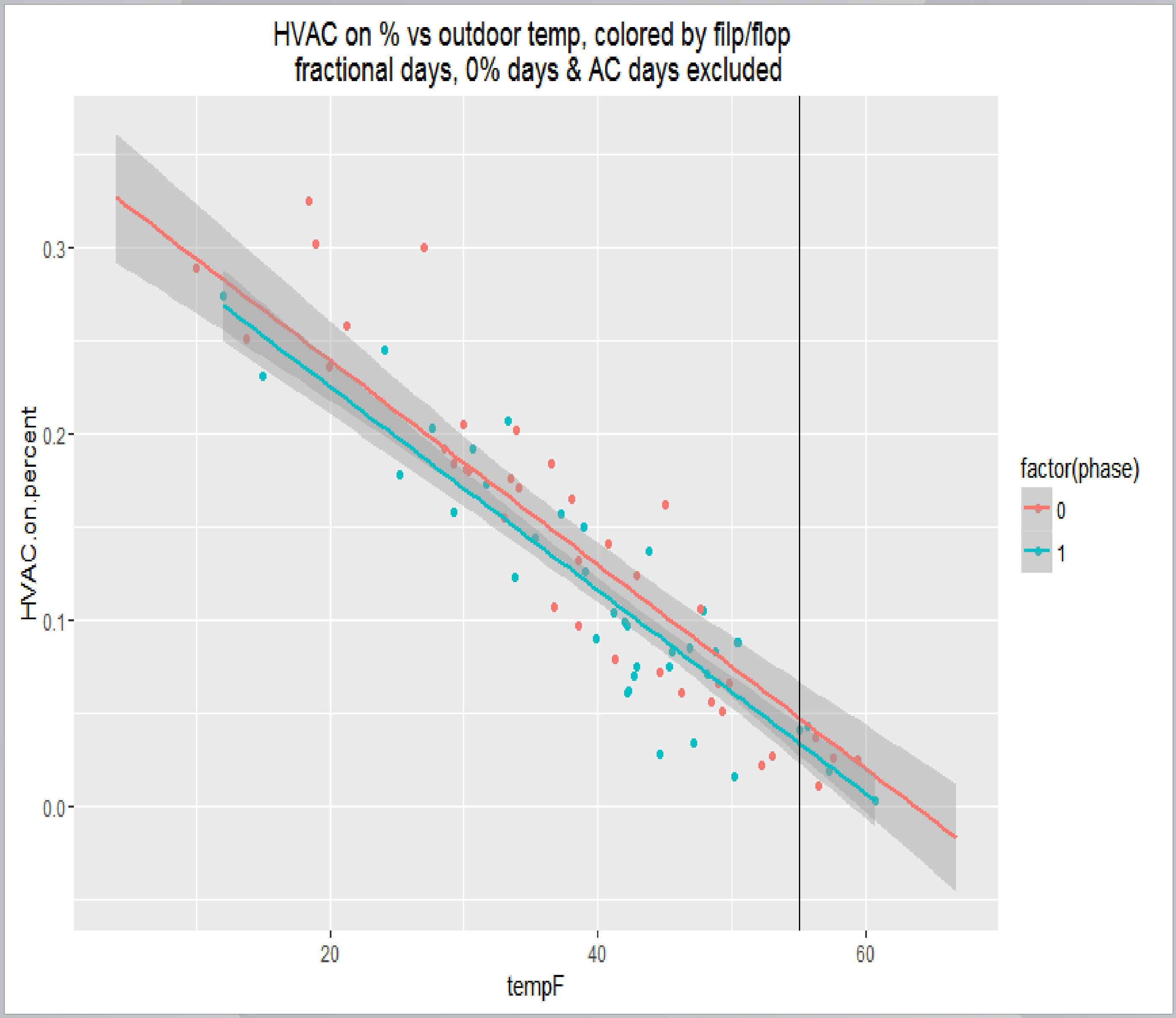
WA Case Study



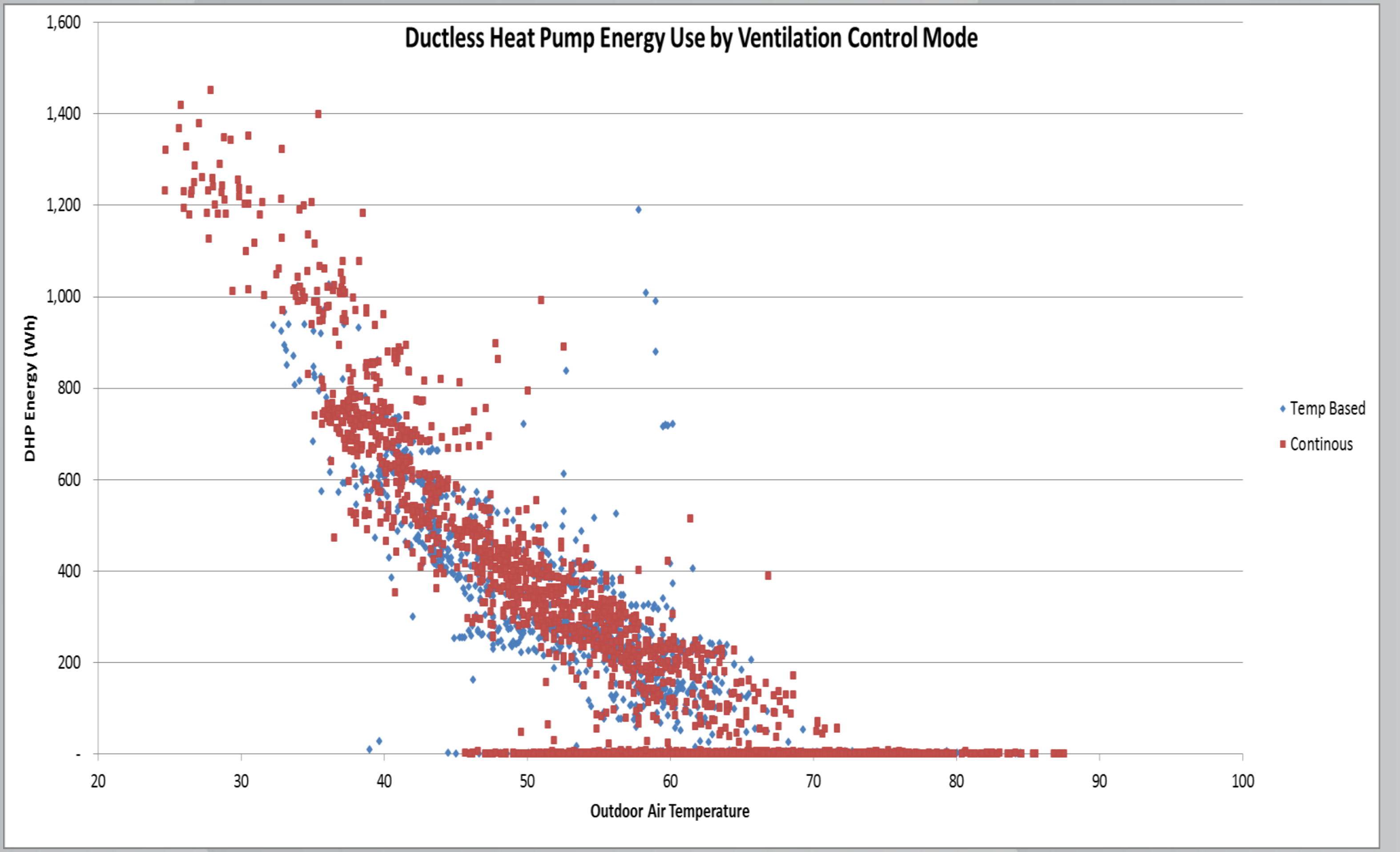
IL Case Study

Note: Vertical lines at 55°F for TSVC cutoff and 32°F Intercept

Results – Need Larger Sample Size
IL: HVAC Runtime



Results – Need Larger Sample Size
WA: HVAC Energy Use



Future Work

- Temperature Smart Ventilation Control (TSVC):
  - Minimum flow rate vs. locked out
  - Condensation control to override “lock-out”
  - Lock-out at high wind speeds (Weather Smart)
  - Combine with occupancy and other SVC (RIVIC – Residential Integrated Ventilation Controller) (LBNL)

Future Work (continued)

- Occupancy Smart Ventilation Control:
  - IAQ pollutant generation maybe lower in unoccupied homes depending on pollutants.
  - Is the home really unoccupied?
    - CO_2 & VOC sensor technology emerging
    - “Smart” connected thermostats that control ventilation
    - Smart phone location
    - Kitchen or bath fan operation
    - Security system “away” mode

Conclusions

- Two-site study not intended as statistically valid research project
  - Proof of concept on TSVC
- Difficulty obtaining convenient & accurate on-site temperature
  - Internet-based data?
  - Local microclimates?
- Equivalent ventilation not necessarily achieved
  - Higher CO_2 levels at lower temperatures with TSVC
- Small but “cost effective” energy savings if TSVC is installed for under $80 (maybe as part of a “Smart Connected Thermostat”)

Discussion

- Are TSVC &/or OSVC promising control technology?
- SVC Application in hot/humid climates?
- Maintenance & operation issues & opportunities?
- Can SVC better inform occupants to operate and maintain per 62.2?

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Go Cougs!