DEHUMIDIFICATION IN MINNESOTA'S SINGLE FAMILY HOMES

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Center for Energy and Environment

Wednesday, February 26th

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Center for Energy and Environment

- In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

  "This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 hours** of credit toward **Building Officials and Residential Contractors code /1 hour energy** continuing education requirements."

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CEE – Discover + Deploy

The most effective solutions for a healthy, low carbon economy

Agenda

- Dehumidification: What is it and why is it important?
- Project Overview
- Relevant Findings
  - Dehumidification in Minnesota
  - Field Performance Results
  - Field Intervention Performance Results
  - Cost Effectiveness of Dehumidification
  - Energy Star Ratings and Minnesota's Technical Reference Manual
- Practical Guidelines

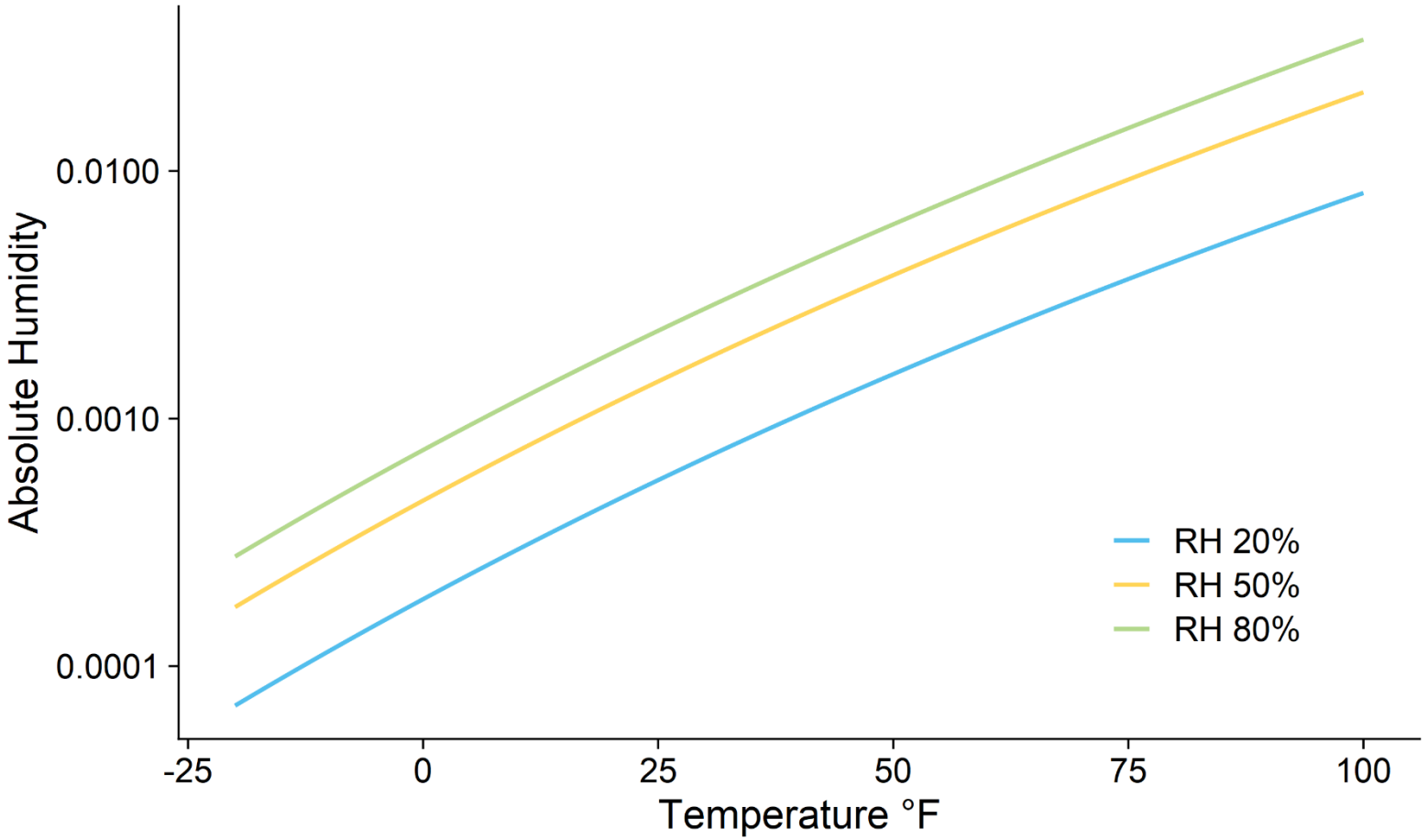
Learning Objectives

1. Characterize standalone dehumidification use in Minnesota single family homes
2. Describe operation and control of dehumidifiers
3. Identify homeowners' perceptions on humidity
4. Describe the effectiveness of dehumidification use
5. Describe dehumidification performance
6. Cost effectiveness of dehumidification
7. Identify accurate energy savings calculations used within the Minnesota Technical Reference Manual
8. Explain a set of practical guidelines for Minnesota specific dehumidification based on homeowner comfort, building health, and energy efficiency

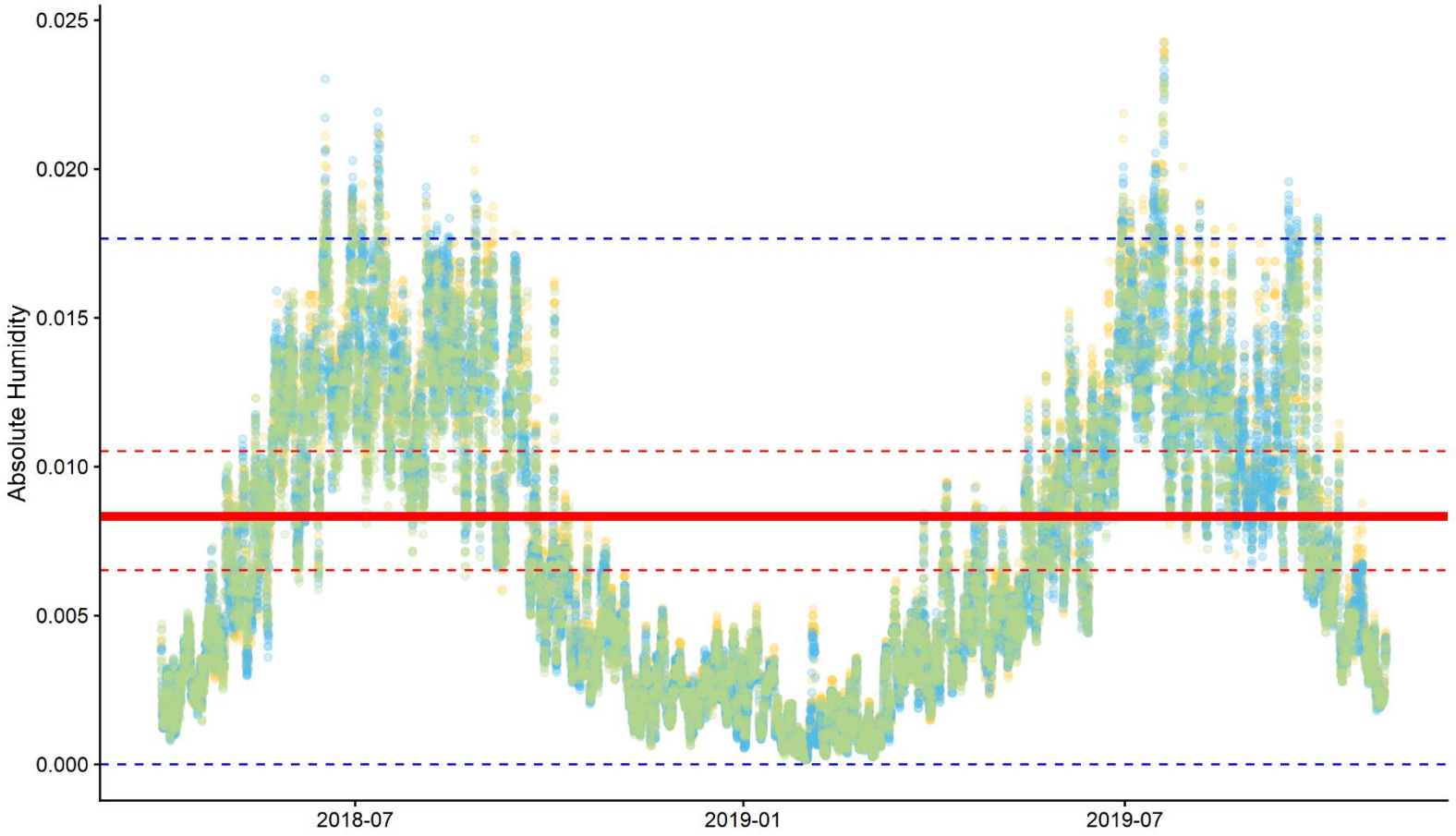
The Language of Humidity

- Absolute Humidity
  - How much moisture is in the air
- Relative Humidity
  - How much moisture ***relative*** to maximum moisture capacity
- Partial Pressure
  - Thermodynamic activity of gas molecules
- Dew point temperature
  - Temperature at which saturated water vapor will condense
- Wet bulb temperature
  - Temperature read by a thermometer flung about in a water soaked rag

Psychrometrics



Seasonal Humidity in Minnesota

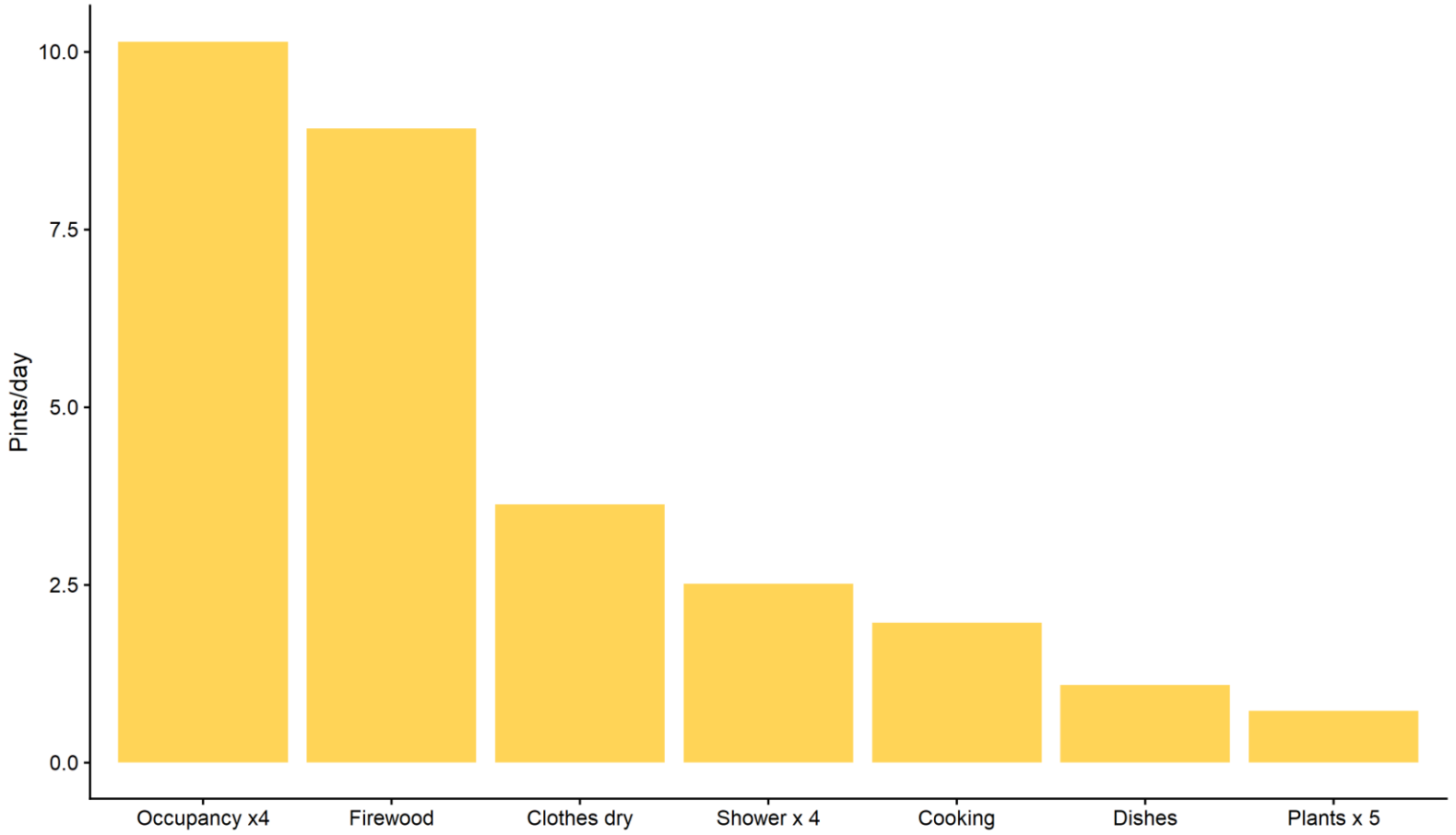


Humidity Sources – An Example

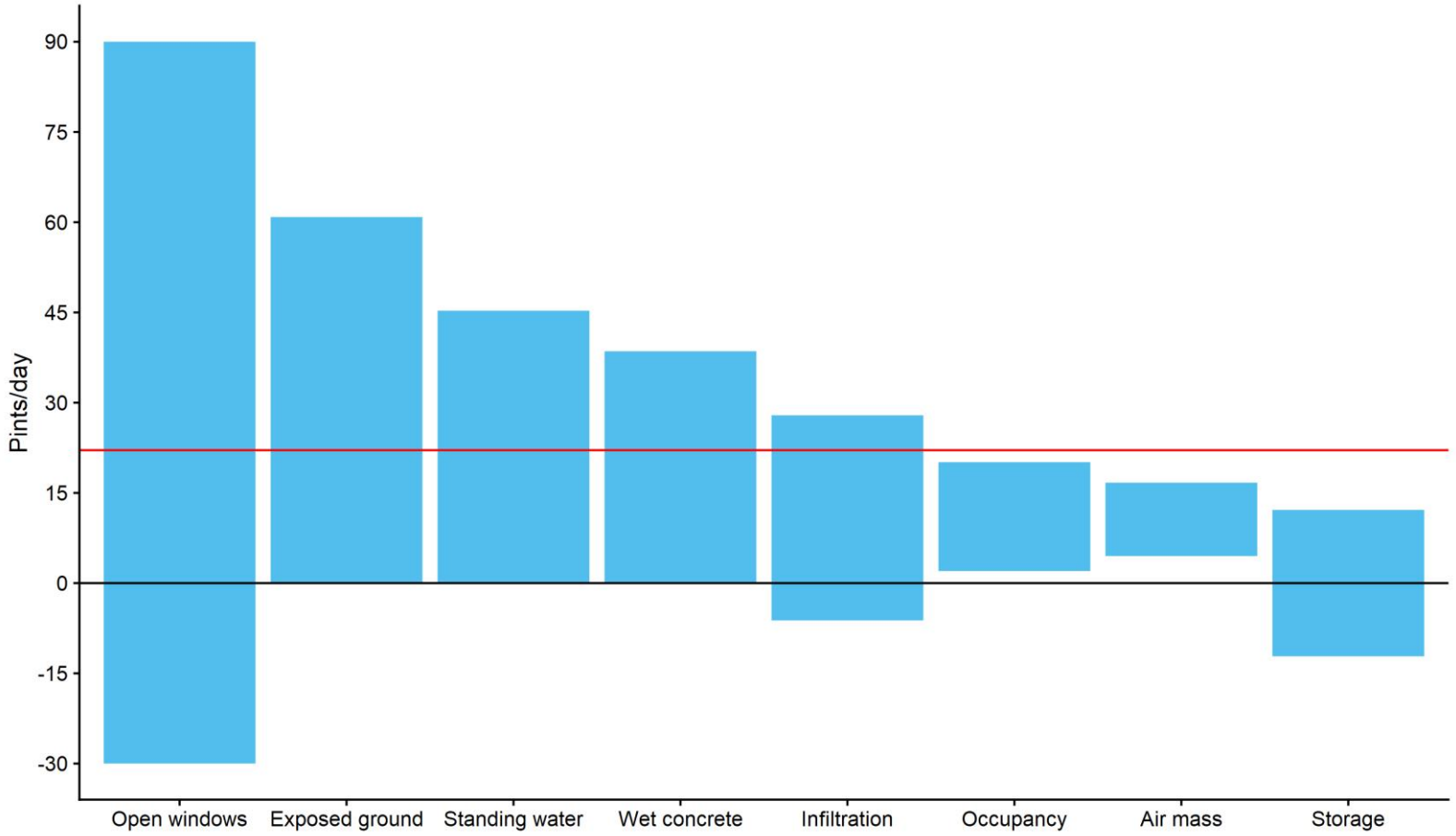
- Size: ~2000 ft^2
- Occupancy: 2 – 4 people
- ACH_{50} = 8
- Leaky by todays standards, but representative of existing construction

https://www.realtor.com/

Occupancy Moisture Sources



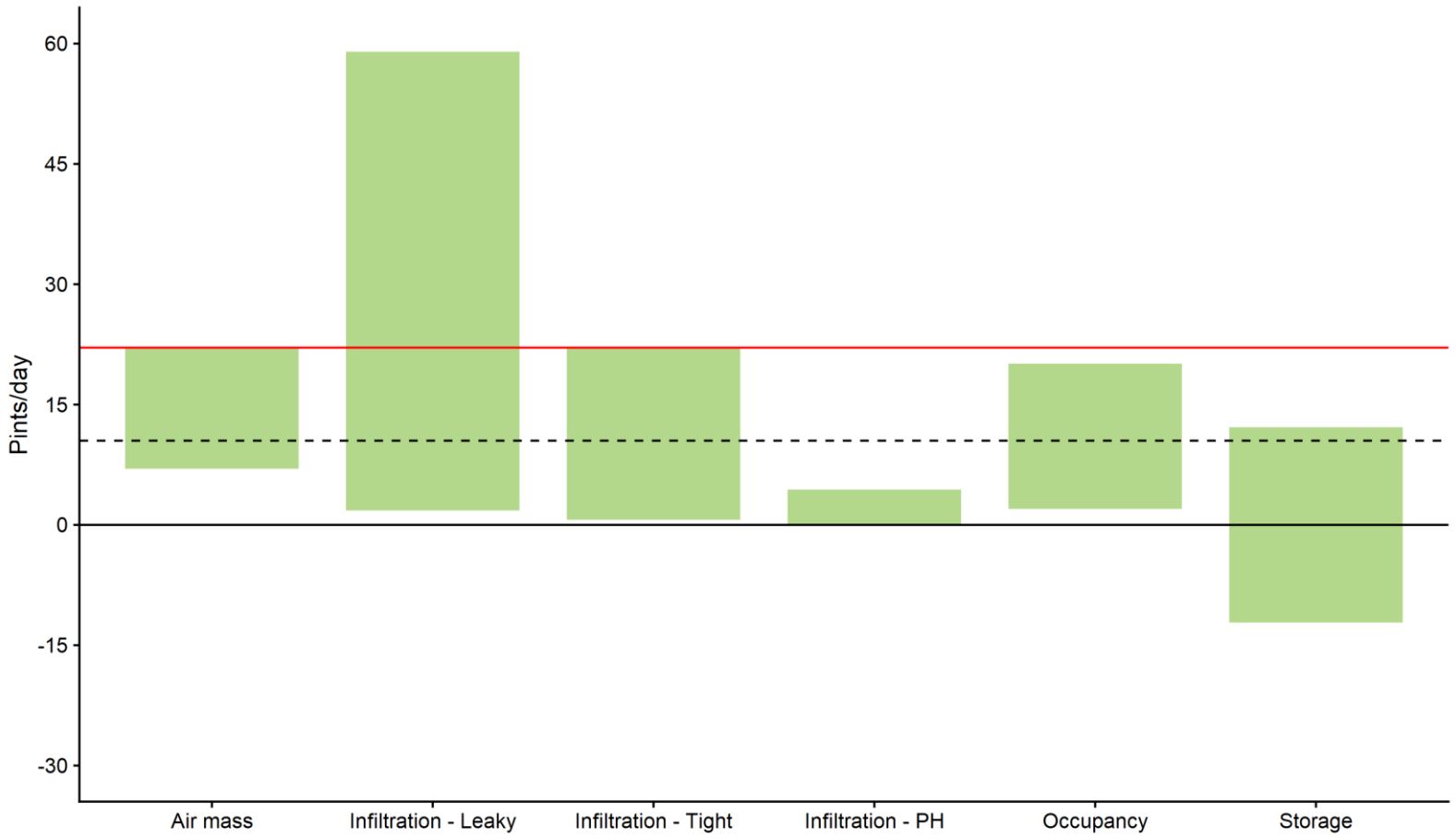
Natural Moisture Sources



Key takeaway

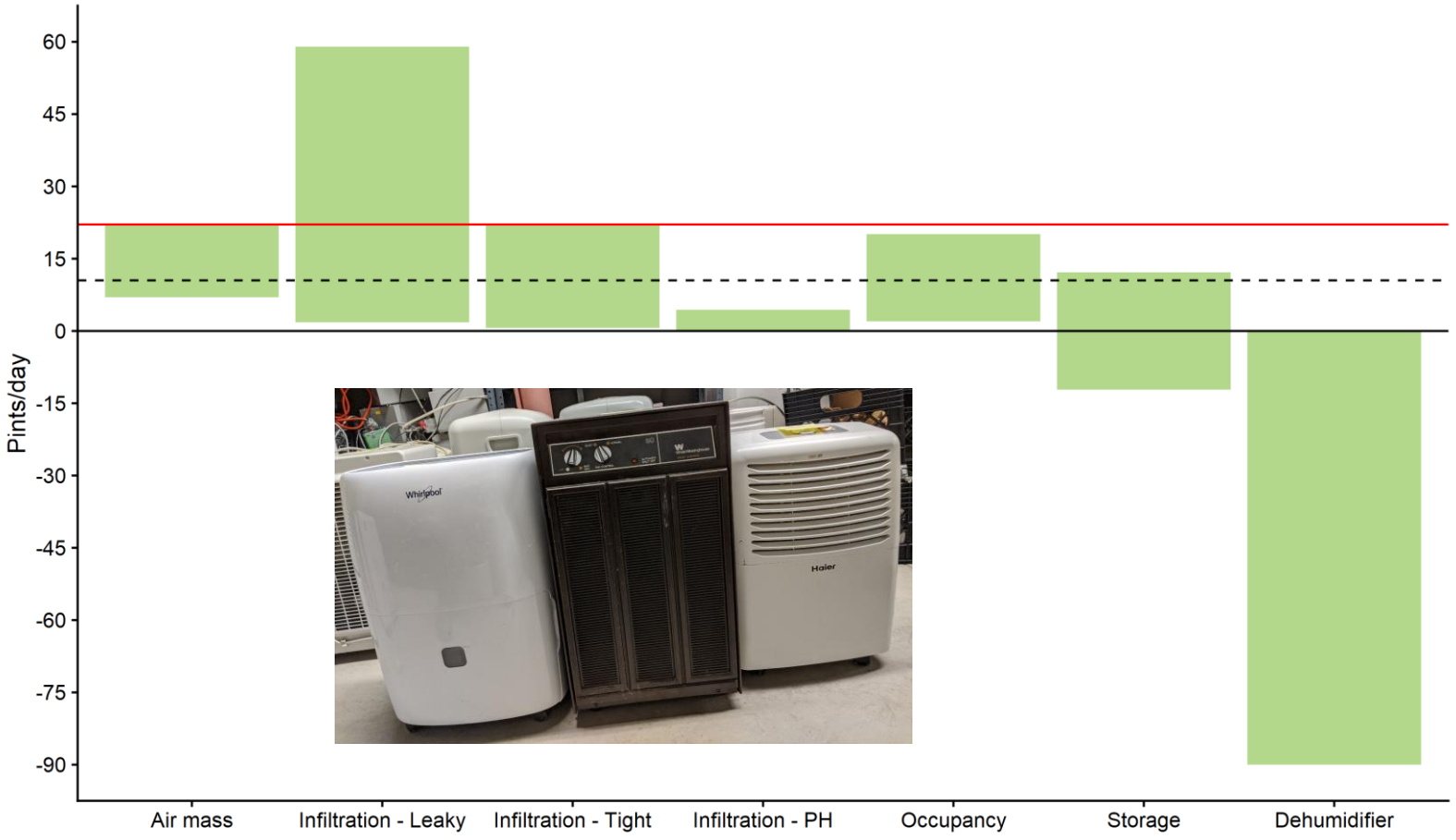
Dehumidifiers are not a solution for major below grade intrusion of liquid or vapor water, aka bulk water entry

Putting it together



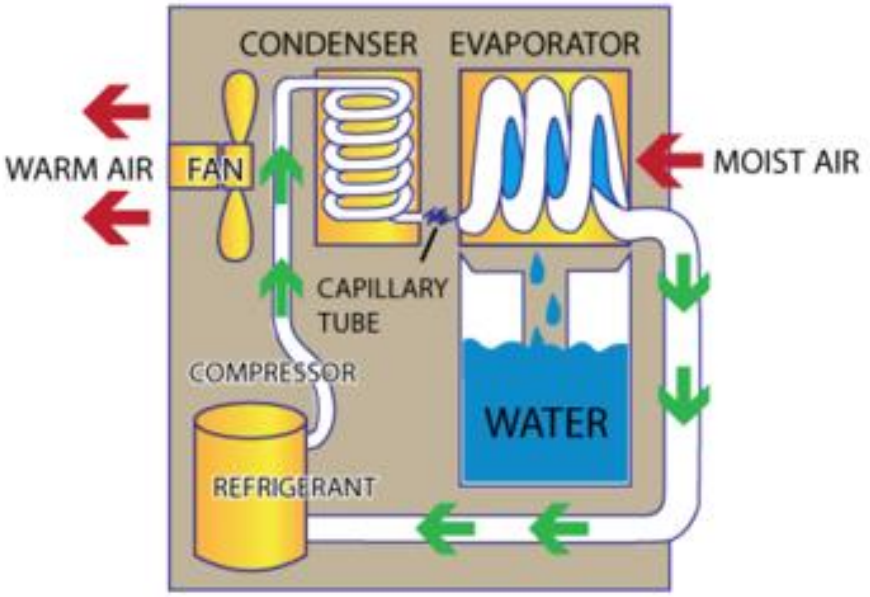
Moisture Removal Systems

Dehumidification



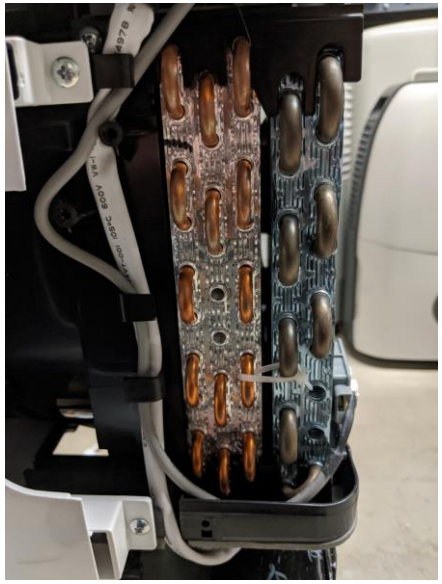
How does a VCS dehumidifier work

- Vapor compression device
- Collocated condenser and evaporator
- Humid air passes cool coil
- Vapor condenses
- Cool air heats up across evaporator
- Dry, warm air returns to room



https://www.achooallergy.com/

The insides




WARNING! VIOLATION OF ANY OF
THE FOLLOWING COULD RESULT IN
SERIOUS INJURY AND/OR DEATH.


3MR101A
R410A

Energy Efficiency: Energy Star

- Energy Star Ratings since 2001
- Specify efficiency (L/kWh) at capacity (Pints/day)

- EnergyStar 5.0 as of October 2019

Max Capacity (Pints/day)	Minimum Energy Factor (L/kWh)
<25	1.57
25.01-50	1.80
50.01+	3.30

- Old standard “Energy Factor” 80°F / 60% RH
- New standard “Integrated Energy Factor” 65°F / 60% RH

Dehumidification: What is it and why is it important?

- Remove moisture
  - Reduce discomfort
  - Health reasons
  - Mitigate stale or musty odors
  - Prevent microbial growth
  - Control moisture content of building materials and possessions
- Uses energy
  - Cost
  - Efficacy
  - Trade offs

Dehumidification in Minnesota's Single family homes

- Goals:
  - Who, How, and Why do Minnesotans dehumidify?
  - How well do they dehumidify?
  - What is the performance and cost of dehumidification?
  - Can cost and performance be improved?

- Methods:
  - Statewide penetration survey (n = 1493)
  - Phone survey (n = 211)
  - Site visits (n = 63)
  - Unit monitoring and intervention (n = 20)

- Evaluate conventional wisdom, common sense, and rules of thumb regarding standalone dehumidification systems

Conservation Applied Research & Development Fund

- **Purpose is to help Minnesota utilities achieve 1.5% energy savings goal by:**
  - Identifying new technologies or strategies to maximize energy savings;
  - Improving effectiveness of energy conservation programs;
  - Documenting CO_2 reductions from energy conservation programs.

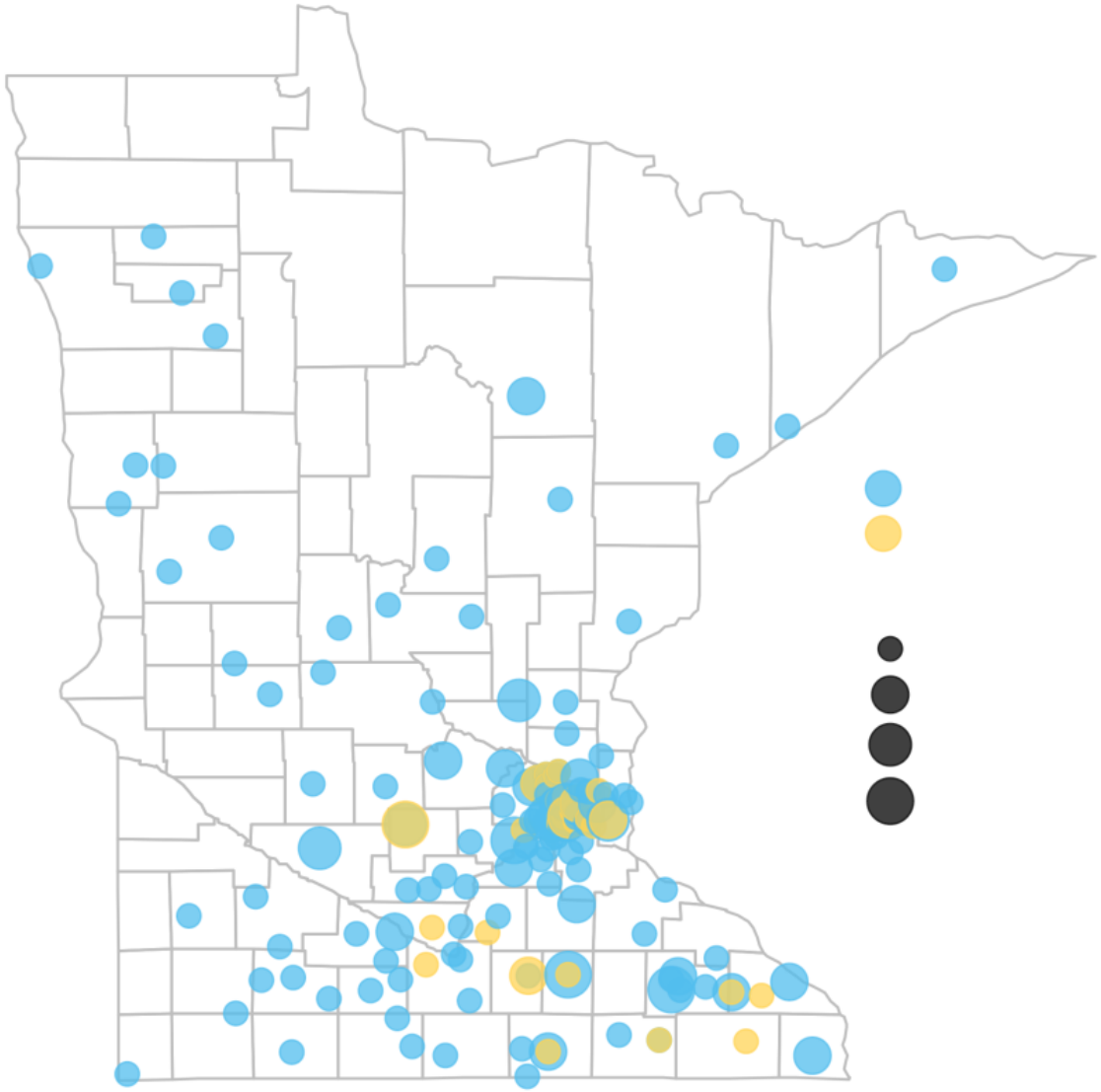
Minnesota Statutes §216B.241, Subd. 1e

COMMERCE DEPARTMENT

Project Overview

- Goals:
  - Characterize stand-alone dehumidification in Minnesota through surveys, site visits, and performance monitoring
  - Assess the motivation for dehumidification, monitor the energy performance, determine efficacy with which units solve moisture problems, and examine alternative solutions
- Methods:
  - Phone survey (n = 211)
  - Site visits (n = 63)
  - Unit monitoring (n = 20)

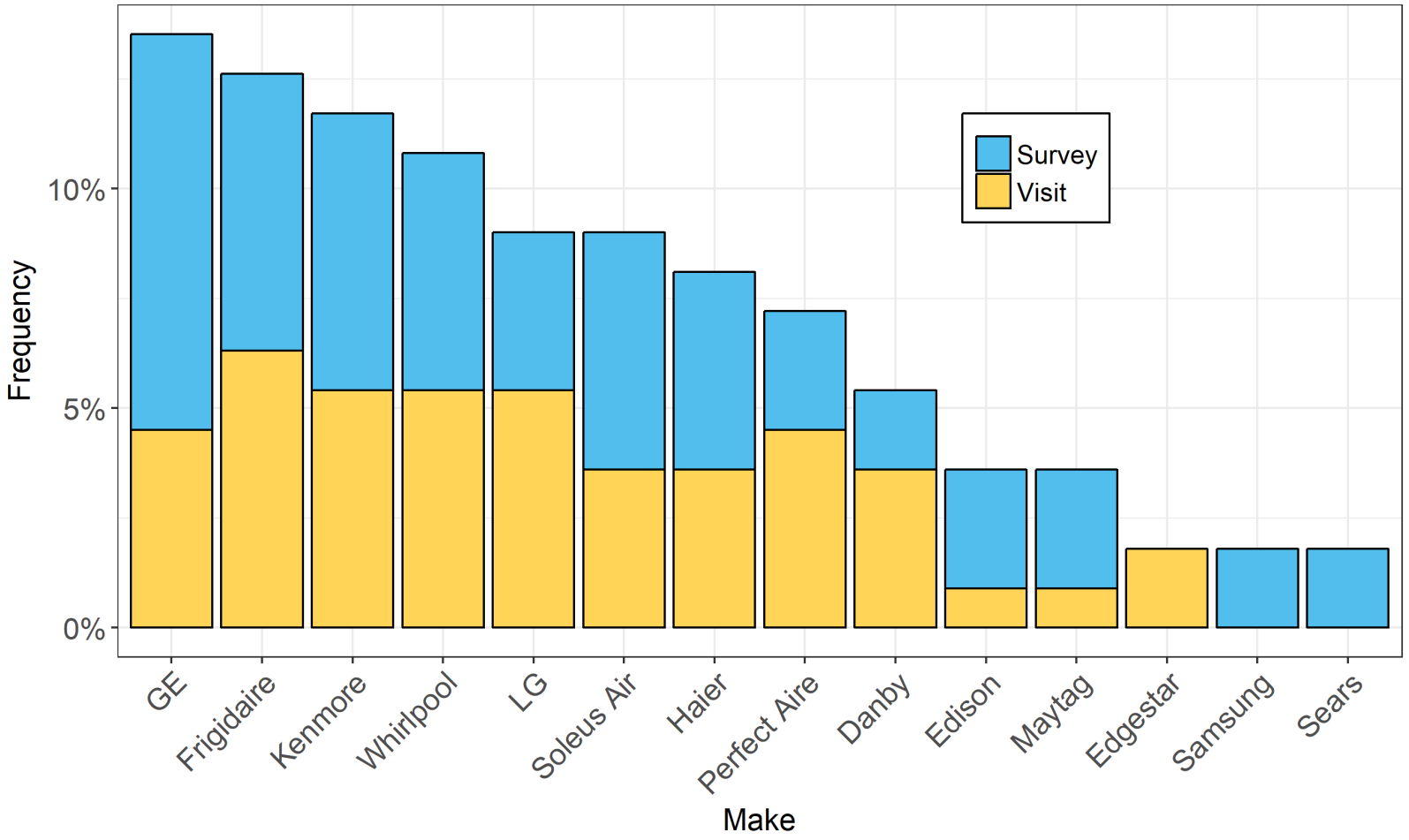
Dehumidification in Minnesota



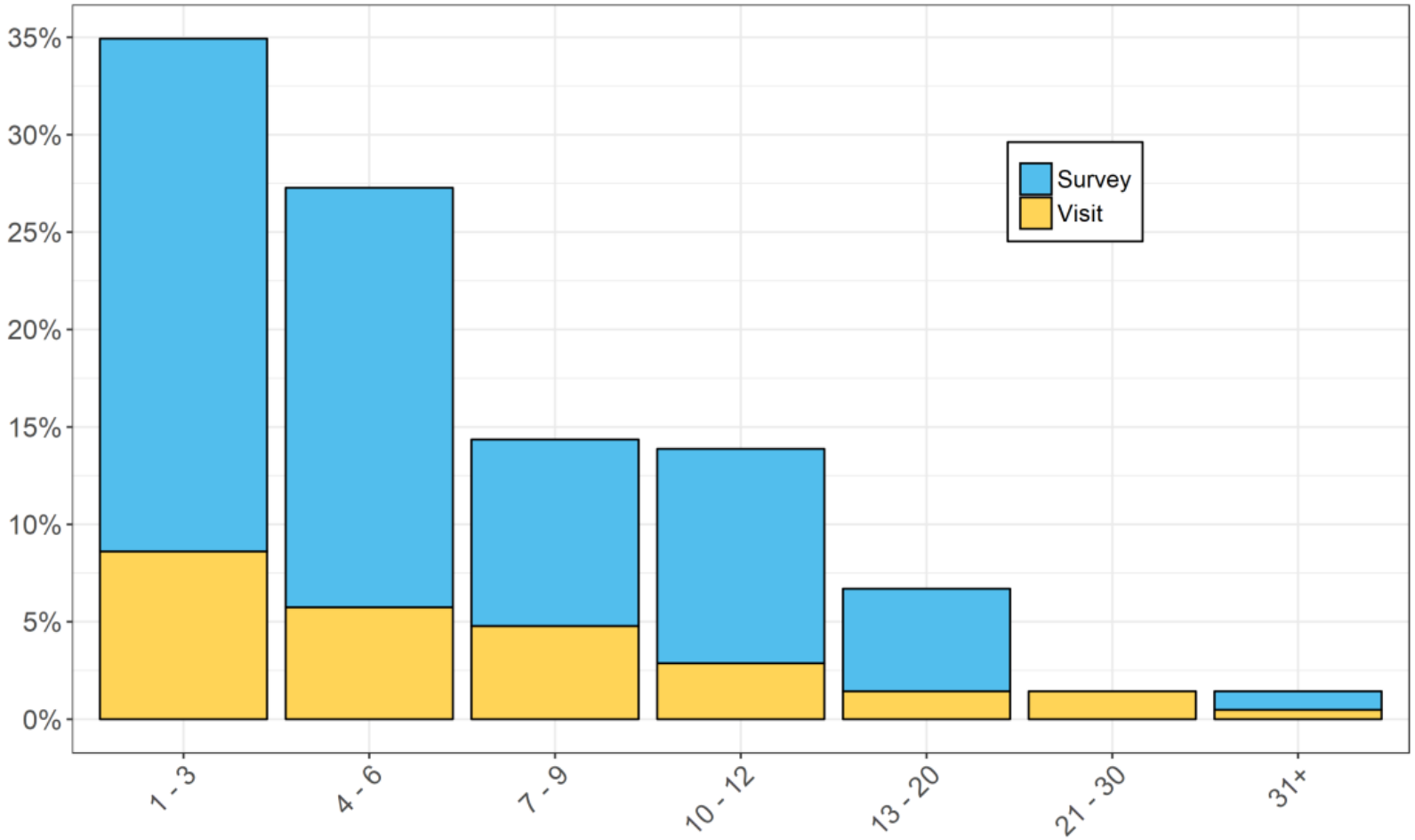
Penetration in MN

- 56% of Minnesota single family homes have a dehumidifier
- 43% in NE up to 59% in SW
- Renters 25% less likely to have unit than homeowners
- 95% operate in basements
  - 86% below grade / 14% walkout
  - 59% of basements are finished or partially finished
  - 70% operate in utility space
- 91% believe unit meets needs
- One person cited Energy efficiency as a concern

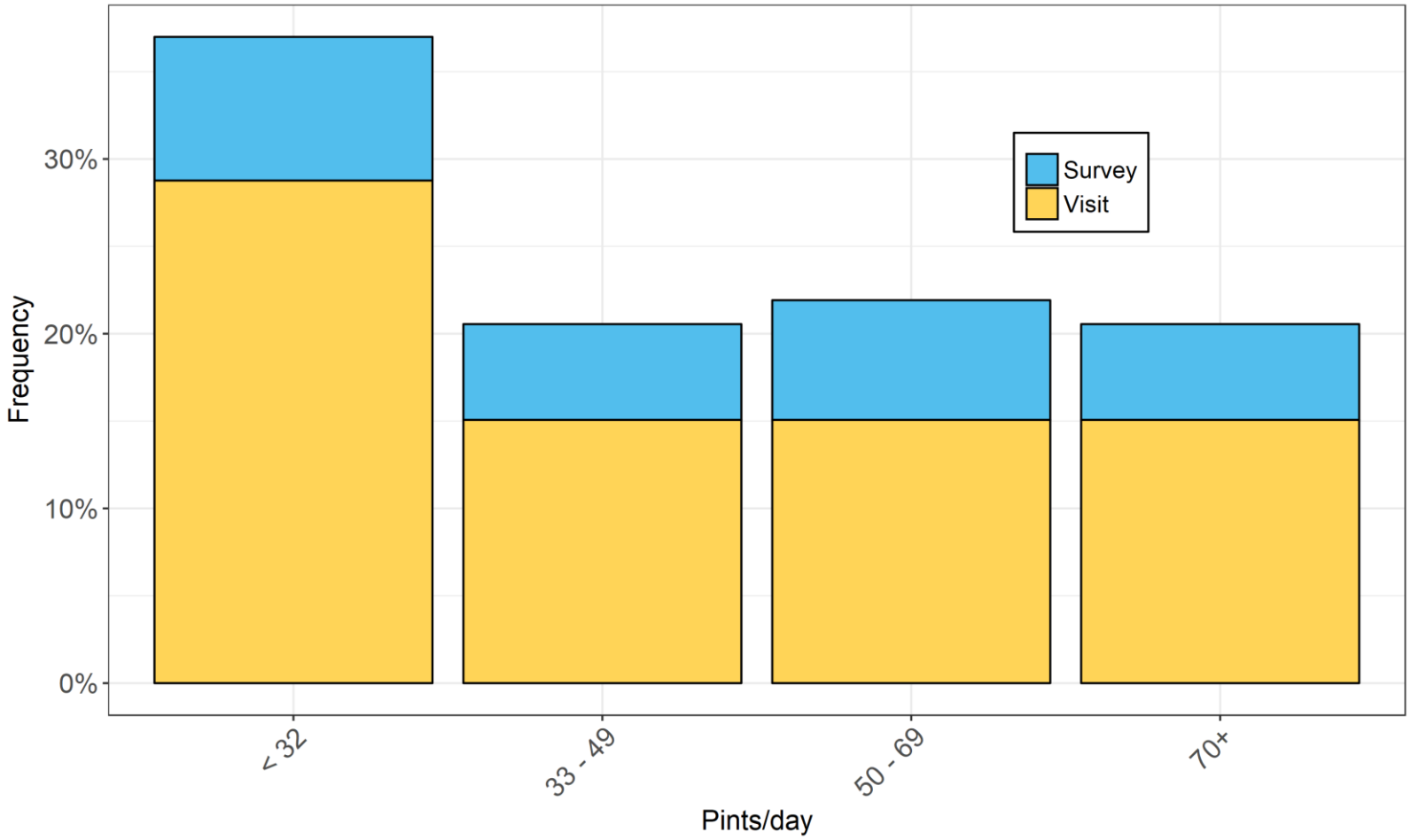
Dehumidifiers



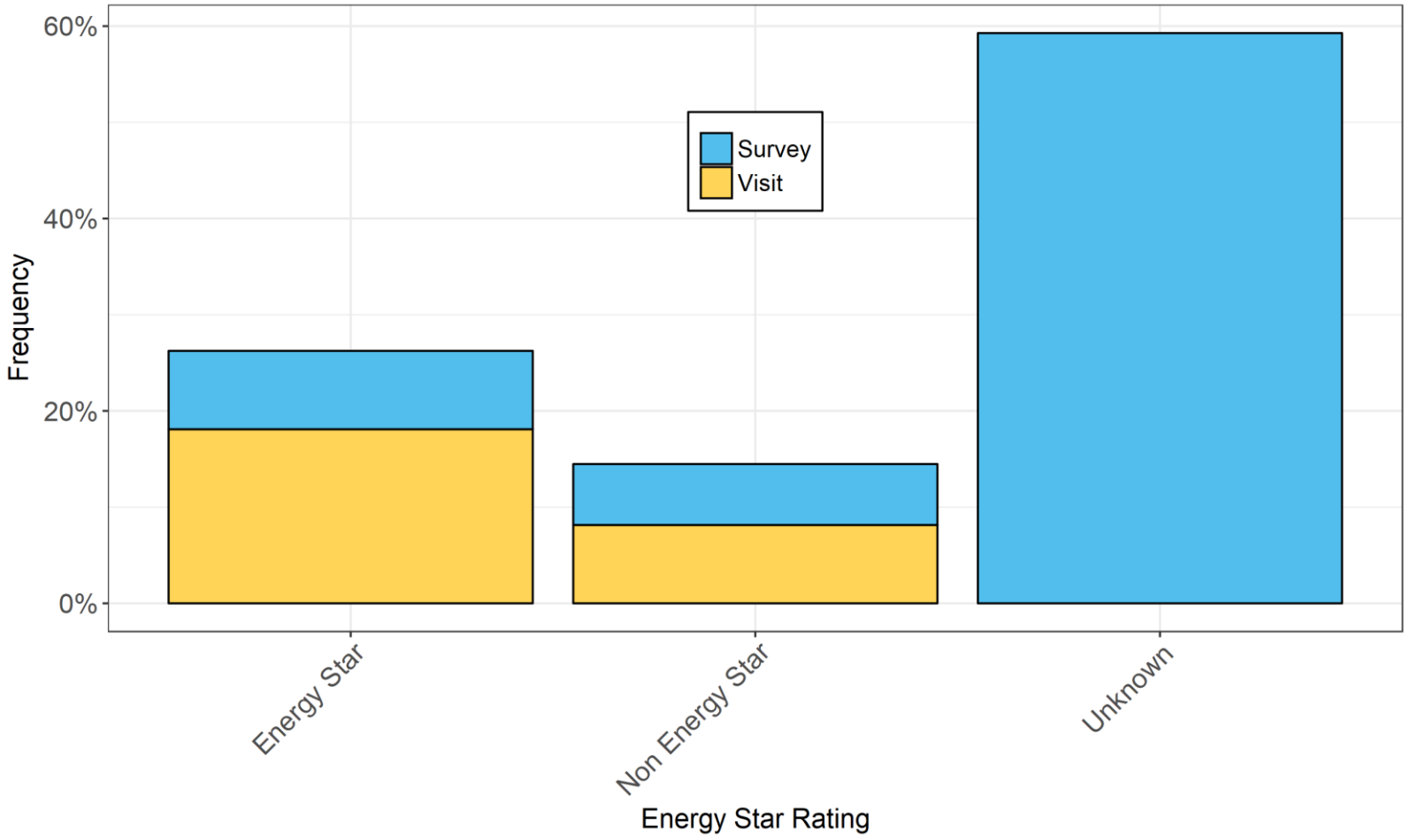
Age



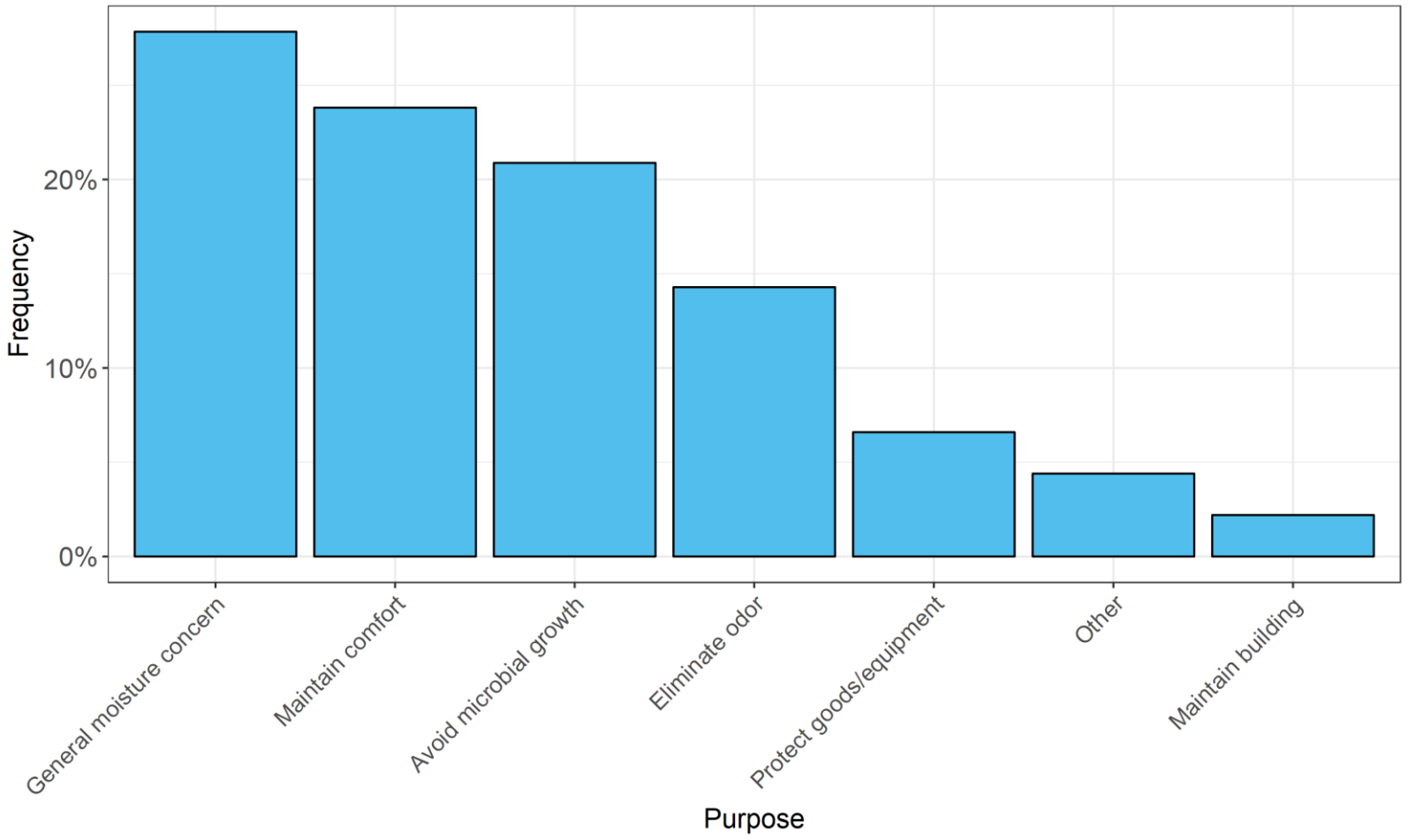
Capacity



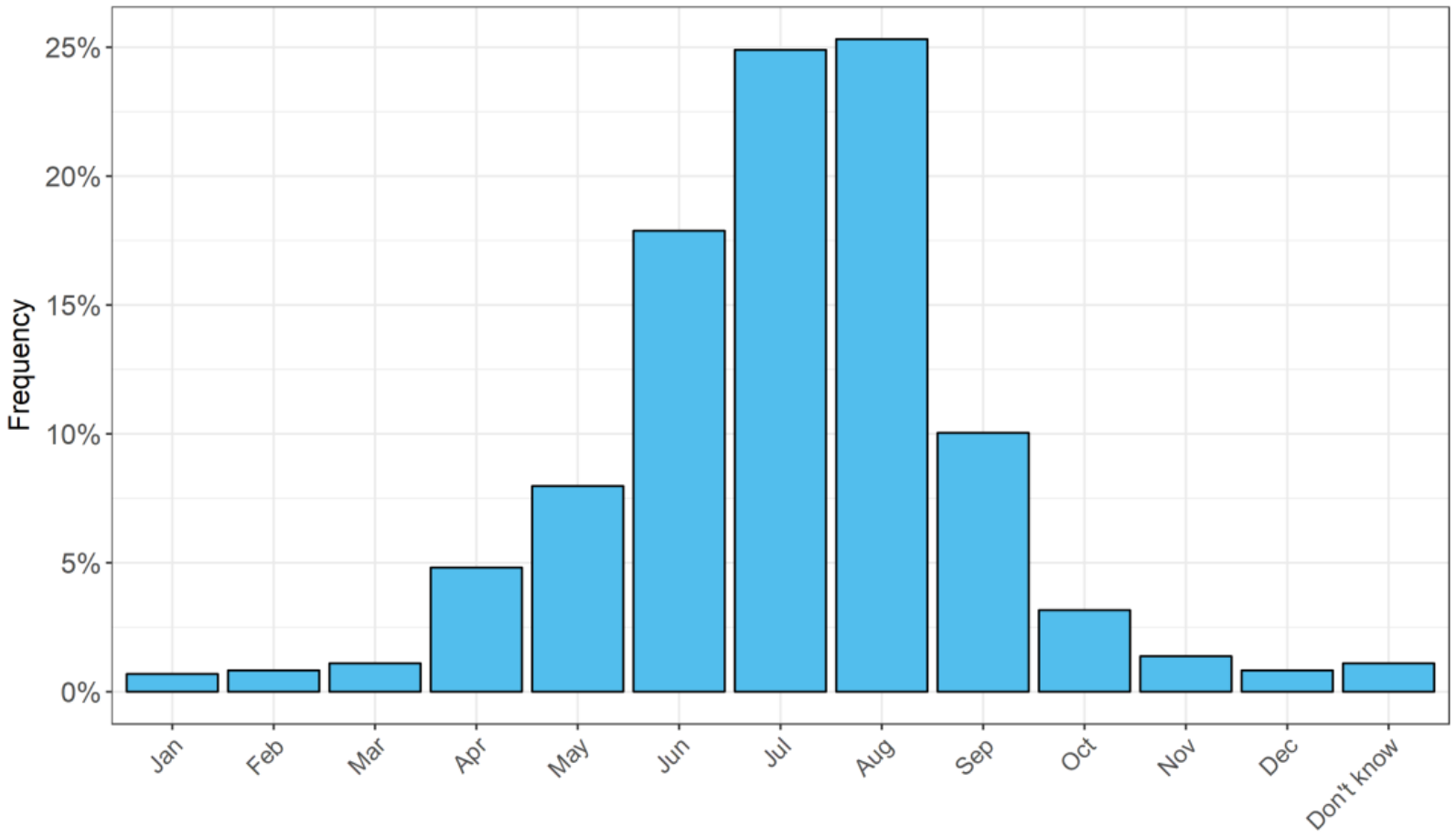
Energy Efficiency



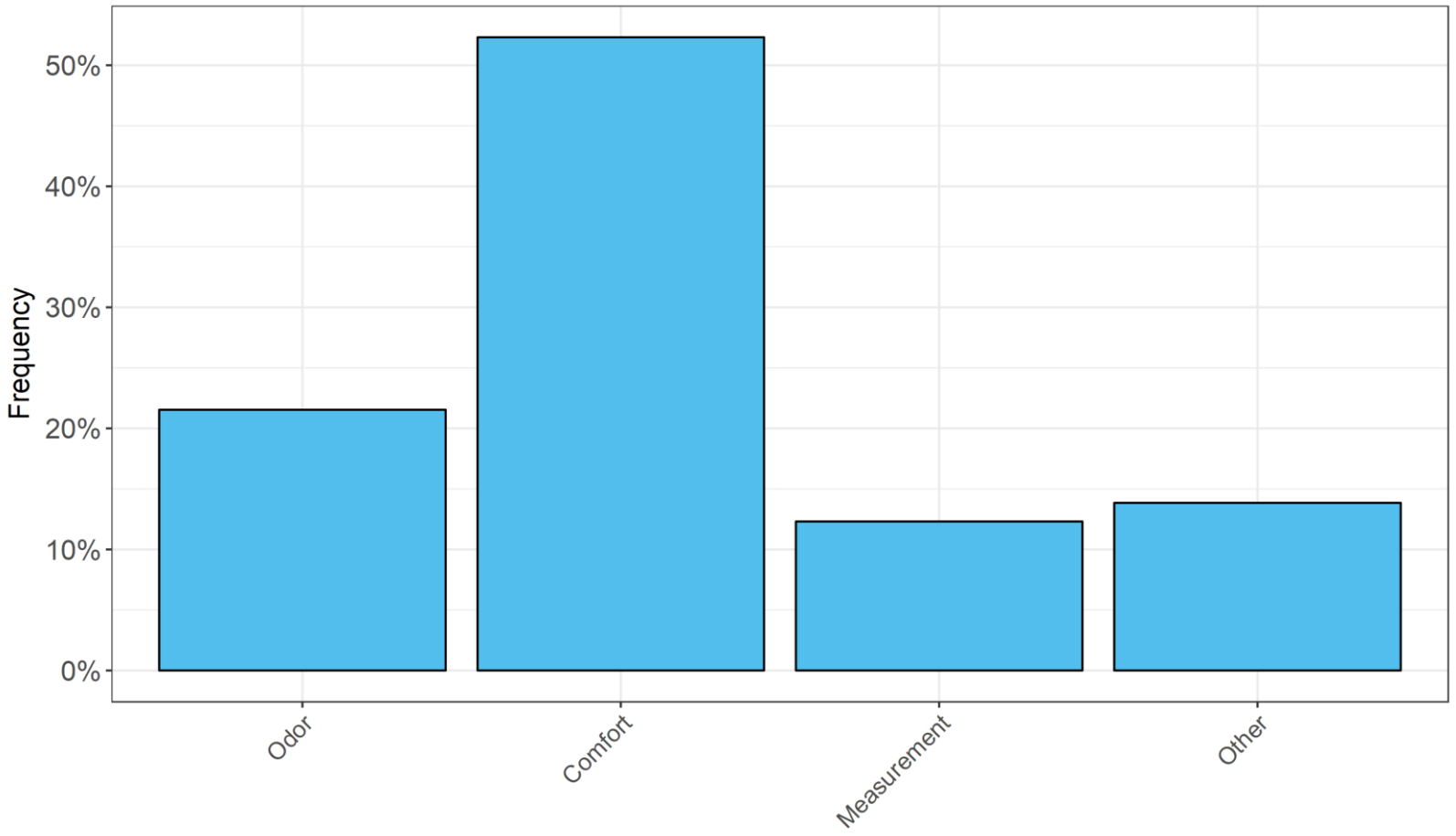
Why Dehumidify?



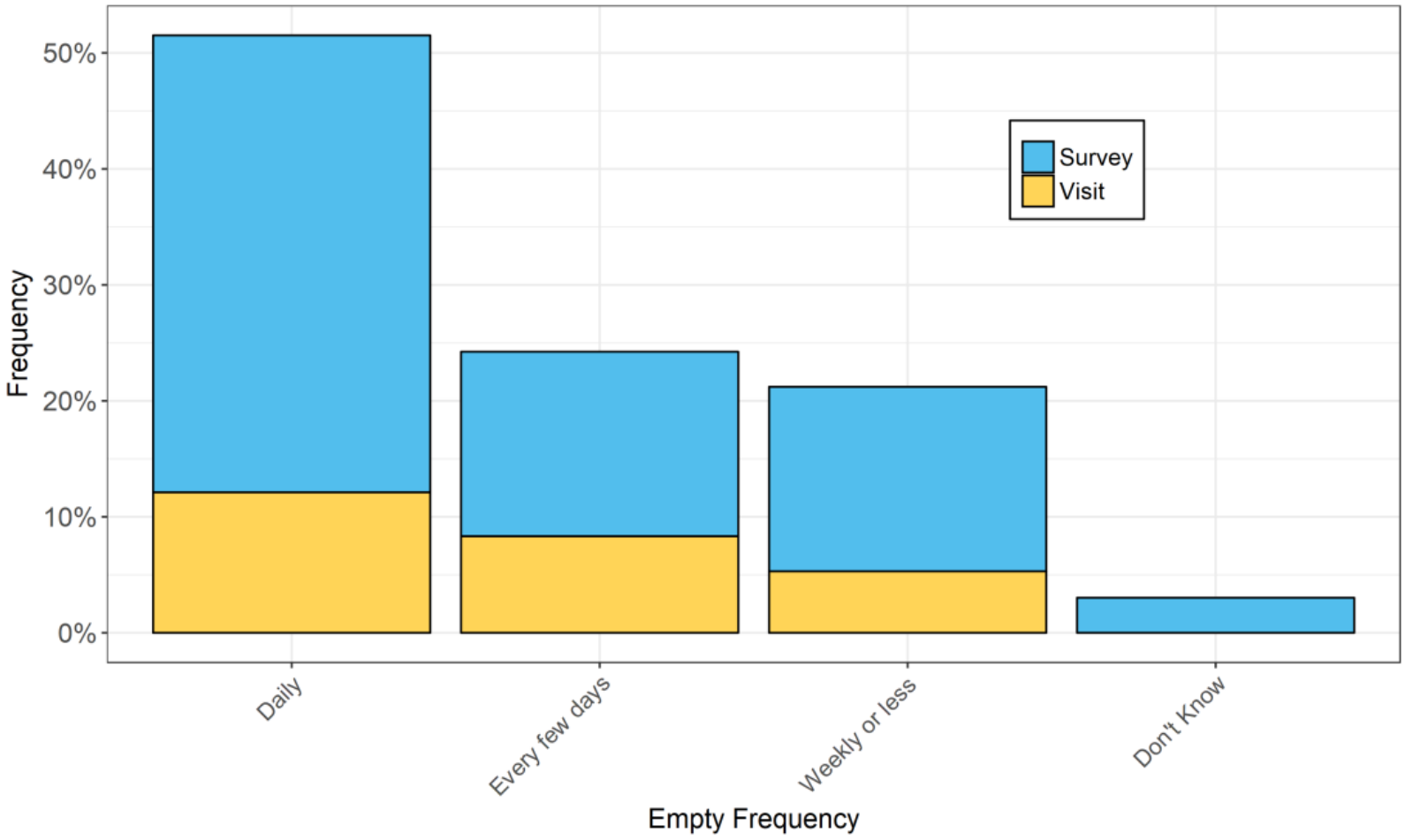
When do people dehumidify?



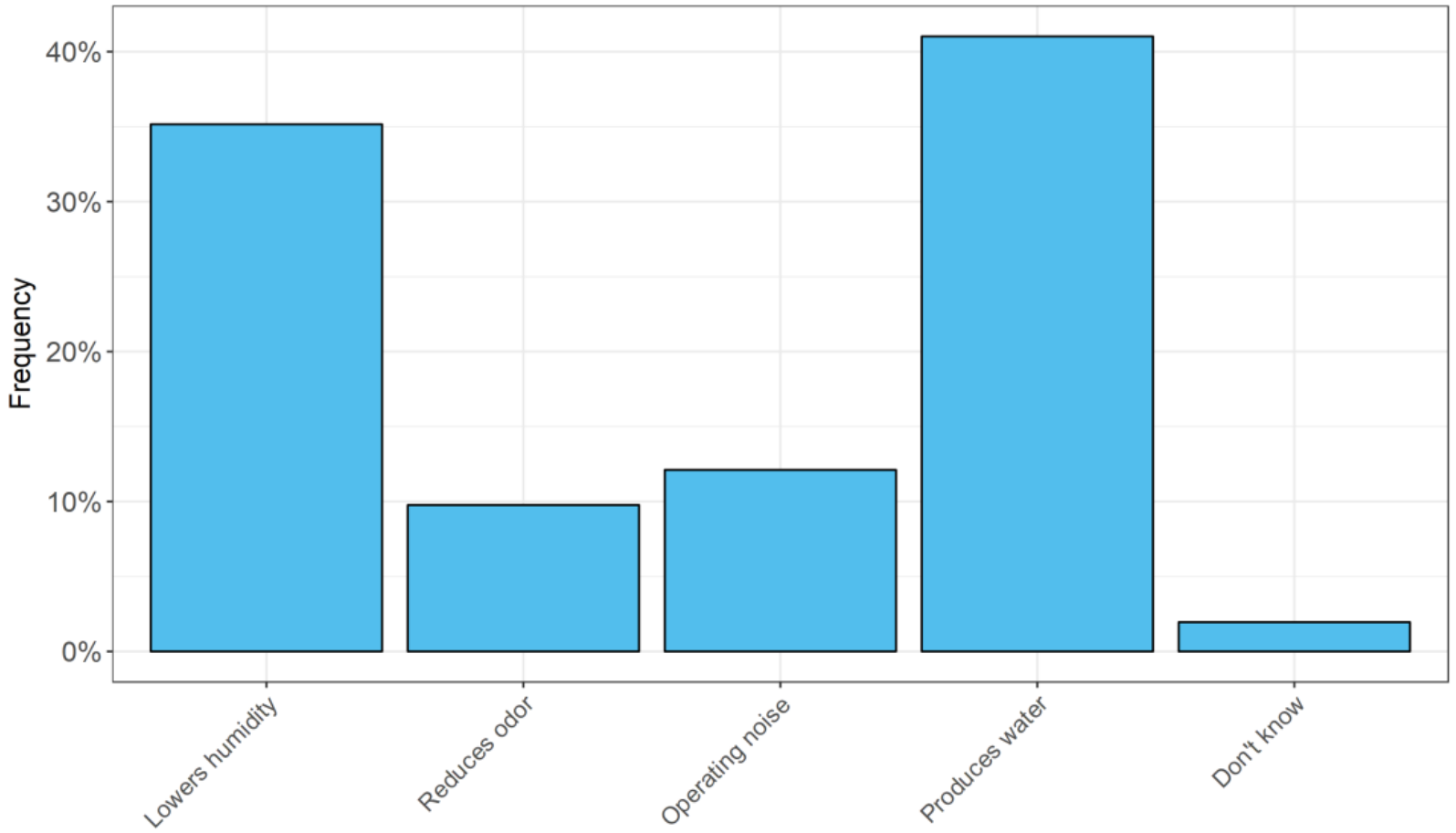
What prompts use?



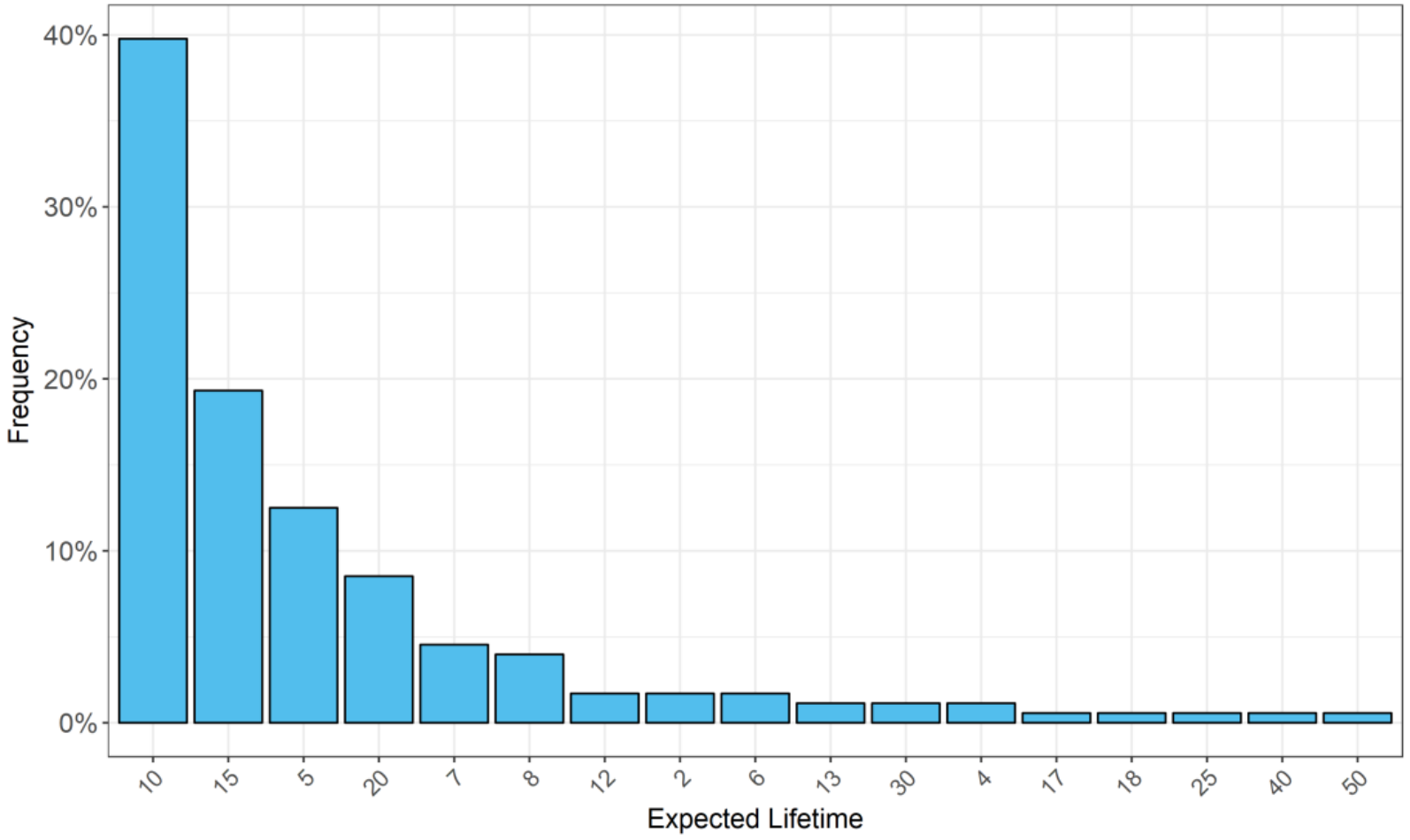
Drainage


50%
40%
30%
20%
10%
0%
Frequency
Survey
Visit
Daily
Every few days
Weekly or less
Don't Know
Empty Frequency

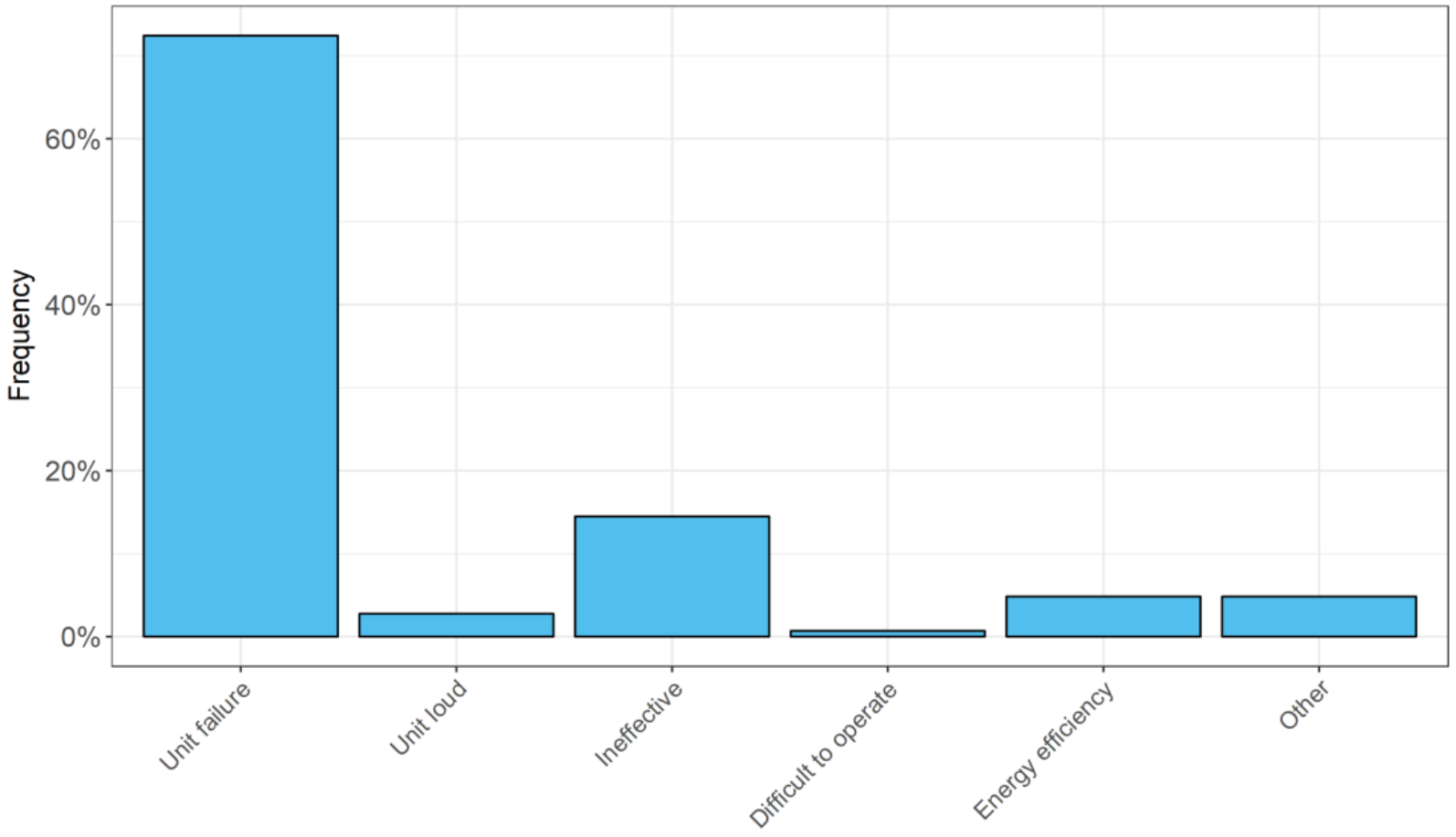
How do you know it works



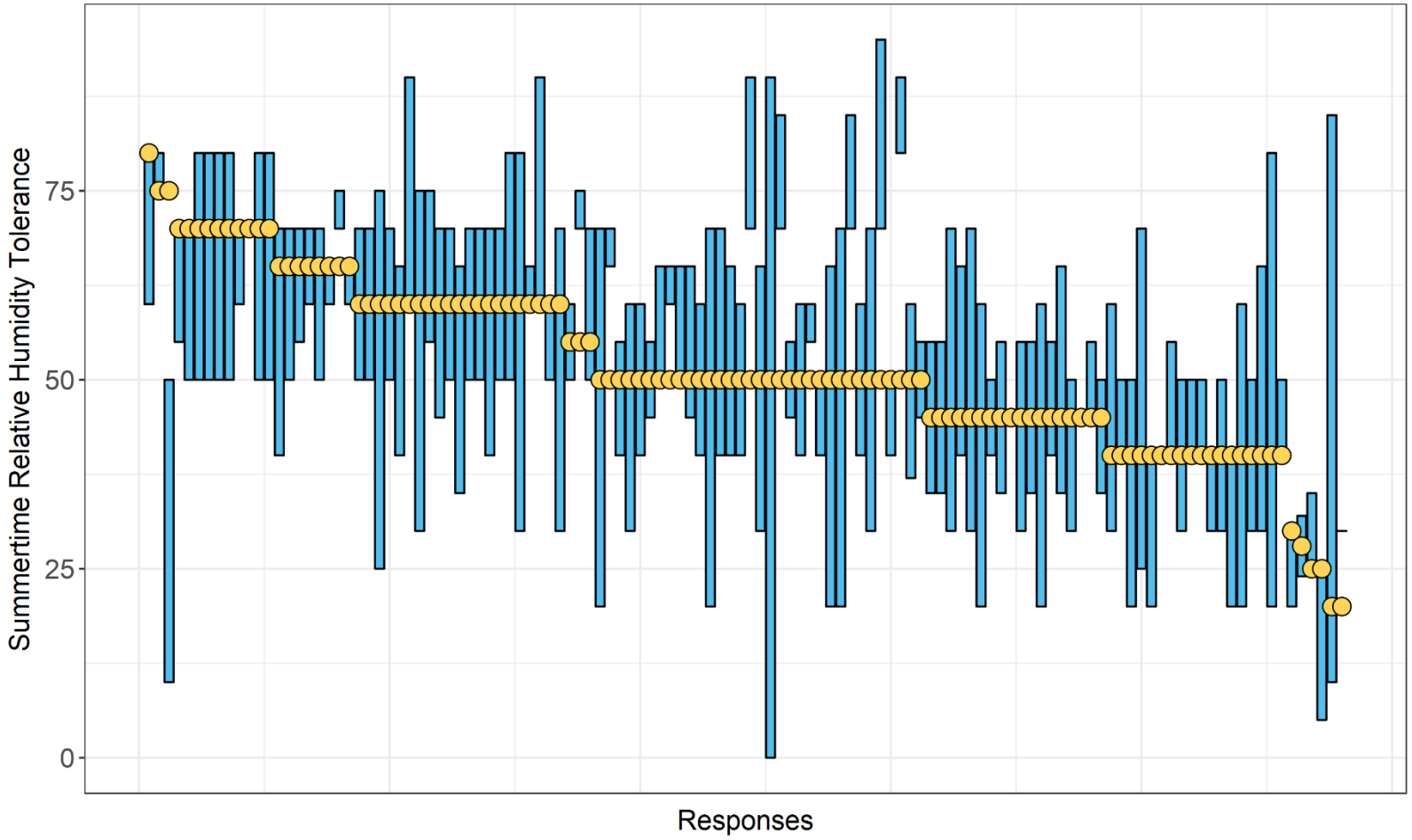
Expected lifetime



Have you replaced a unit?



Humidity Perceptions



Field Work in MN

- Identify (20) representative sites form site visit work
  - Basements (finished, unfinished, hvac, no hvac)
- Instrument dehumidifiers to remotely monitor operations for one dehumidifier season
- Evaluate performance, efficacy, and costs
- Intervene (if necessary)
- Monitor changes in performance, efficacy, and cost over a second dehumidification season

Instrumentation

- Dehumidifiers
  - Power consumption
  - Temperature and relative humidity at outlet
  - Condensate production
- Ambient conditions
  - Temperature and relative humidity of ambient space
  - Temperature and relative humidity at main Thermostat
  - Temperature and relative humidity where necessary
- AC runtime

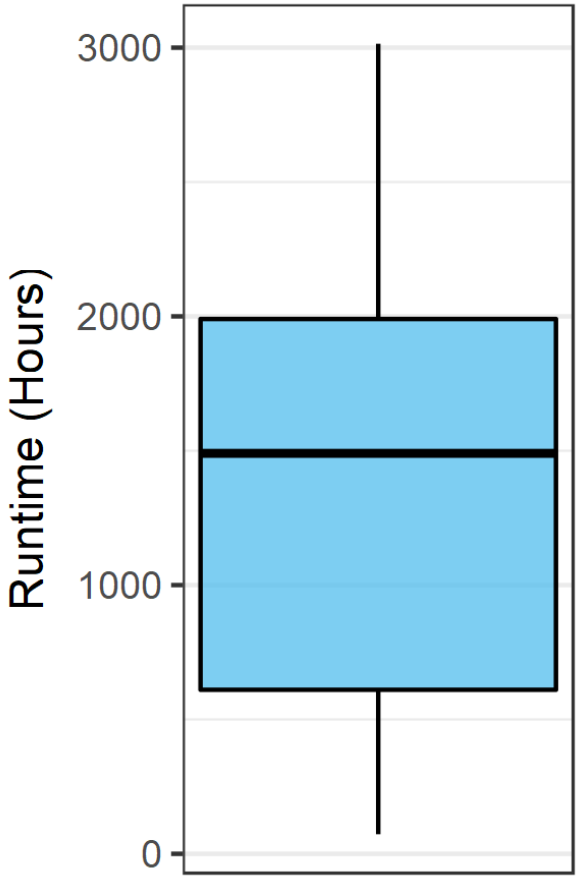
Condensate Measurements

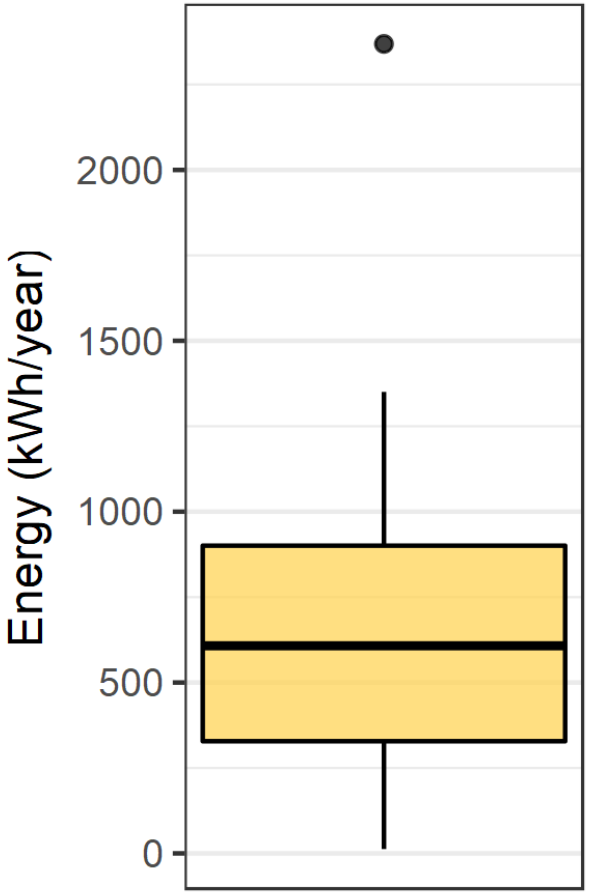
(a)
Scale

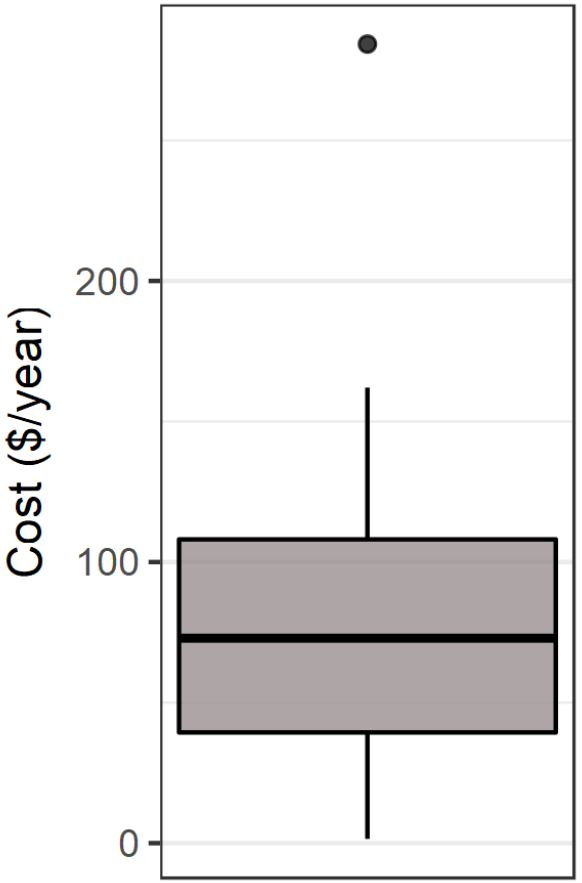
(b)
Rain gauge – Manual

(c)
Rain gauge Auto

Overview for 20 monitored units

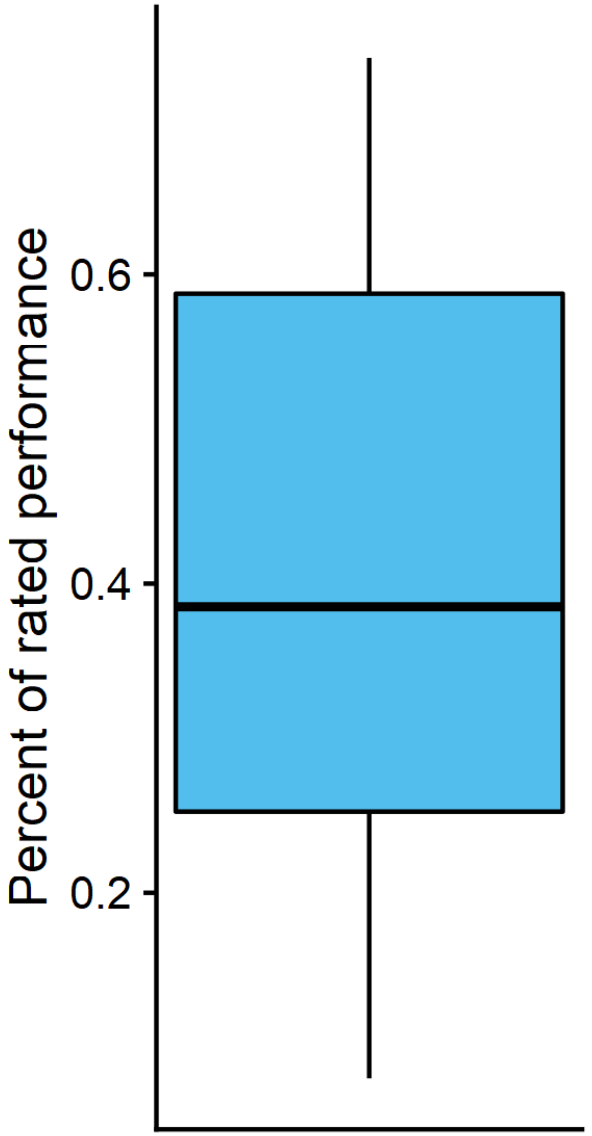






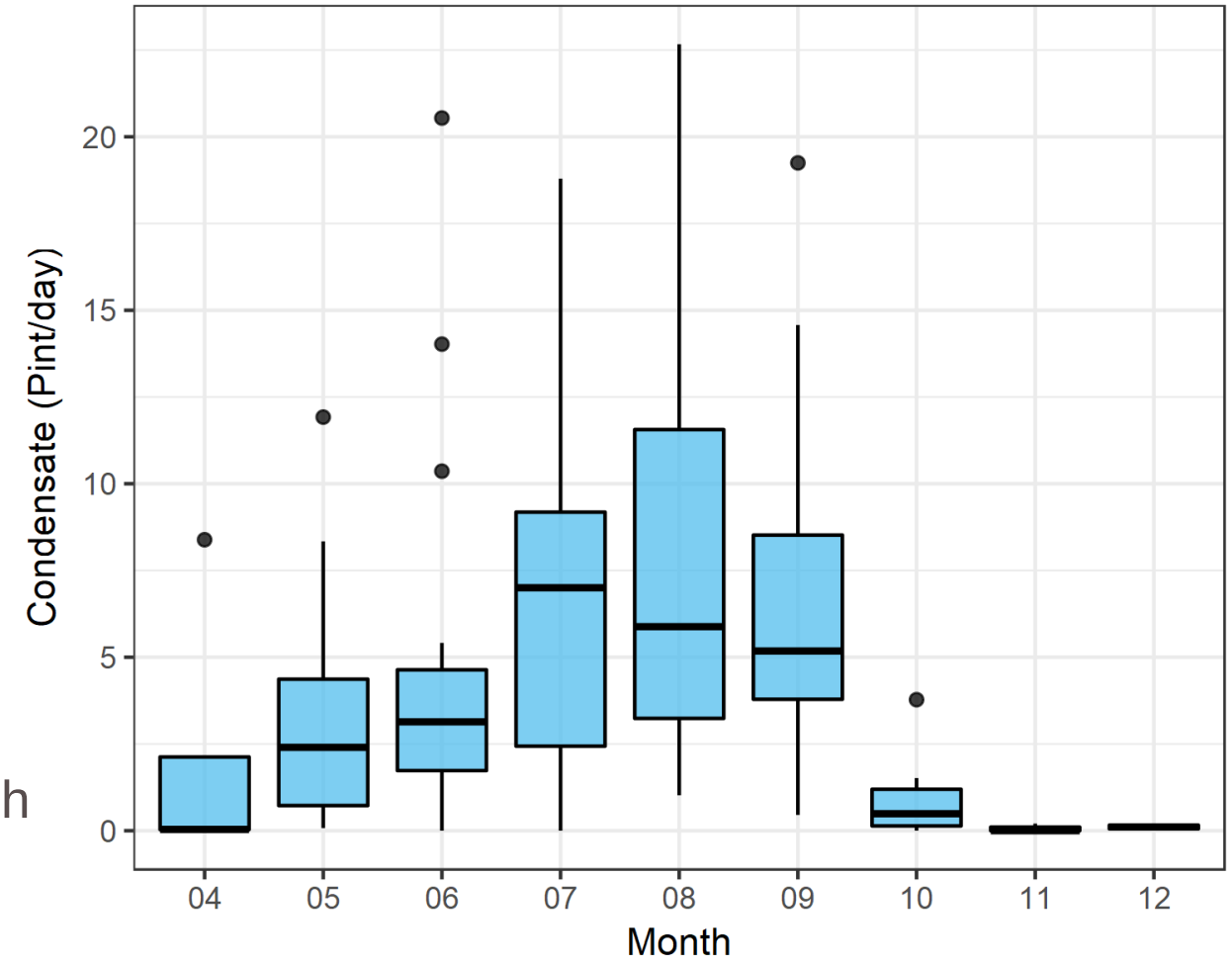
Measured Performance

- Measured energy factors range between 8% and 74% of rated performance
- Oldest units performed worst
- Unit ages ranged from 1 – 48 years old (average 11)
- EnergyStar rated units underperformed by similar amounts as non EnergyStar rated units

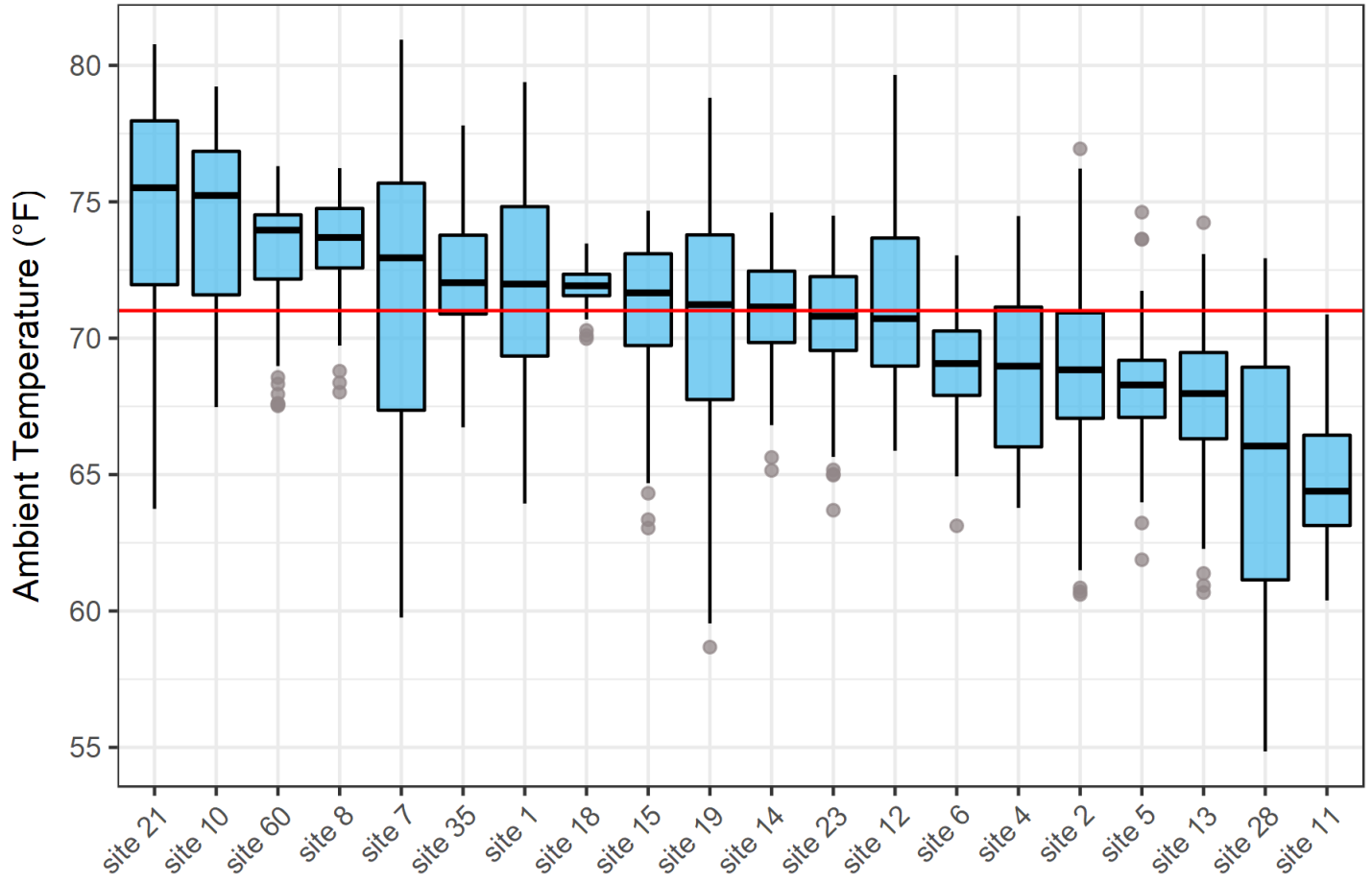


Condensate Production

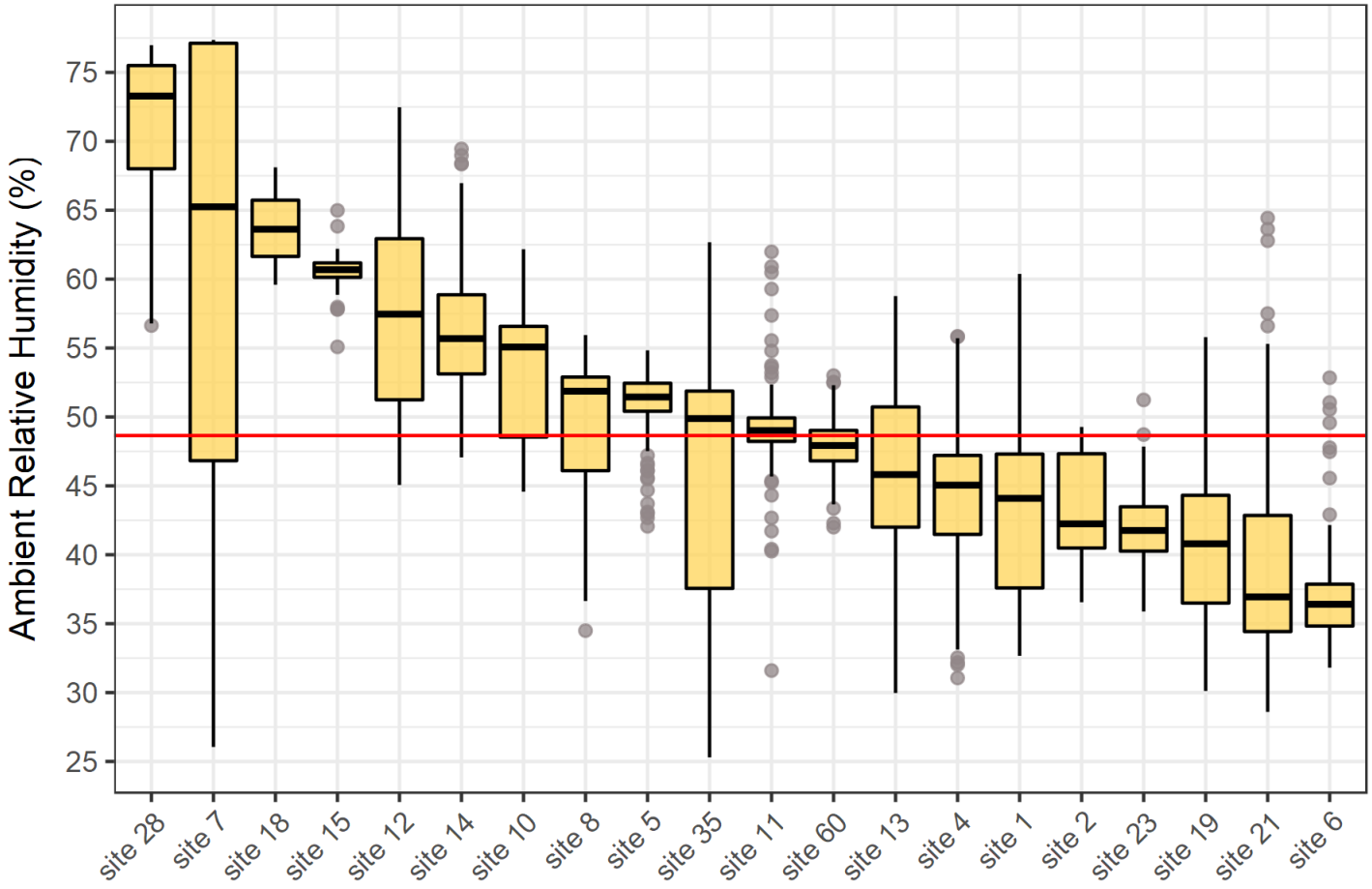
- Typical 3 - 10 pints/day
- Not correlated with unit size (25 – 75 pint/day units)
- Correlated with outside absolute humidity
- Few homes with high loads, most home with low loads



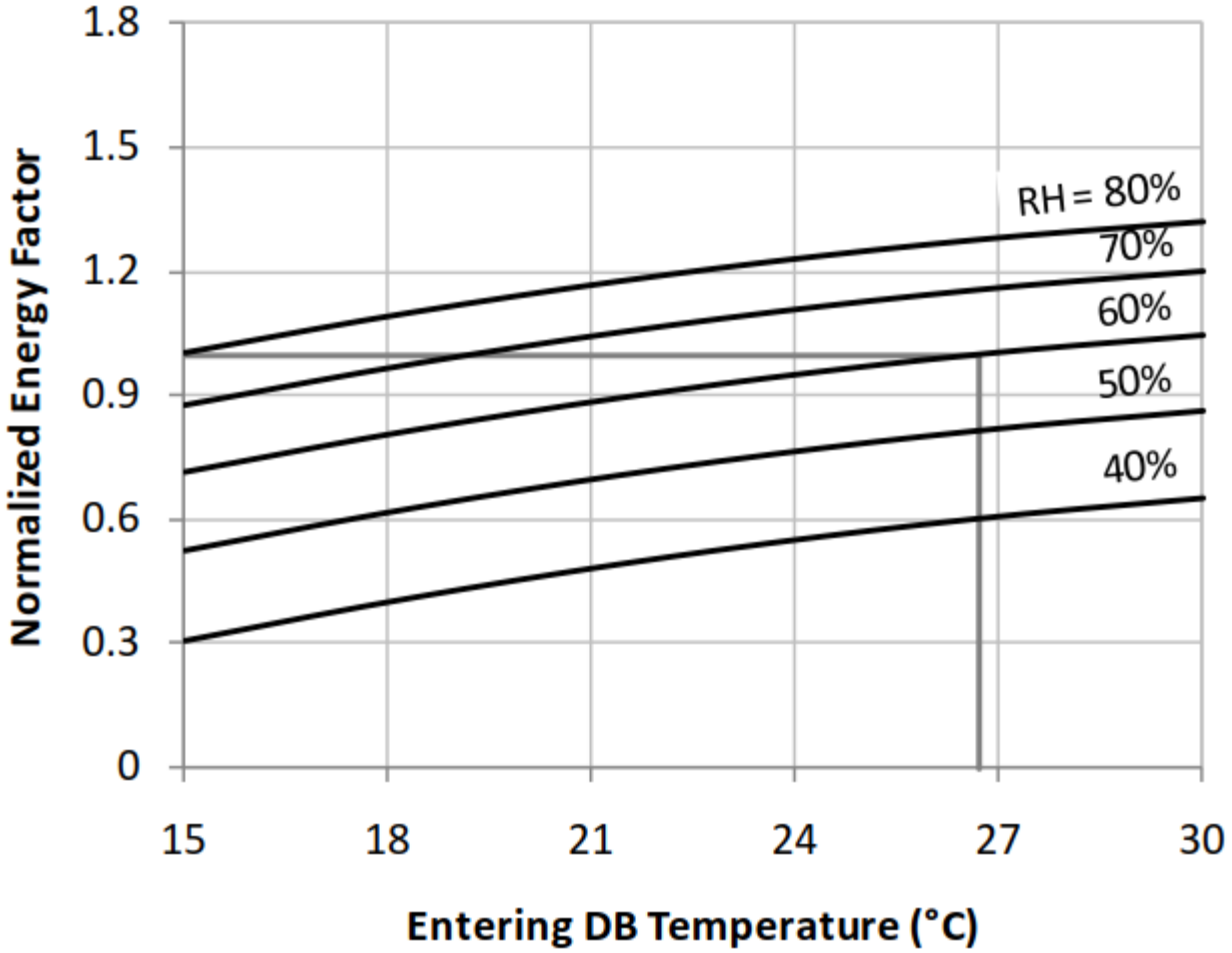
Temperature



Relative Humidity

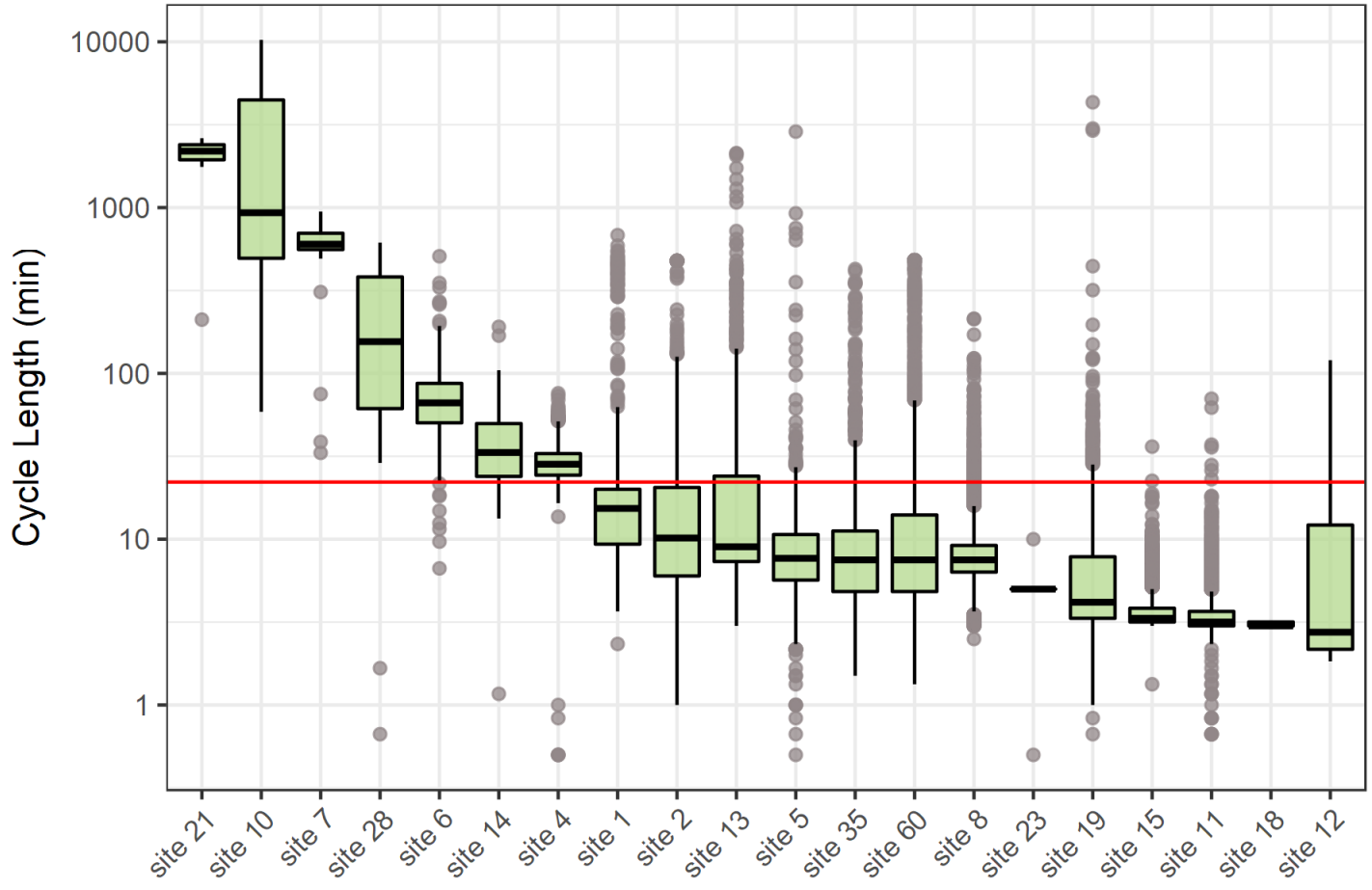


Lab Performance

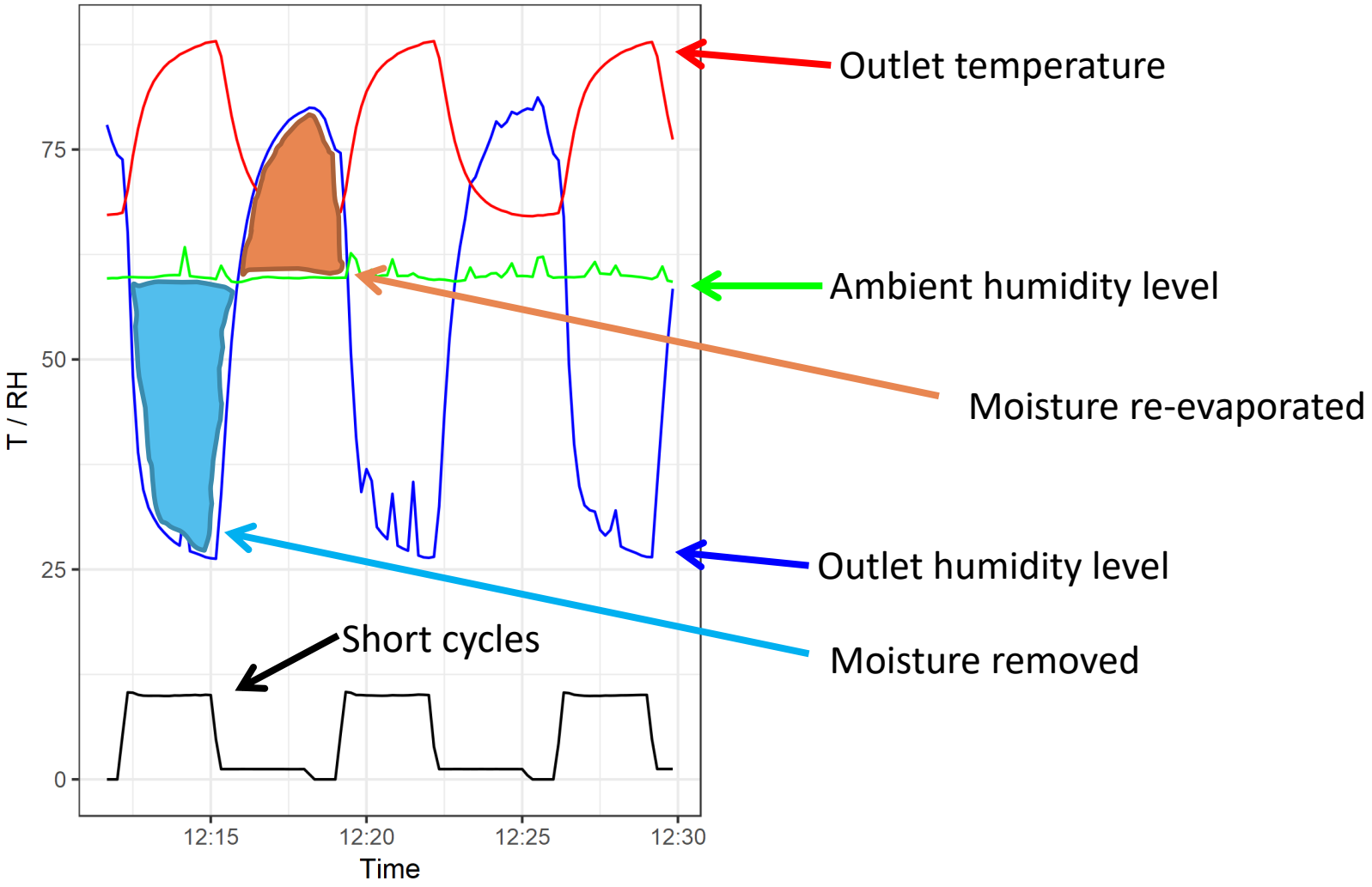


Winkler, J. (2011) "Laboratory Test Report for Six ENERGYSTAR Dehumidifiers"

Cycling


Cycle Length (min)
10000
1000
100
10
1
site 21
site 10
site 7
site 28
site 6
site 14
site 4
site 1
site 2
site 13
site 5
site 35
site 60
site 8
site 23
site 19
site 15
site 11
site 18
site 12

Short Cycling Consequences



Take away: Underperformance

- Efficiency Ratings don't consider basement conditions
  - Standard rating units at 80 °F / 60% RH while average basement conditions in study are 70 °F / 50% RH
- Short cycles greatly reduce performance
  - Units take ~5+ minutes to reach steady state
  - Fan operation at end of operation re-evaporates water off coil
- Age
  - Very old units (1970 & 1992) precede efficiency standards
  - Somewhat old units (1999 & 2003) subject to early efficiency standards

Take away: Dehumidifiers are effective

- One dehumidifier was broken
- One dehumidifier broke during the study
- Identified one dehumidifier that was recalled due to fire hazard

- The 4 spaces with humidity exceeding 60% were set that way

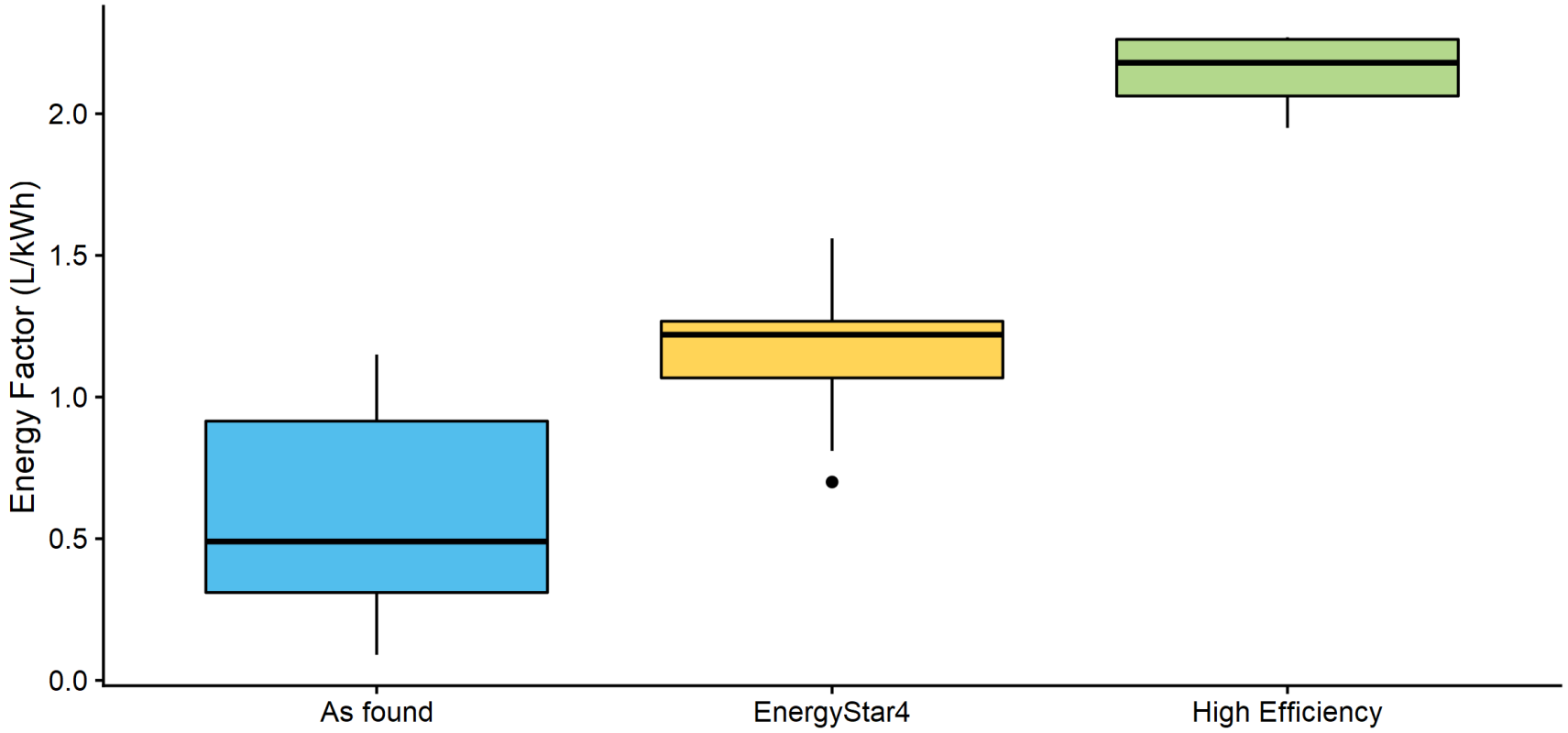
- Humidity levels uniform across basements (and absolute humidity fairly uniform through the home)

Major Interventions

- Equipment interventions
  - Installed (13) 30 pint EnergyStar 4.0 dehumidifiers
  - Installed (4) 55-90 pint High Efficiency dehumidifiers

- Operational Interventions: Goal to maintain 50% RH across basement space
  - (3) increase set points
  - (7) decrease set points
  - (4) increase fan speeds
  - (11) conversions from manual to automatic drain
  - (6) units moved locations

Measured Performance



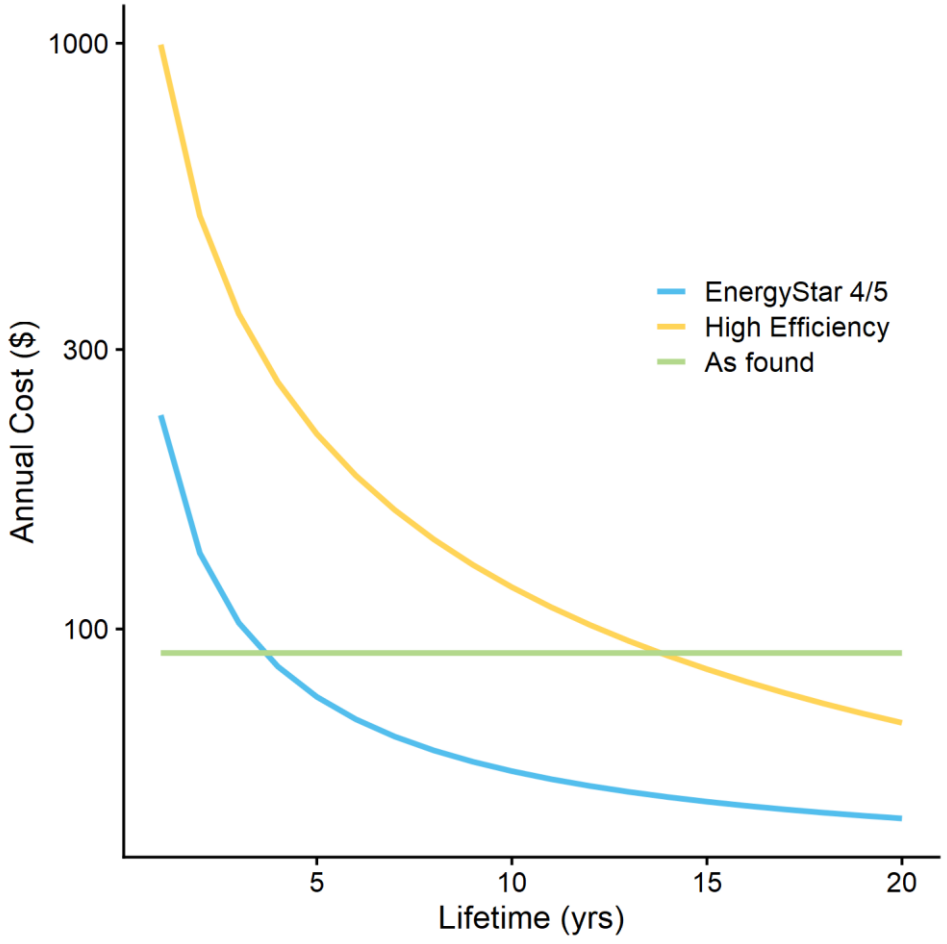
Cost Effectiveness

- Existing costs $91/yr
- EnergyStar4 $38/yr
- High Efficiency $21/yr

- 4 year payback on EnergyStar 4 rated units

- 14 year payback on high efficiency units

- May be an opportunity for better payback of HE units depending on unit durability



Additional Observations

- Dehumidifiers are substantial plug loads, units in this study are 10% of average MN residential electric load
- Digital controls (RH display) are reliable
- Humidity control can be maintained throughout multi-room basements through open doorways
- Dehumidification loads are smaller than commonly assumed (<30 pint, ~ 66% below 10 pint)

Observations Part 2

- Automatic draining units maintain better control than manual drained units
  - No intervention required (~20% of people empty as frequently as they say they do)
  - Tank capacities are much smaller than unit capacity
  - Units can reside in utility space (floor drain) or use existing condensate pumps
  - Most widely-commented upon intervention
- No basement humidistats present (outside existing digital control)
- Homeowner sense of comfort and ideal humidity is inconsistent with measured relative humidity level
  - Analog controls are ambiguous
  - Humidistats help manage this connection by providing calibration
- Low AC runtimes do not provide consistent dehumidification

Practical Guidelines

- Dehumidifiers are not solutions for bulk moisture problems
- Replacing <2016 dehumidifiers with EnergyStar 4/5 units is justified on economic payback about $50/yr average savings across 13 different replacements
- 50% RH set point is a good starting point and can be adjusted based on preference
  - Efficiency decreases below 50%
  - Risk of humidity related issues increases above 55%
- Drain dehumidifier automatically
- High efficiency units are generally not recommended, but should be considered in special cases
  - High humidity loads
  - New construction / whole home dehumidification or ventilation
  - Conditioned, compartmentalized basements

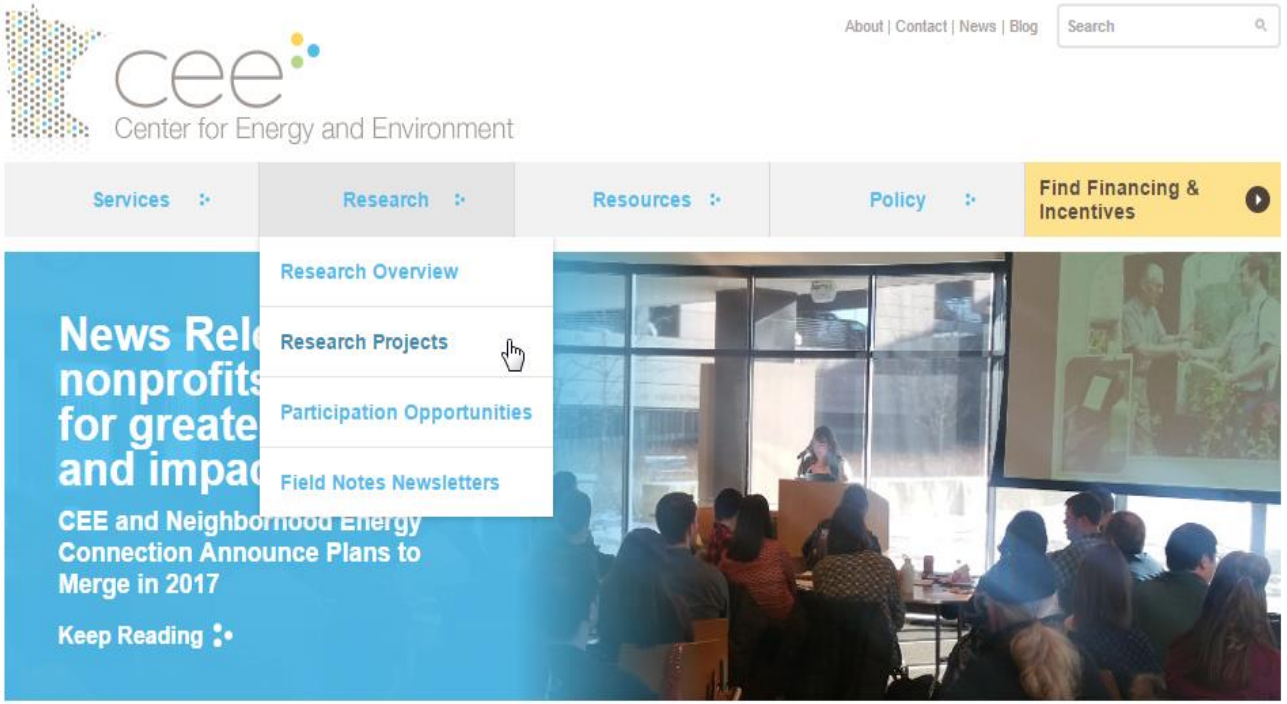
Minnesota TRM

- Assumptions:
  - Runtime: 1620 hours/year
  - Power: 440 – 812W
  - EnergyStar v3 Power: 320 – 720W
  - Energy Factors: Federal Baseline & EnergyStar Ratings
- Measured:
  - Runtime: 1450 hours/year
  - Power: 320 – 770W
  - EnergyStar v4 Power: 250 – 620W
  - Energy Factors: Less than 50% rated EF

- Will recommend updates to TRM based on measured savings, EnergyStar v5 standard

EnergyStar 5

- Temporary confusion in the retail space
- EnergyStar 4 units still available
- Some marketing that recognizes both old and new capacity ratings
- Ambiguity about capacity and performance
- https://www.energystar.gov/



Practical energy solutions for homes, businesses, and communities

https://www.mncee.org/resources/projects/field-study-of-stand-alone-dehumidification-and-ef/

THANK you!

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