Needs and Opportunities to Improve RHC Performance Metrics *Air Source Heat Pumps*

NEEP/RTA Renewable H&C Conference

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Saratoga Springs, NY

Bruce Harley Energy Consulting

My related background/efforts

- Mostly residential
  - Field testing and repair for utility programs and research (CAC, ASHP, GSHP since 1992)
  - RESNET (Home energy rating): GSHP pumping/fan energy documentation and defaults (~2010)
  - Designing/supporting efficiency programs with savings estimates, building science, modeling, training, etc. since 1990

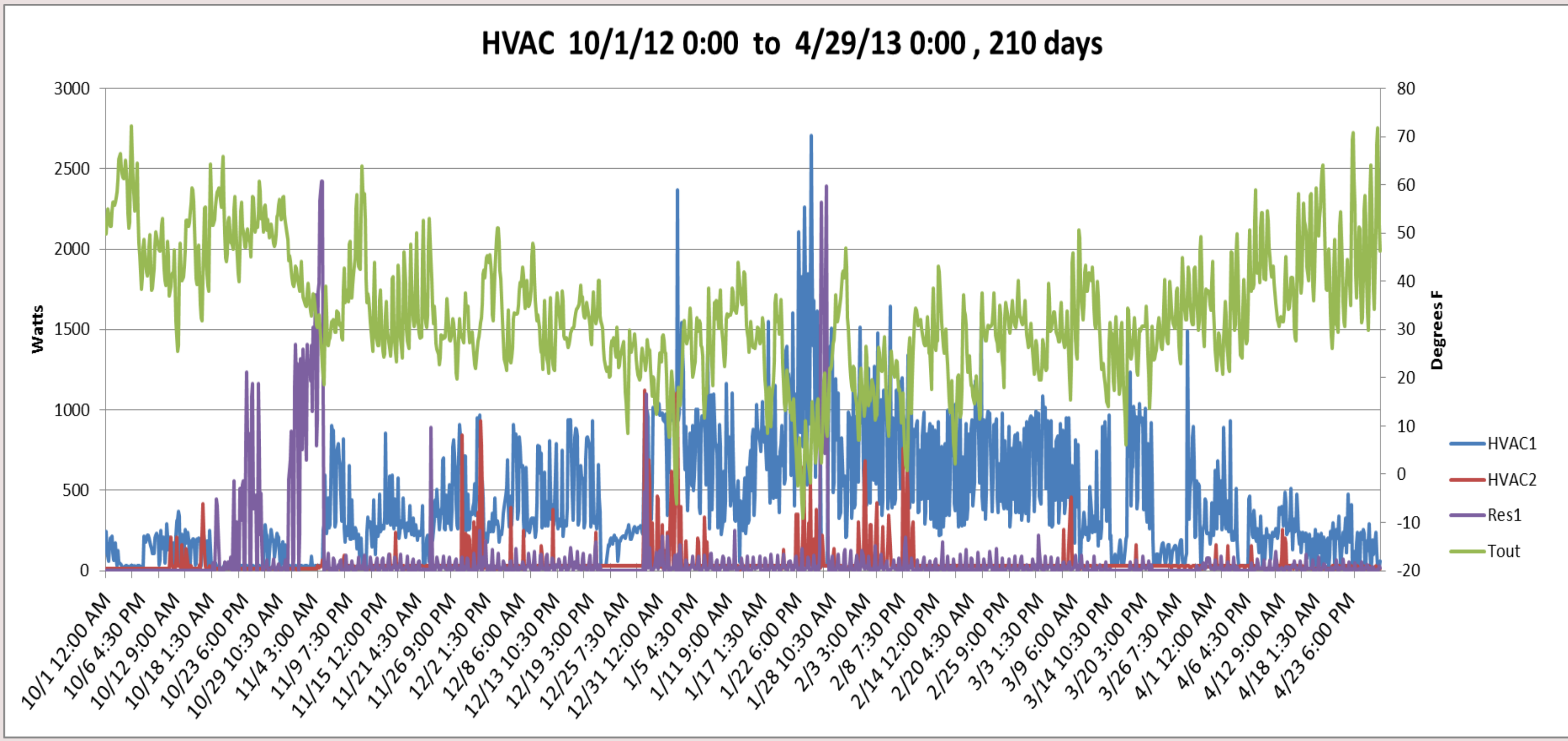
Current Work, Heat Pump Related

BHEC (that's me)* since 2016:

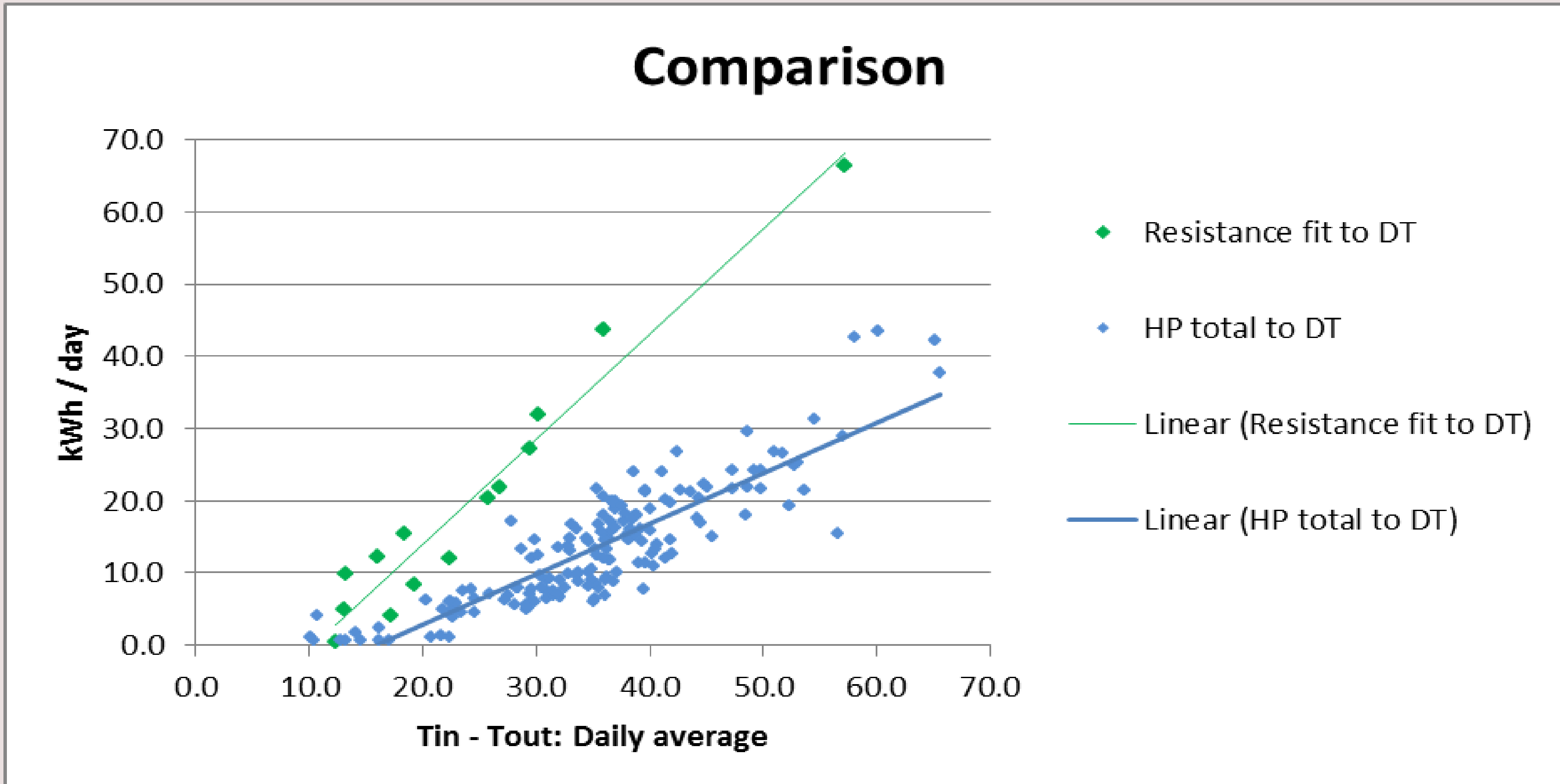
- Codes and Standards
  - Load based lab test and rating procedure for ASHP: Canadian Standards Association (CSA)
- Consulting to utilities, state & federal agencies
  - Program design, savings estimates, technical evaluation, sizing and installation guidance
- Program implementation
  - Including monitoring / measurement, analysis
- Design review, diagnostics/repair

* Bruce Harley Energy Consulting, LLC

HVAC kWh and Tout (my house)



Resistance Heat, ASHP



Outline

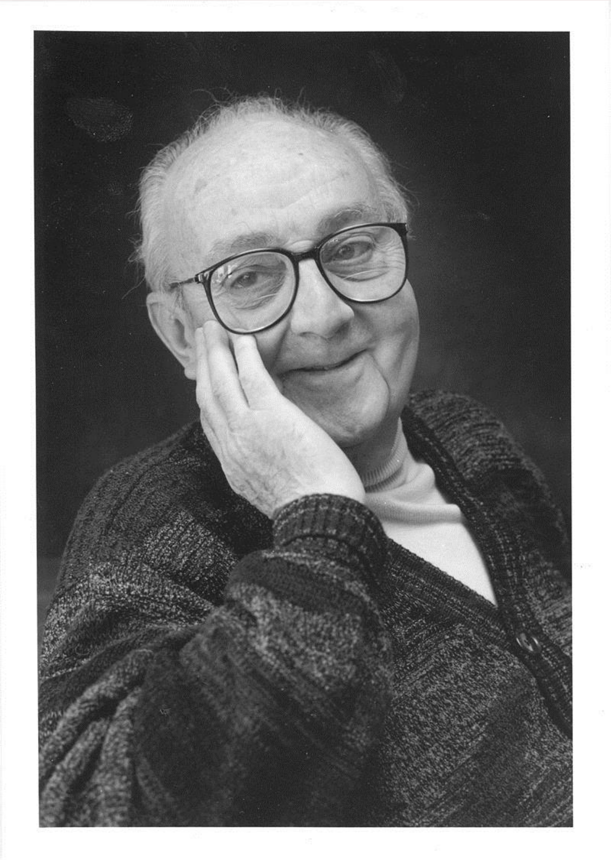
- What explains deviations [**WHY**]
  - Between ratings and in-field performance?
- What can be done? [**WHAT**]
  - Reduce deviations
  - Drive [appropriate] market growth
- How can the region work together? [**HOW**]
  - Support **improvements to rating methodologies** across RHC technologies

Heat Pump Terms

- CAC: Central air conditioner
- ASHP: Air source heat pump
- GSHP: Ground source heat pump
  - Also known as “geothermal”
- COP: Coefficient of performance, “efficiency”

  = Energy delivered / energy input (like units); 1 = 100%
- HSPF: Heating Season Performance Factor

  = (delivered btu / input watt) ~ (COP x 3.41)
  - DOE lab test and rating, simplified model
  - 2 outdoor temperatures, one climate, fixed speeds



All models are wrong,

but some are useful.

- George Box, famous statistician (1919-2013)

Field Studies – a few highlights

- 1990s, Ecotope (WA):
  - Heat pumps: more energy than resistance heating
  - Big losses in ductwork, other installation issues
- 2003 (Ecotope, ductless heat pumps):
  - 14 electric heat homes retrofitted, 1 zone DHP
  - Saved average of 40% (range was very wide)

Recent Studies

- Building Science Corp (Building America) 2014
  - Long term monitoring in 8 low-energy homes
  - Predictable issues with indoor distribution
  - Big issue with “on/off” (*deep* setback = poor eff.)
- Steven Winter (Building America) 2015:
  - Measured 7 mini-splits retrofitted in homes
  - **COP range from 1.1 – 2.3**
  - Issues: **low air flow, high inlet temperature, poor integration with central heat**

Recent Studies

- Cadmus 2016 MA/RA impact evaluation:
  - **Operating hours much lower than expected (only running 19-27% of the time in winter)**
  - Efficiencies somewhat lower than ratings
  - Net result: savings pretty small
- Issues: **lack of use (many installed w/AC focus)**
  - Need **better controls/thermostat placement**
  - **Multi-zone had lower efficiency**
- Cadmus 2017 Vermont
  - Higher utilization, better efficiency and savings
  - Still somewhat below expectations

WHY

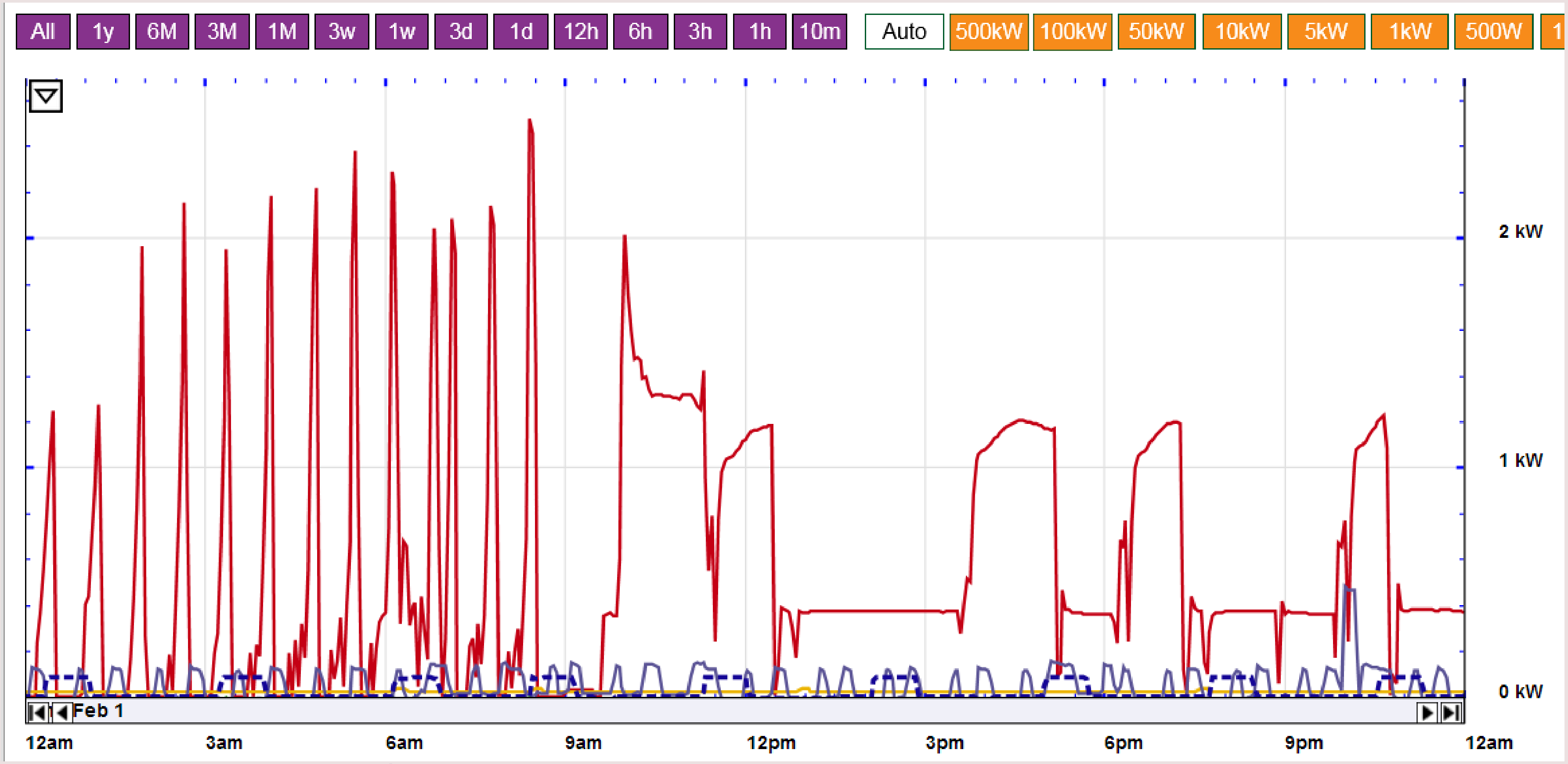
…the discrepancies between rated and field performance?

WHY?

- Low utilization
  - People don’t consistently understand heating value
  - Controls often favor central heating in retrofit
- Inflated ratings
  - Test procedures based on decades-old technology
- Internal algorithms not optimal
  - E.g., cycling at above-minimum speeds,
  - Ignored in rating procedures
- Oversizing – especially multi-zone

My Heat Pump

- Before and after firmware adjustment, 2018
  - An example of why this matters



WHAT

… can be done to reduce variations

and drive growth?

WHAT?

- Provide better metrics / ratings
  - To compare systems to each other
  - To assist designers with consistent info
- Craft those metrics to reflect reality
  - Capture/reveal inefficient operating modes
  - Be responsive to climate variations
- Provide consistent signals to marketplace
  - Rewarding good performance in a relevant way

CSA Test Procedure Development

- Working group hosted by CSA, established 2015
- Comprised of Canadian, US members:
  - Canadian utilities (Chair: Gary Hamer – BC Hydro)
  - Natural Resources Canada (NRCan) / CanMet Energy
  - Northwest Energy Efficiency Alliance (NEEA)
  - Pacific Gas and Electric (PG&E)
  - Electric Power Research Institute (EPRI)
- Tasked to develop a CSA "Express Document"
  - Not full ANSI process, but similar – standards language

EXP-07 Development Objectives

- Response to stakeholder needs:
  - Realistic rating for variable speed equipment
  - Seasonal efficiency for heating & cooling reported for a range of climate zones (**8** in US/Canada!)
  - Detailed data for hourly computer simulation
- Voluntary test – *not intended as regulation*
  - Marketplace differentiation of high-performance products
  - E.g. market support via qualified product lists

EXP-07 Scope

- ***Single stage, multiple stage, and variable speed heat pumps and air conditioners***
- **Residential** equipment sizes <65,000 Btu/h
- **Ducted/ductless (including central ducted)**
- **Air-to air, single zone**
  - Multi-zone, air-to-water, VRF are planned
- Use dynamic, load based test rather than fixed speed "test-mode"

Stakeholder Needs

- Climate sensitivity
  - For heating and cooling performance
  - Allows for customized “application rating”
- Include standby energy
  - Can be significant in shoulder seasons
- DOE rating: HSPF is not representative
  - Based on two data points and one climate profile
  - Cannot provide accurate heating kWh estimates
  - Meaningful product comparisons impossible

DOE Climate Regions

(only used for heat pump ratings)

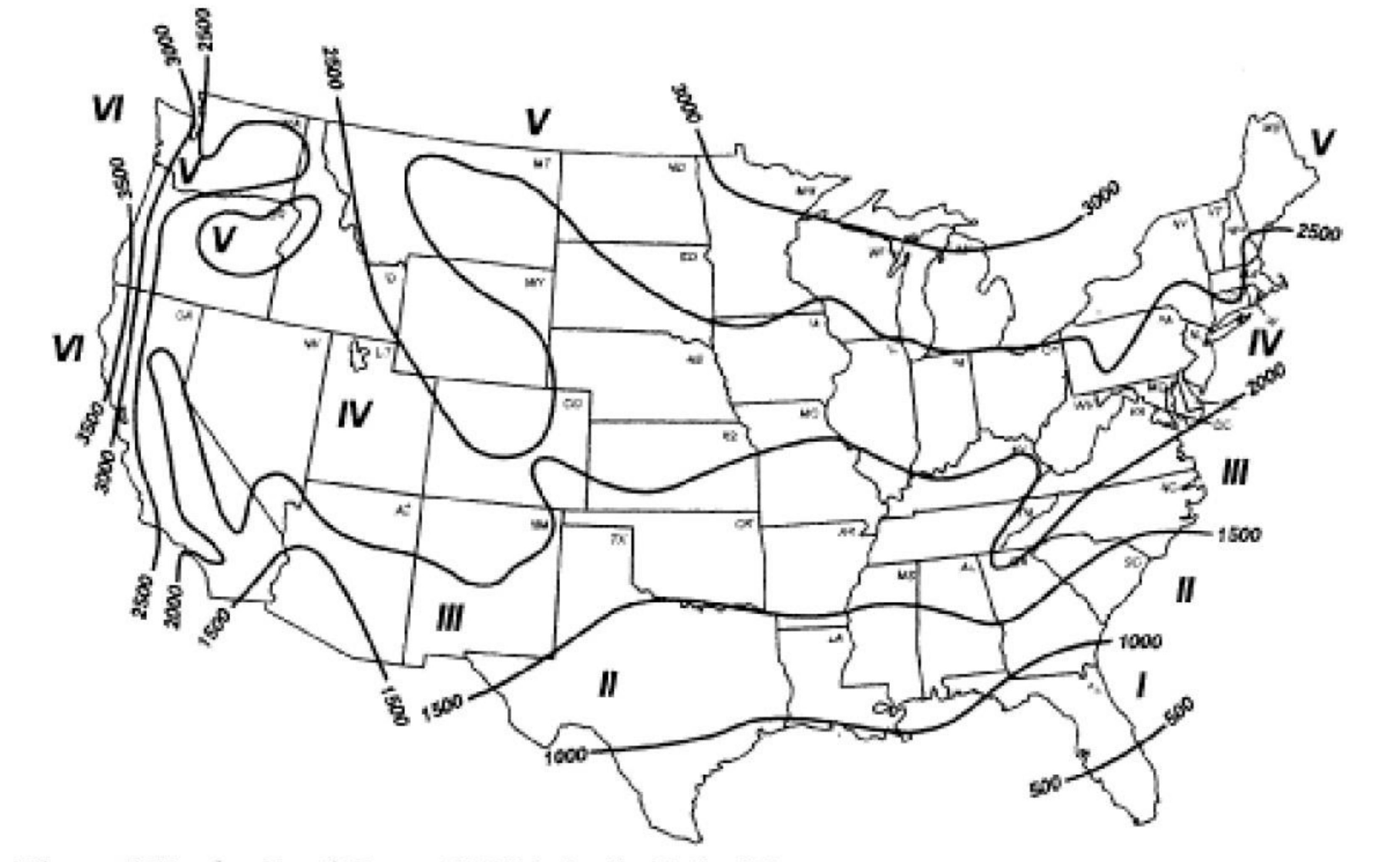
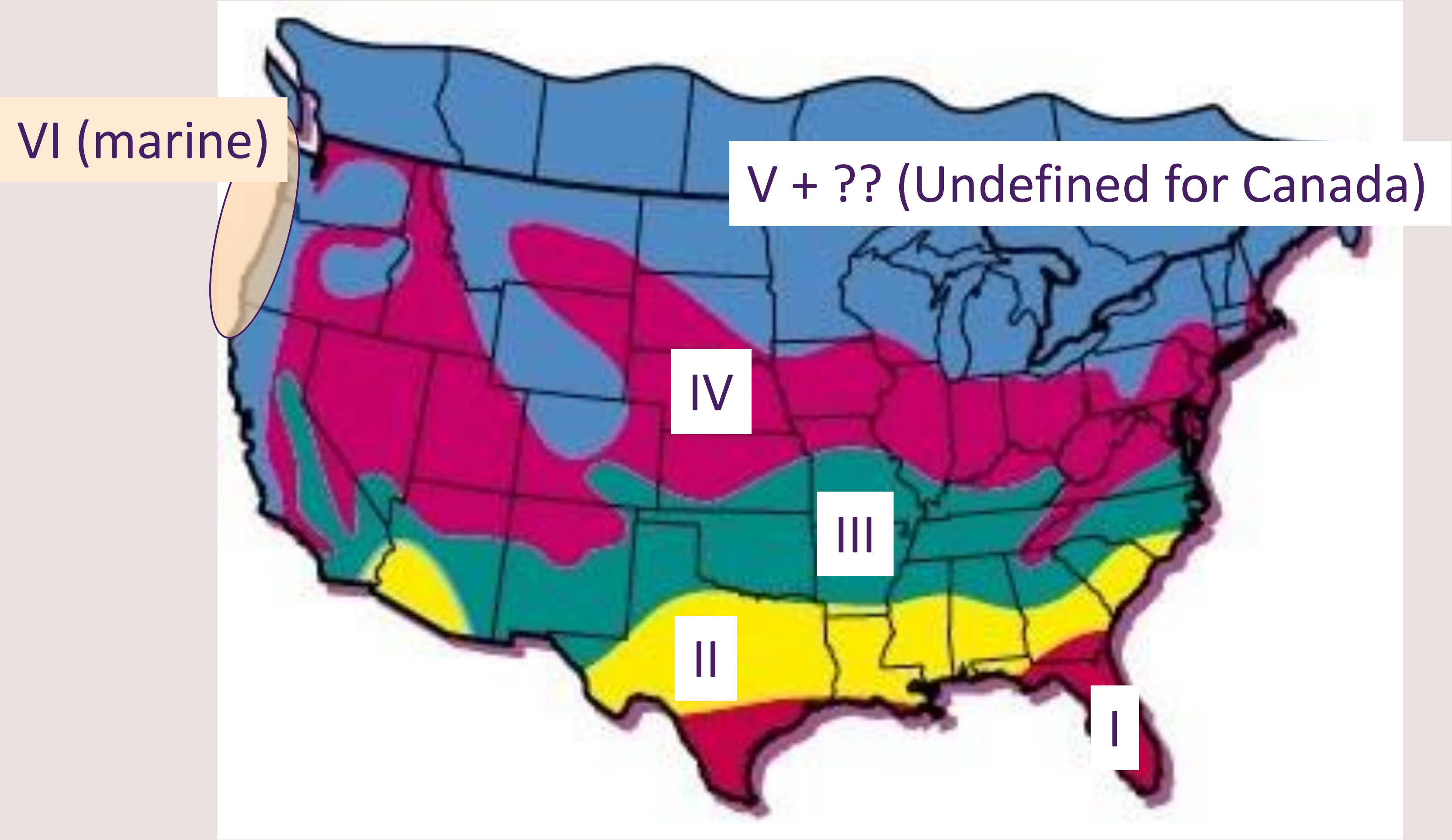
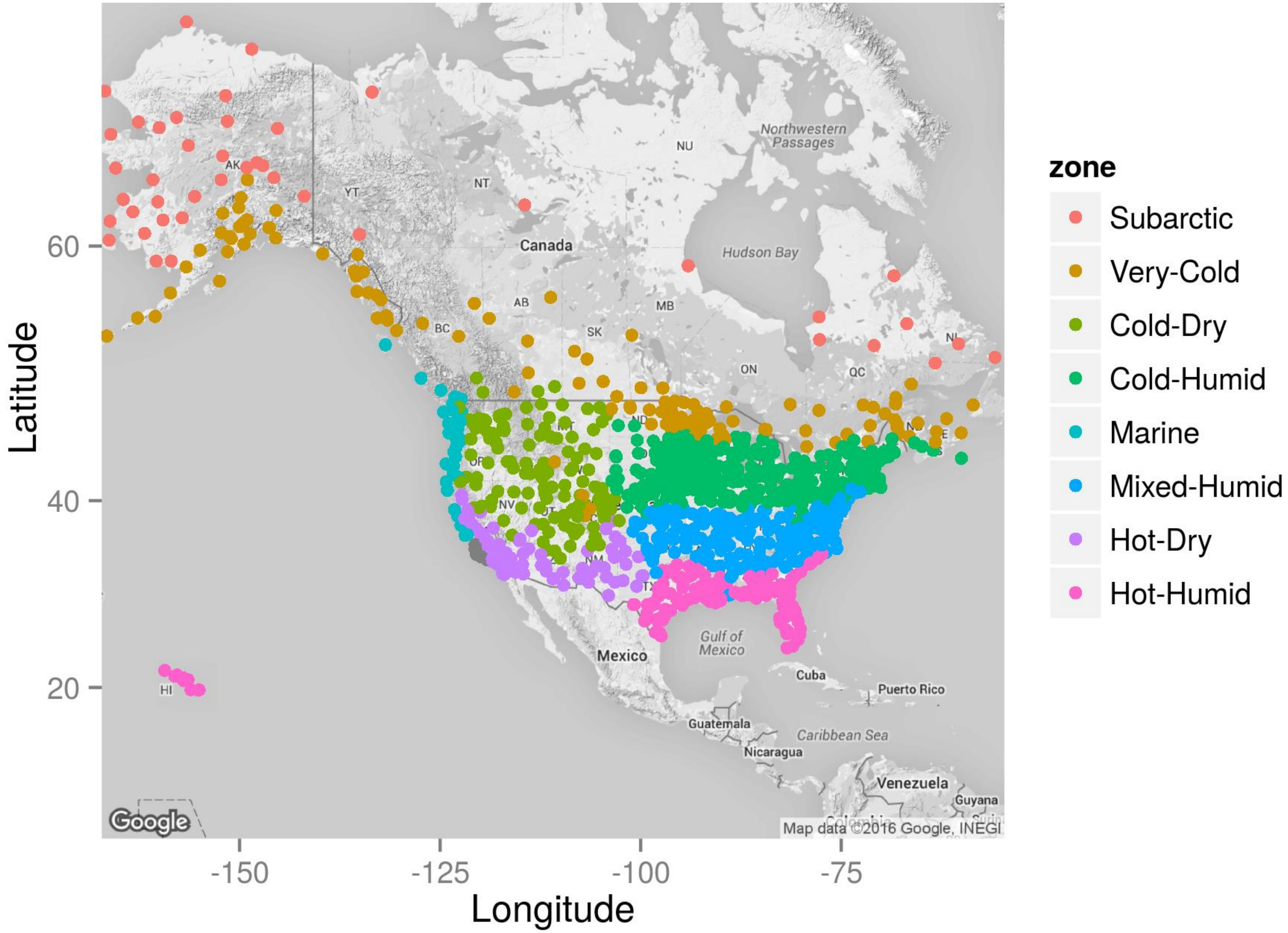


Figure 2 Heating Load Hours (HLH_A) for the United States



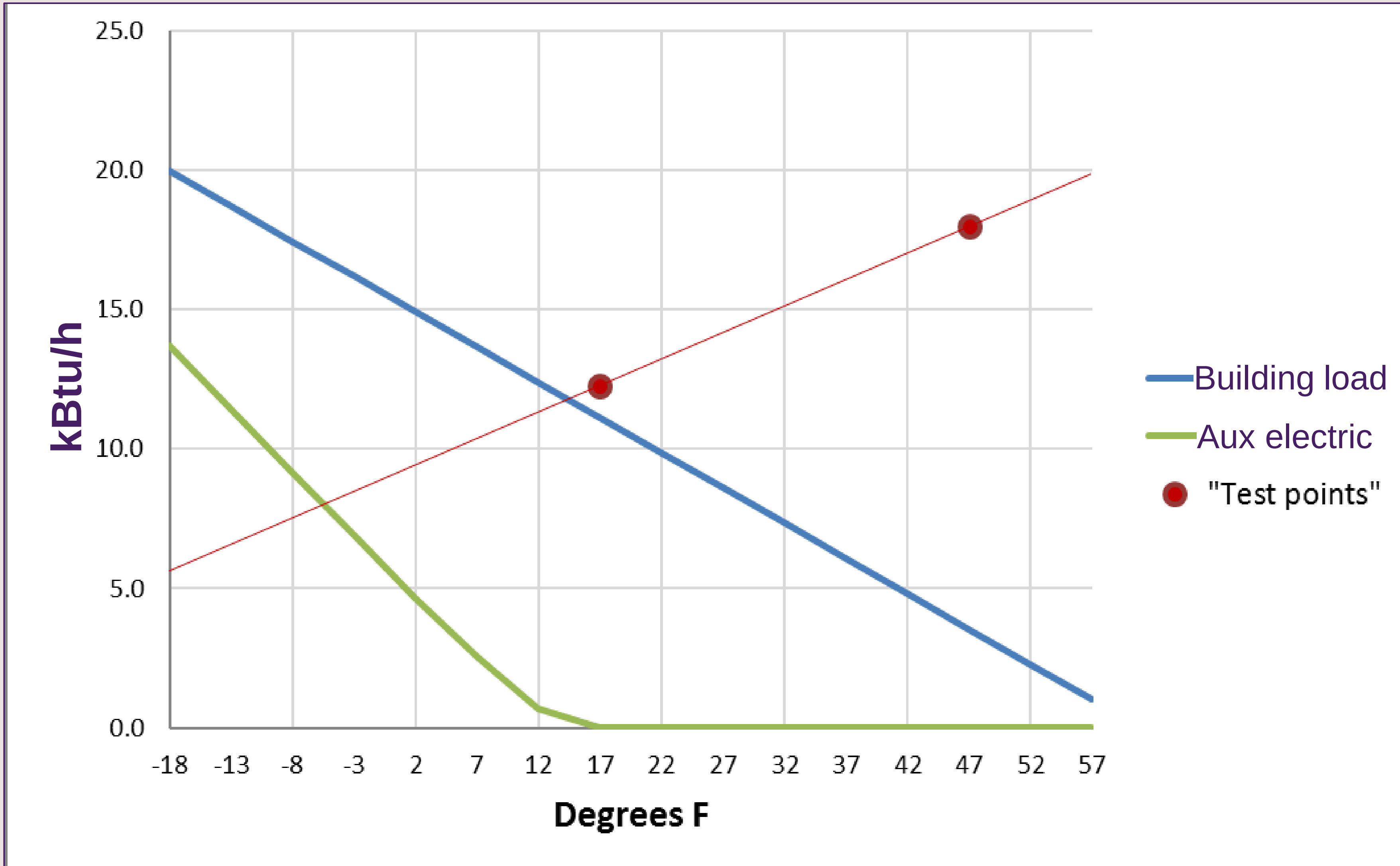
- ***Can only use Region IV (pink) to report HSPF***

CSA Climate Zone Assignments

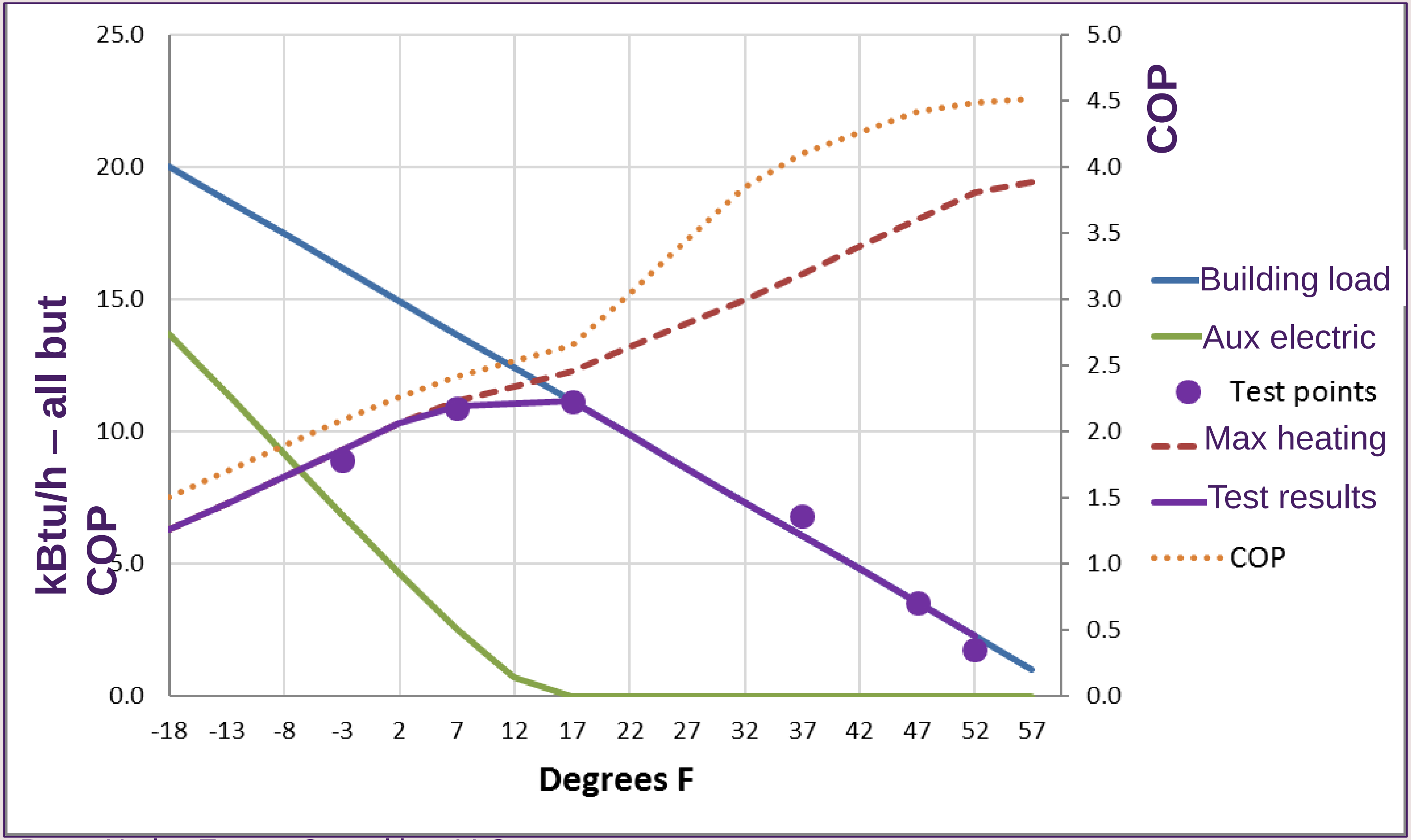


Based on data analysis, Building America climates

Conventional (DOE) Heating Test – 2 points extrapolated to wide range of conditions



CSA Test Approach: Multiple points Match loads with outdoor conditions



DOE Test: Locked Test Mode

- Fixed fan and compressor speeds
  - High fan speeds, not available in normal operation
  - This increases ratings but not real performance
- Doesn’t include low-load cycling behavior
- Manufacturer’s technicians install equipment and monitor testing using proprietary test modes
  - Can’t be independently duplicated

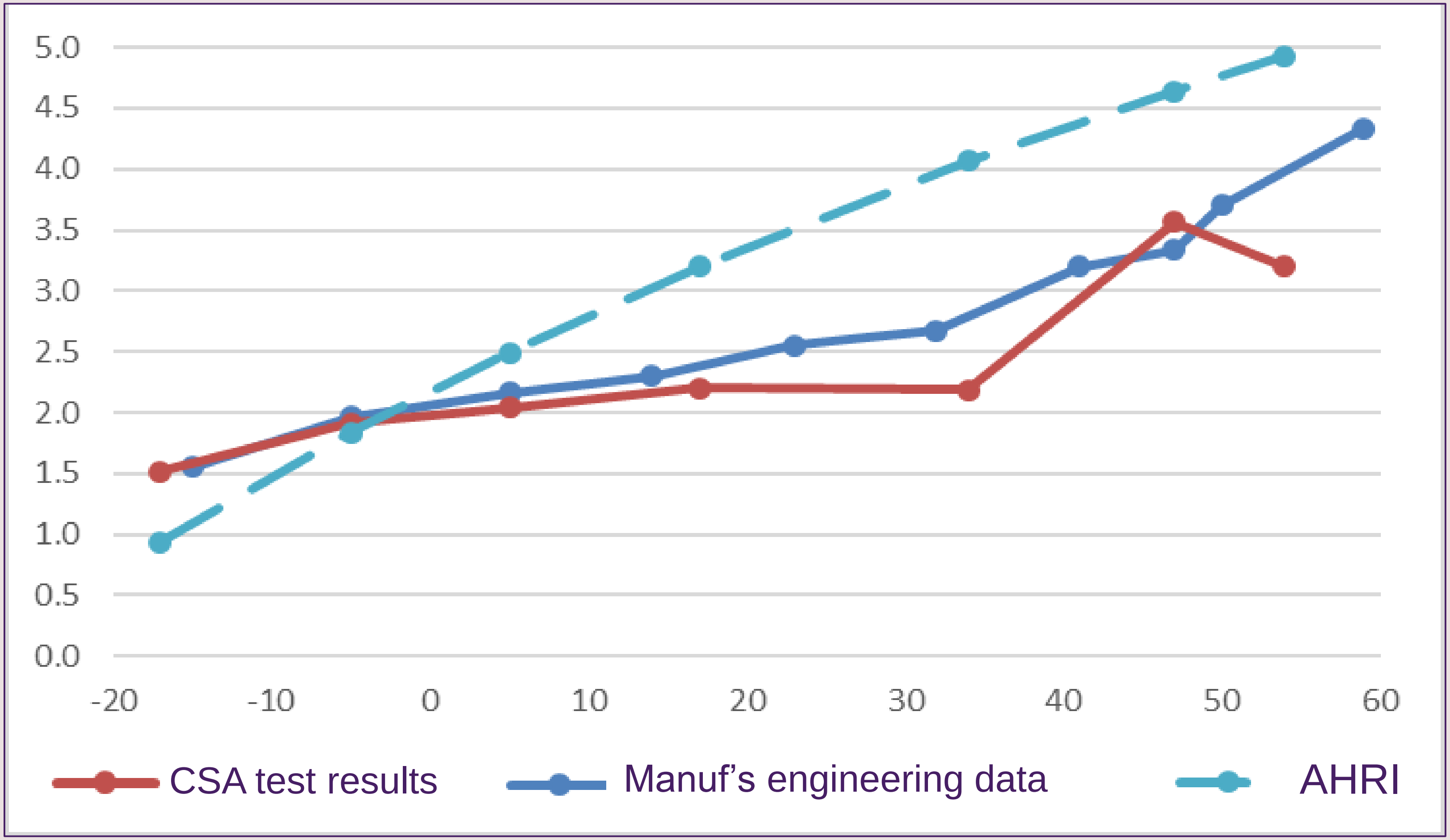
Dynamic Load Based Testing

- Indoor room has a simulated load
  - **Load is "imposed" by indoor room reconditioning equipment, programmed to mimic load**
  - **Load varies based on outdoor conditions**
  - Includes dynamic moisture load for humid/cooling
  - **Equipment under test installed per manufacturer's instruction manual**
- On-board controls govern fan, cycling, defrost and latent removal in single test procedure

CSA Test, Manuf. data, AHRI values

- **Test COPs match manufacturer engineering data fairly well**
- AHRI shown for illustration purposes

  (From published values at 17/47; not including defrost, C_D)



HOW

… can the region work togethe?

HOW?

- **Support improvements to rating methodologies across RHC technologies**
- Support and encourage use of load-based testing, voluntary rating/metrics

Other efforts: NEEP

- Sizing/selection guide and installation guide
- neep.org, “Initiatives/air source heat pumps”, “Air-Source Heat Pump Installer Resources” link on right side
- Also, “Cold Climate Air Source Heat Pump” link at right to cold climate list
- Updates coming in 2018, + consumer’s guide

Sizing and Selecting Guide

Application Sheets

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Heating (or Heating & Cooling) Displacement

Application Description	Custo Heati servi
Suggested ASHP System Configuration (Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)	For th locat syste and s make
Suggested Treatment of Existing HVAC System	Left i of ho
Sizing Strategy Overview	Place (as a to he desig coolir
Load Calculation	See "
Equipment Selection Considerations	Heati Unde even outdo
Oversizing Concerns / Tradeoffs	Cooli is ove capa

Further Guidance

- Consider floor mount unit serving first floor especially

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Full Heating System Replacement

Application Description	Typicall poorly i decomm are loca suitable
Suggested ASHP System Configuration (Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)	For this mini du above),
Suggested Treatment of Existing HVAC System	Existing ducts tl register are cut
Sizing Strategy Overview	Size for design heat. O

Guide To Sizing & Selecting Heat Pumps in Cold Climate

A companion to NEEP's Guide to Installing Air-Source Heat

Isolated Zone

Application Description	One room or zone that is otherwise thermally isolated a newly finished basement room, build out above gara had poor thermal comfort.

Installation Guide

Guide To Installing Air-Source Heat Pumps in Cold Climates

A Companion to NEEP's Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates

Introduction

High-quality installations of air-source heat pump (ASHP) systems generate referrals, increase sales, reduce callbacks and improve customer comfort and satisfaction. Installation practices also have a major impact on efficiency and performance of an ASHP system. Efficient ASHPs have seen significant sales growth in colder climates in recent years. The recent generation of cold-climate ASHPs, combined with insights from large-scale installation programs and installers, has led to a better understanding of the full range of practices to ensure maximum system performance and customer satisfaction. This guide provides a list of these best practices, as well as homeowner education and system setup guidance, to help ensure efficient air-source heat pumps and happy customers in cold climates.

Heat pumps should always be installed by licensed, trained professionals. Always follow manufacturer's specification and installation instructions, and all applicable building codes and regulations. All installers should attend a manufacturer's training or preferred installer program.

ASHPs come in a number of configurations, and in some cases the following guidance may be specific to one or more of those system types. There are many variations and terms used, but these guidelines will focus on the following broad categories: "ductless ASHP" refers to any non-ducted cassette type indoor unit (including wall-mount air handlers, floor mounted consoles, in-ceiling cassettes, etc.); "mini-duct ASHP" refers to remote air handlers that are typically designed for compact, concealed-ceiling or short-duct configurations; and "centrally ducted ASHP" refers to whole-house systems with central air handlers. The icons shown here are used below to indicate when guidance is specific to a certain system type. All items without icons are generally applicable to all ASHP configurations.

Applies to: Ductless ASHP | Mini-Duct ASHP | Centrally ducted ASHP

NEEP ccASHP Listings

	A	B	C	D	E	F	G	H	I	J	K
1	DISCLAIMER- Some of the performance values reported as part of the Cold-Climate ASHP Specification are NOT derived from industry standard test procedures or third-party tested/v										
2	Products added to list since previous update highlighted in pink										
3	General Information										
4											
5	Updated: March 9, 2017										
6	Manufacturer	Brand (if applicable)	AHRI Certificate No.	Outdoor Unit Model	Indoor Unit Model(s)	HSPF (Region IV):	SEER	EER (@ 95°F)	ENERGY STAR Certifie	Ductless or Ducted	If Ductless, Multi-zone or Single-zone
7	Daikin		3208521	RXG09HVJU	FTXG09HVJU	11	26.1	15.8	Yes	Ductless	Single-zone
8	Daikin		3208522	RXG12HVJU	FTXG12HVJU	10.55	24.2	14	Yes	Ductless	Single-zone
9	Daikin		3208523	RXG15HVJU	FTXG15HVJU	10	21	12.9	Yes	Ductless	Single-zone
10	Mitsubishi		4217888	MUZ-FE18NA	MSZ-FE18NA	10.3	20.2	14.2	Yes	Ductless	Single-zone
11	Mitsubishi		4908219	MUZ-FE09NA	MSZ-FE09NA	10	26	15.5	Yes	Ductless	Single-zone
12	Mitsubishi		4934170	MUZ-FE12NA	MSZ-FE12NA	10.5	23	12.9	Yes	Ductless	Single-zone
13	Fujitsu		5063325	AOU9RLS2	ASU9RLS2	12.5	27.2	16.1	Yes	Ductless	Single-zone
14	Fujitsu		5063326	AOU12RLS2	ASU12RLS2	12	25	13.8	Yes	Ductless	Single-zone
15	Daikin		5265753	RXS09LVJU	FTXS09LVJU	12.5	24.5	15.3	Yes	Ductless	Single-zone
16	Daikin		5265755	RXS12LVJU	FTXS12LVJU	12.5	23	12.8	Yes	Ductless	Single-zone
17	Daikin		5265756	RXS15LVJU	FTXS15LVJU	11.6	20.6	14.4	Yes	Ductless	Single-zone
18	Daikin		5265757	RXS18LVJU	FTXS18LVJU	11	20.3	12.7	Yes	Ductless	Single-zone
19	Daikin		5265758	RXS24LVJU	FTXS24LVJU	10.6	20	12.5	Yes	Ductless	Single-zone
20	Nortek Global	Maytag	5597453	PSH4BG024K	B6VMAX024K-B	10	19	13.9	Yes	Ducted	N/A
21	Nortek Global	Maytag	5597457	PSH4BG036K	B6VMAX036K-B	10	19	12.9	Yes	Ducted	N/A
22	Fujitsu		5751311	AOU9RLFC	AUU9RLF	13	24	14.5	Yes	Ductless	Single-zone
23	Fujitsu		5751312	AOU9RLFC	ARU9RLF	12.2	21.5	14.5	Yes	Ductless	Single-zone
24	Fujitsu		5751313	AOU12RLFC	AUU12RLF	12.2	21.9	12.8	Yes	Ductless	Single-zone
25	Fujitsu		5751314	AOU12RLFC	ARU12RLF	11.5	20	12.8	Yes	Ductless	Single-zone
26	LG		5859619	LUU187HV	LCN187HV	10.1	20	15	Yes	Ductless	Single-zone
27	LG		6236101	LSU240HSV3	LSN240HSV3	10.2	20	12.5	Yes	Ductless	Single-zone
28	American Standard		6749789	4A6V0024A1	*AM8C0B30V21	10	19.25	13.75	Yes	Ducted	N/A
29	American Standard		6749791	4A6V0048A1	*AM8C0C48V41	10	19.25	12.5	Yes	Ducted	N/A
30	Trane		6749942	4TWV0024A1	*AM8C0B30V21	10	19.25	13.75	Yes	Ducted	N/A
31	Trane		6749944	4TWV0048A1	*AM8C0C48V41	10	19.25	12.5	Yes	Ducted	N/A
32	American Standard		6750232	4A6V8036A1	*AM8C0C36V31	10	18	13	Yes	Ducted	N/A
33	American Standard		6750233	4A6V8048A1	*AM8C0C48V41	10	18	12.5	Yes	Ducted	N/A

Current Product List (3.9.17) | Delisted (on 1.1.17)

Thanks!

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