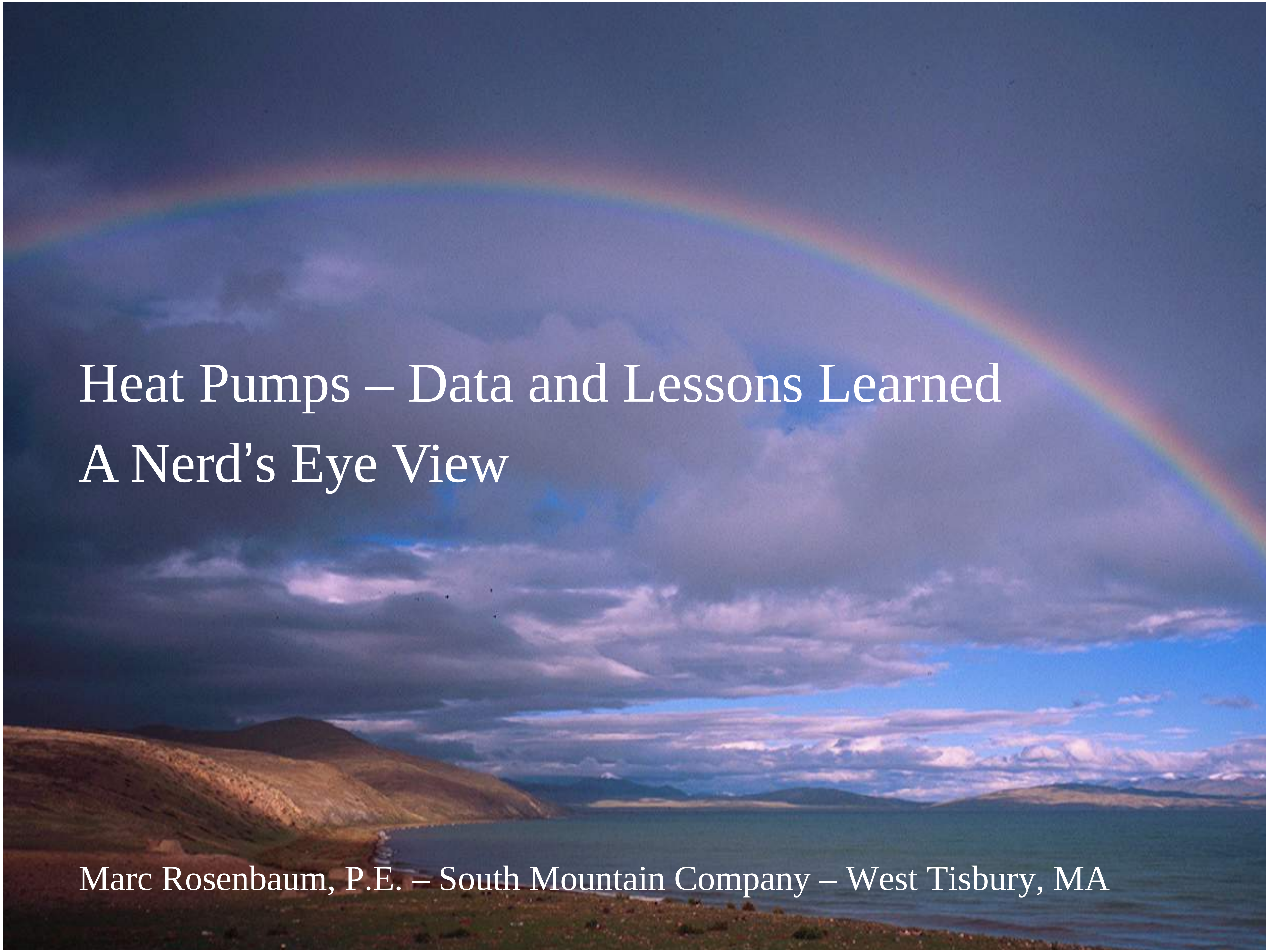


Heat Pumps – Data and Lessons Learned

A Nerd's Eye View

Marc Rosenbaum, P.E. – South Mountain Company – West Tisbury, MA

NESEA is a registered provider with the American Institute of Architects Continuing Education Systems. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificates of Completion for non-AIA members will be mailed at the completion of the conference.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

Attendees will:

- understand the general benefits of using heat pumps in low energy use buildings
- learn how air source heat pumps for heating and cooling have performed in actual installations
- learn about heat pump water heaters and how they have performed in actual installations
- learn about CO_2 emission reductions possible when switching from fossil fuel systems to heat pumps

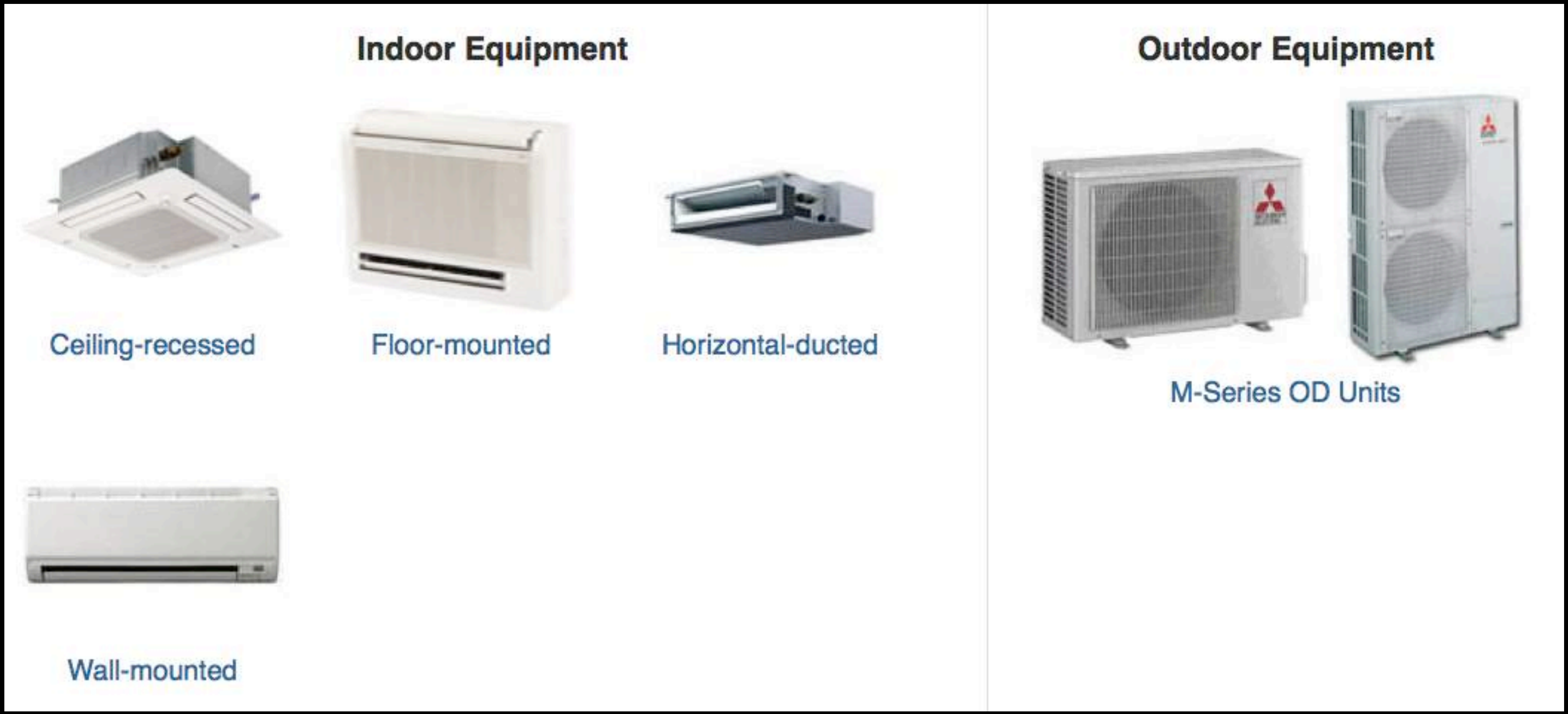
Why Heat Pumps?

- No onsite combustion
- No chimney or venting
- Provide heating and cooling (space conditioning), DHW, pool heat
- Cost-competitive in installation and operation
- Combines with renewable electricity to achieve Zero Net Energy

Space Conditioning with Minisplits

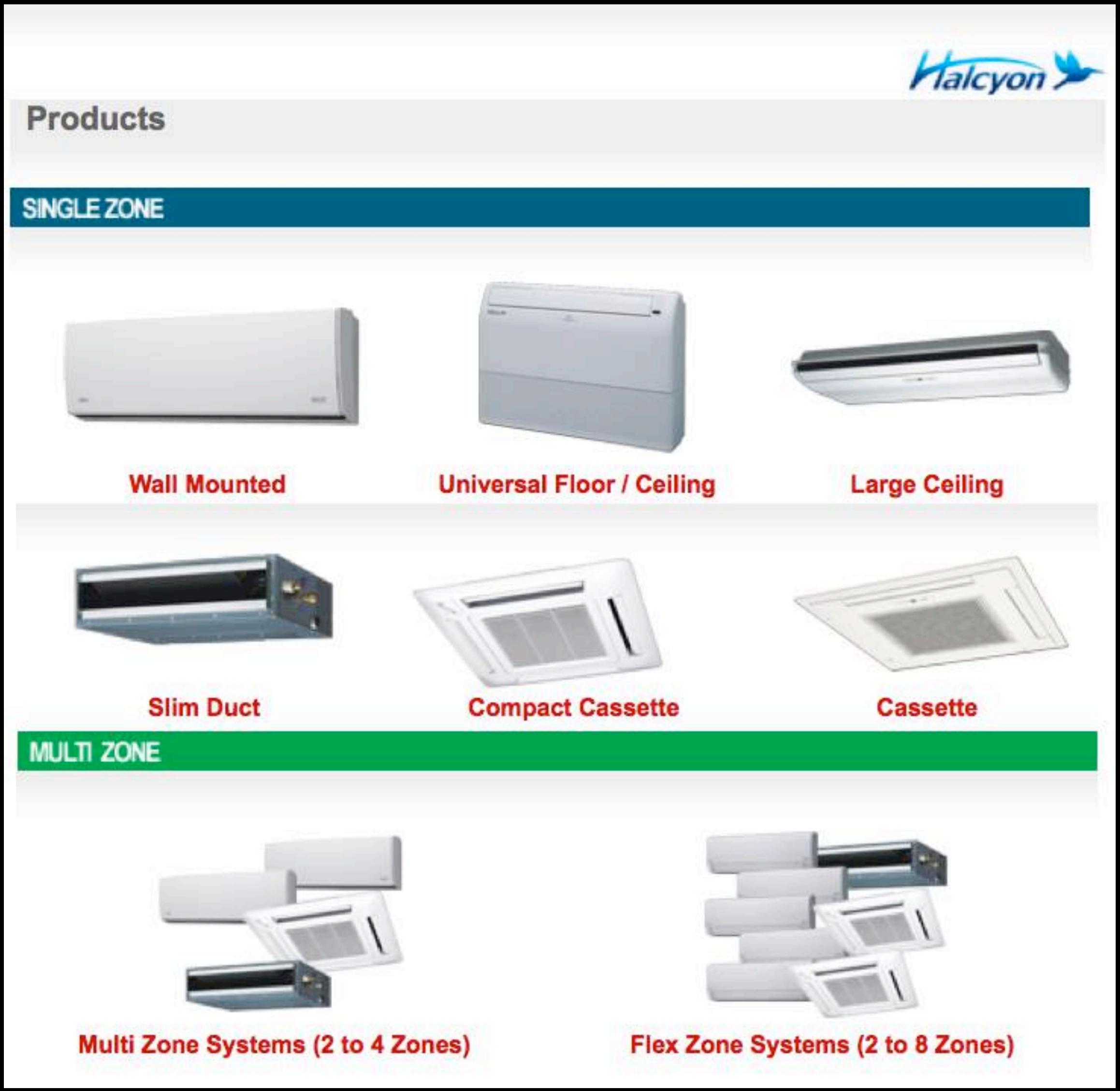
- Packaged technology
- Reliable
- Ducted and non-ducted solutions
- Single and multi-port systems
- Variable refrigerant flow (VRF) systems
- Outdoor air is the source/sink for heating/ cooling

Space Conditioning with Minisplits

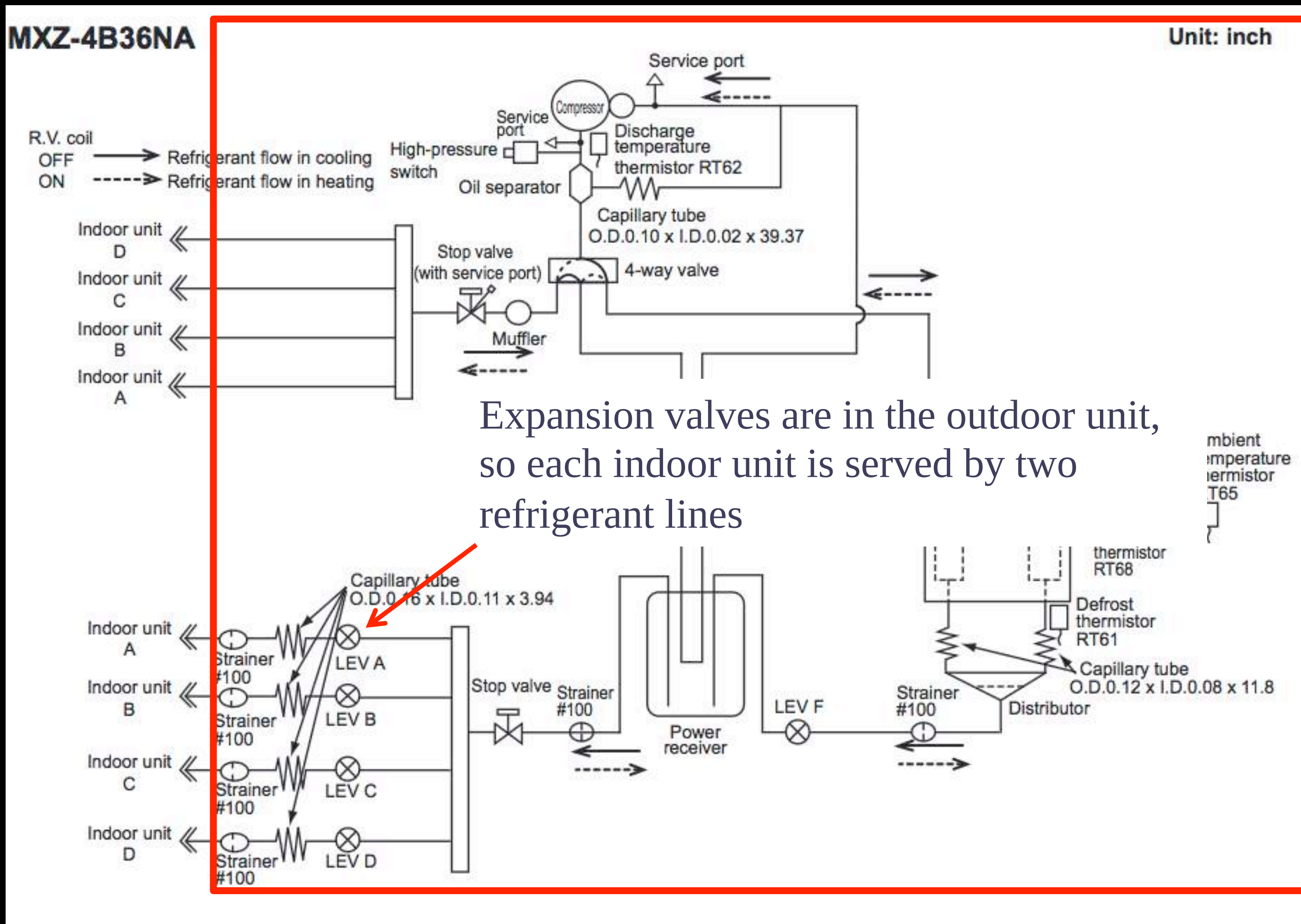


- Rated outputs 9,000 to 48,000 BTU/hour
- Single and multi-zone (up to 8) systems

Space Conditioning with Minisplits



Space Conditioning with Minisplits



VRF Single Phase Minisplits

- Rated outputs to 60,000 BTU/hour
- Multi-zone (up to 12)

VRF Single Phase Minisplits

Expansion valves are in the outdoor unit, so only two refrigerant lines between the outdoor unit and the building

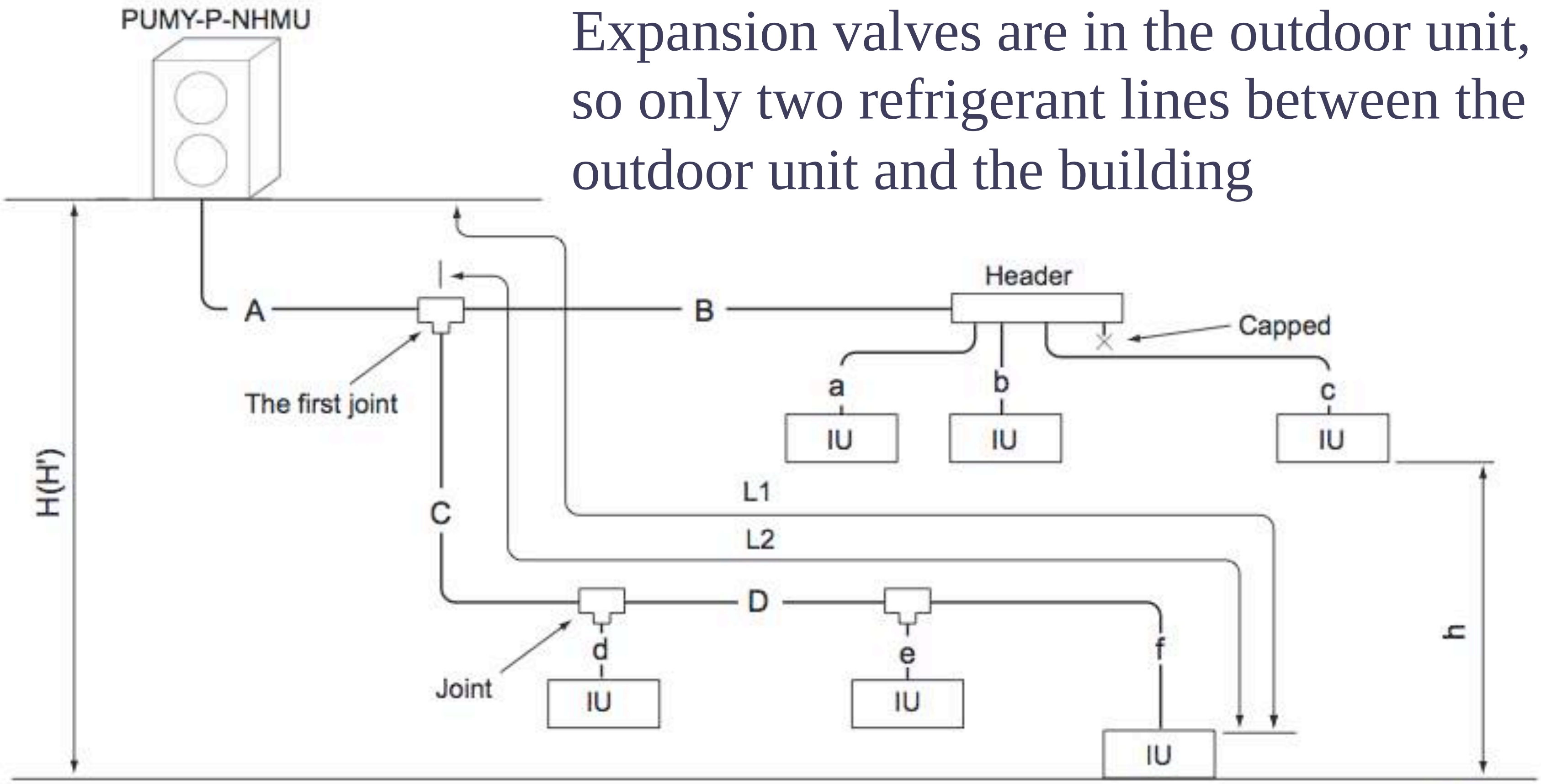


Fig. 3-2-1A Piping scheme

IU : Indoor unit , OU : Outdoor unit

VRF Three Phase Minisplits

VRF Three Phase Minisplits

- These commercial units have many features, including internal heat recovery, where heat rejected by a zone in cooling can be transferred to heat a zone in heating
- Mitsubishi’s Hyperheat series has rated output down to -13˚F

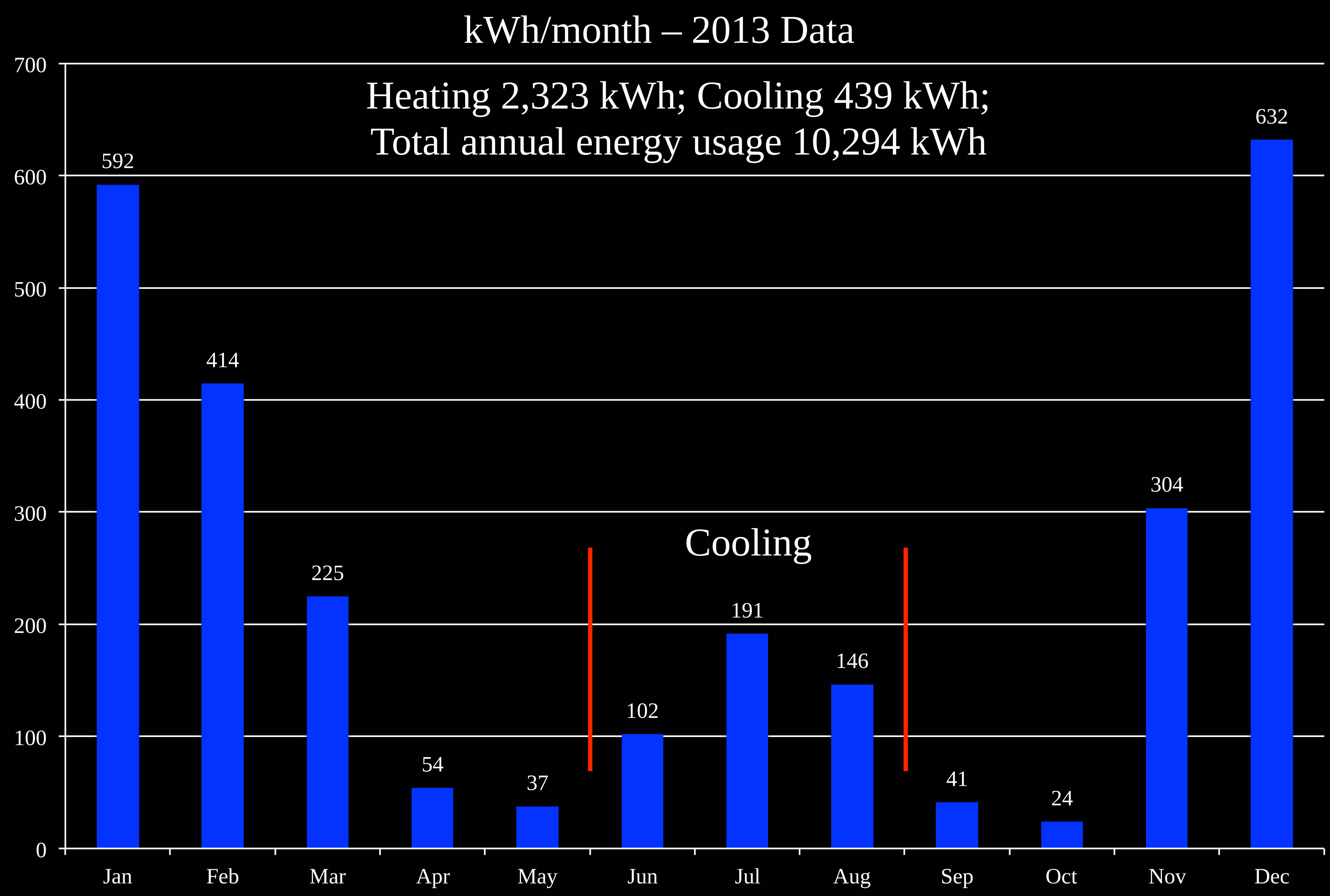
Non-ducted Single Zone System

Lemon Residence - Ironwoodbrand

Non-ducted Single Zone System

- Single family PH in Brattleboro, VT
- 2,392 gsf, 1,766 sf TFA
- Mitsubishi Hyperheat FE12NA – HSPF 10.6
- 2,323 kWh/yr heating – kWh/sf/HDD65 0.000138
- PHPP predicted heating *load* is 4.23 kBTU/sf TFA/yr
- Predicted heating *consumption* 1.7 – 2.1 kBTU/sf TFA/yr, based on COP of 2.0 – 2.5
- Actual 2013 heating consumption 4.4 kBTU/sf TFA/yr
  - Setpoint?
  - COP?
  - Insolation?
  - PHPP?
  - Standby energy usage?
- Cool air doesn't rise

Non-ducted Single Zone System



Ducted Single Zone System

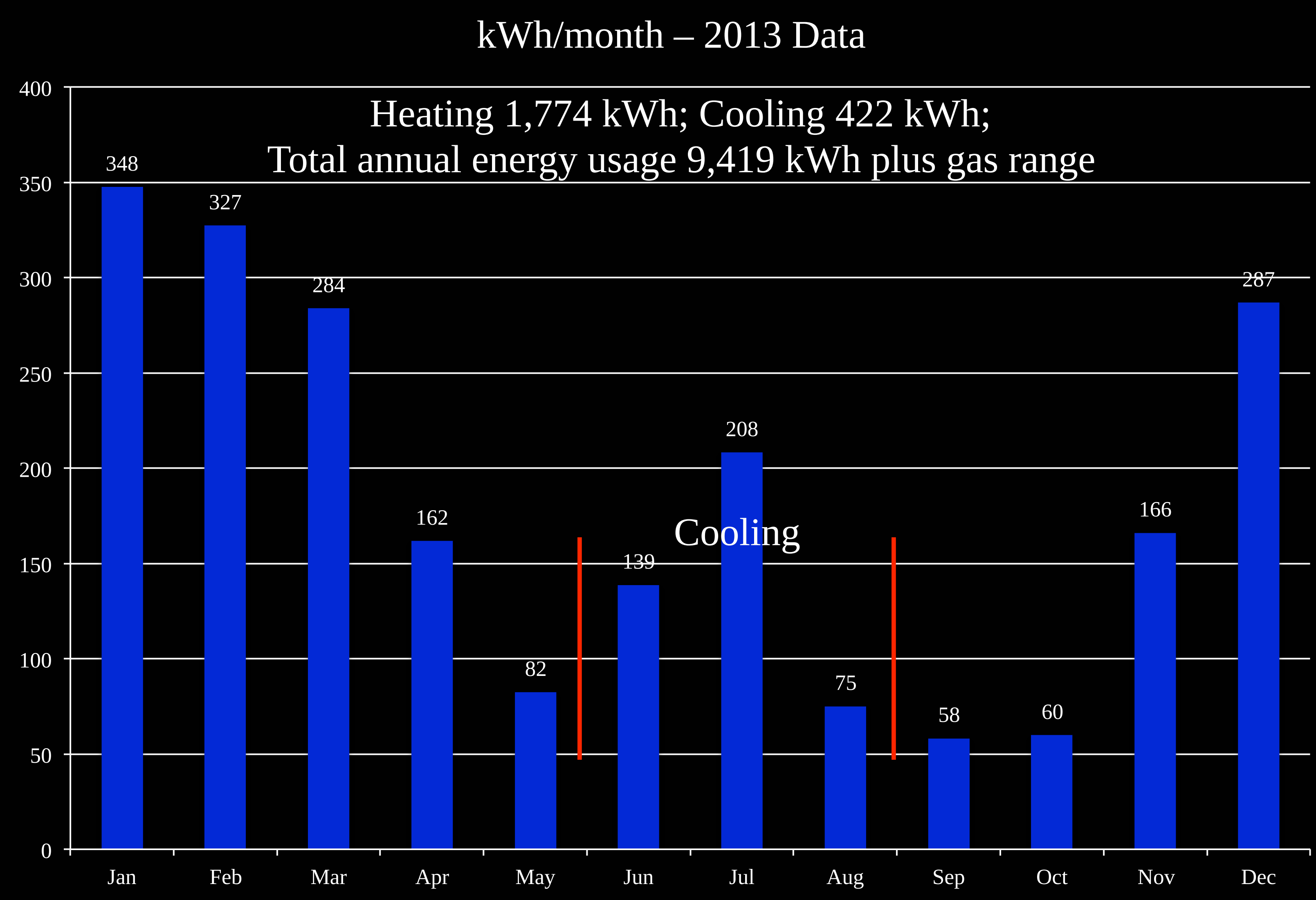
Caretaker Cottage – South Mountain Company

Ducted Single Zone System

- Single family DER in Chilmark, MA
- 1,258 gsf above basement
- Mitsubishi SUZ-KA18NA / SEZ-KD18NA – HSPF 10.0
- Simplified model predicted heating consumption of 1,649 – 2,061 kWh/yr based on COP of 2.0 – 2.5
- Actual heating consumption 1,774 kWh in 2013
- Additional electric heat on 2nd floor used 214 kWh
- kWh/sf/HDD65 0.000281 (2X Brattleboro PH – higher IGs; HPWH; much less solar gain)


86.8
106.4
71.9
107.9
106
104
102
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
69.6
°F

Ducted Single Zone System

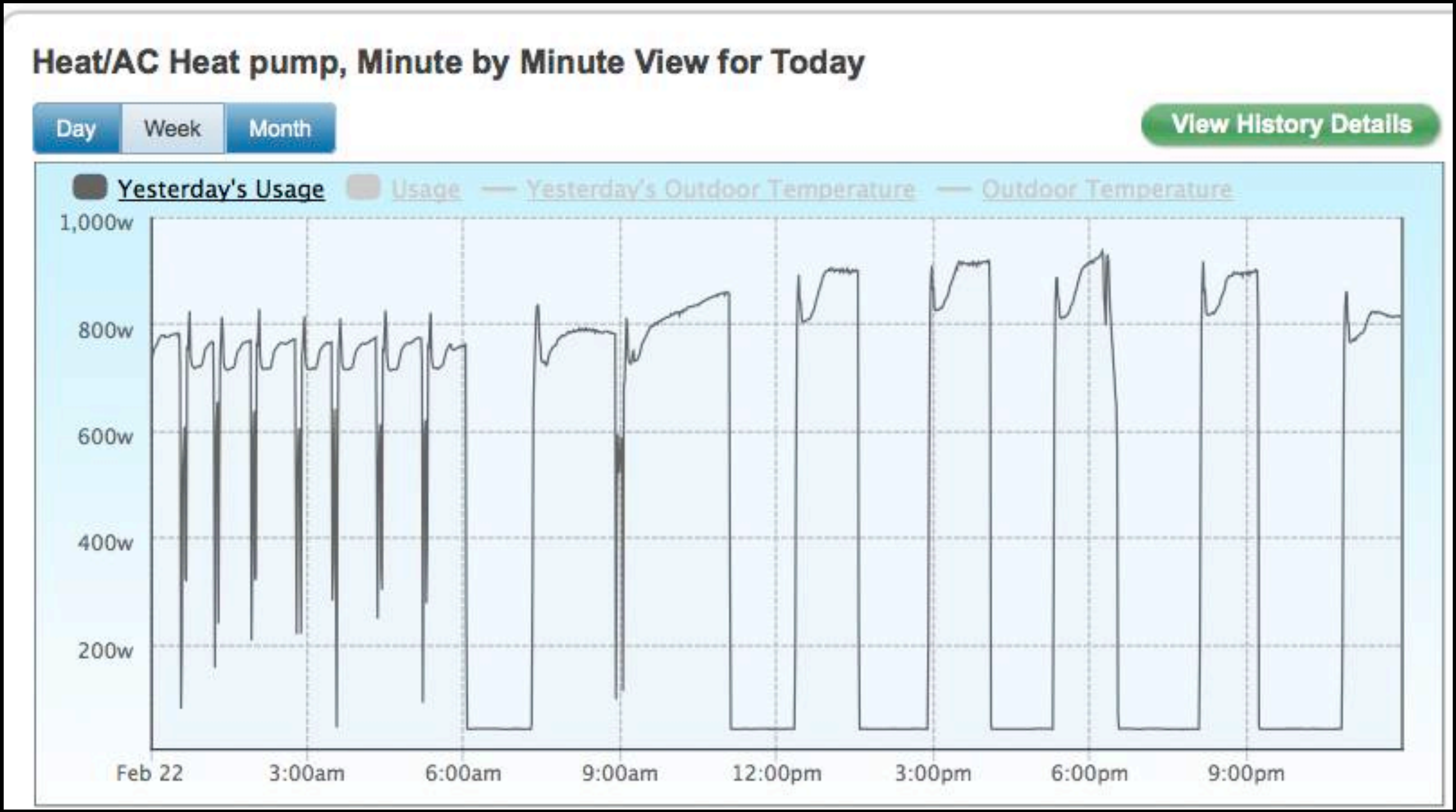


Ducted Single Zone System

- Duct Blaster result 21CFM25 after leaks sealed in AHU – about 3% of system flow
- Very quiet

Ducted Single Zone System

Minimum system power is about 40W



Observations about Ducted Systems

- In small single zone houses we estimate a cost premium of $2,500 – 5,000 vs. a single wall cassette system, depending on if additional electric heaters are provided, and their cost
- Advantages over point source include:
  - Quieter
  - Filtration upgrades possible
  - Very even temperature distribution
  - Cooling throughout the house
  - Possible integration with ventilation

Observations about Ducted Systems

- It takes longer to insulate the ducts well than to install them
- Low external static pressure increases duct sizing
- Duct insulation important in non-conditioned space
- Rigorous duct sealing is mandatory
- Beware short return lengths and fan noise (duh Marc)
- Do as much joint sealing and insulating before putting ducts in place
- Use rigid ducts except for runouts to the registers
- Spiral duct fittings are smoother and have O-ring seals
- Newer products such as Fujitsu RLFC series offer HSPF as high as 12.2, high outputs at low temperatures (9,000 BTU/hr unit rated at 15,400 BTU/hr at 5˚F), and lower system CFM – smaller ducts, higher supply air temperature

Observations about Ducted Systems

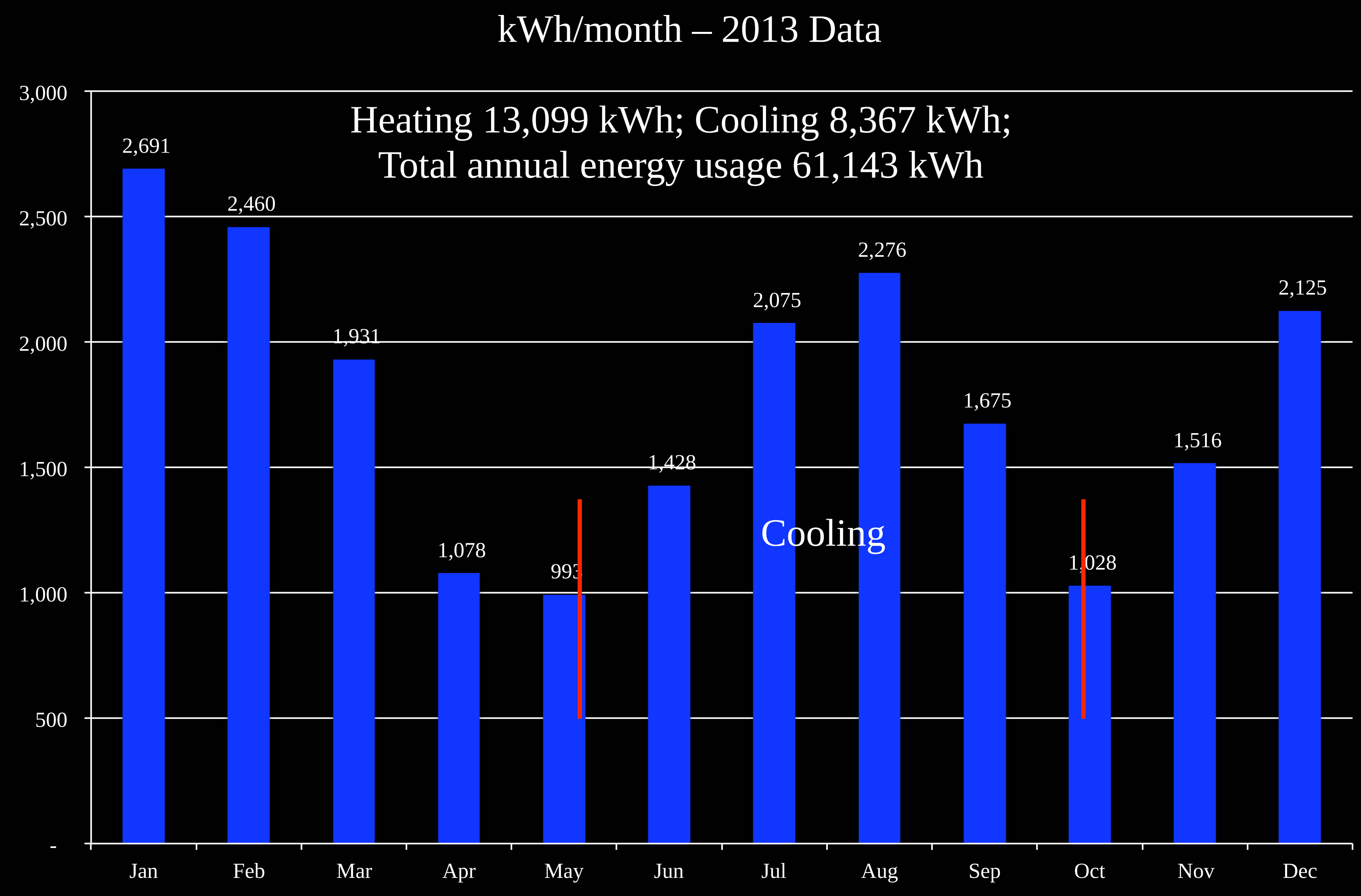
Ducted Multi-zone VRF System

Bement School Dorms – Margo Jones Architect

Multi-zone VRF System

- Dormitory/faculty apartments Deerfield, MA
- 11,000 gsf, superinsulated construction
- (4) Mitsubishi 3 ton City Multi VRF condensers, 11 indoor units – all but 2 are ducted
- Simplified model predicted heating consumption of 12,545 kWh/yr based on COP of 2.5
- Actual heating consumption 13,200 kWh/yr first two years
- kWh/sf/HDD65 0.000187
- Cooling energy consumption first year was 10,231 kWh/yr – second year 8,367 kWh/yr – changed operating mode
- System has operated in below 0˚F conditions and has fulfilled all operating requirements despite not being rated at lowest temperatures seen

Multi-zone VRF System



Multi-zone Cold Climate VRF System

- Public school DER Plainfield, NH
- 8,000 gsf, superinsulated construction
- (1) Mitsubishi 8 ton City Multi Hyperheat VRF condenser, 11 indoor units
- Actual heating consumption 7,703 kWh/yr 9/15/10 – 6/11/11
- System has operated in -22˚F conditions
- System bid for $43K installed
- Most of the school has been retrofitted, and 32 tons of heat pumps added in total, and *electrical usage has not increased* while oil usage has dropped over 8,000 gallons/yr
- Total primary energy is 54 kBTU/sf/yr

Air-to-Water System

Installed by a f@*%#*^ messy French bastard

Chilmark Estate– South Mountain Company

Air-to-Water System

Air-to-Water System

Air-to-Water System

- Main and guest houses totaling 7,500 sf in Chilmark, MA
- Removed Buderus oil boiler providing heat/DHW for both
- Installed (2) 4.5 ton Daikin Althermas and (1) 28 kW electric boiler in Main House, plus (1) 4.5 ton Altherma and (1) 20 kW electric boiler in Guest House
- Installed (2) 80 gallon Daikin DHW tanks as preheat to 120 gallon Viessmann electric DHW tank in Main House and (1) 80 gallon Daikin DHW tank as preheat to 80 gallon Buderus electric DHW tank in Guest House
- Installed Buderus gas boiler as emergency back-up for power outages
- At outdoor temperatures below ~25˚F, switchover to electric boilers
- Houses heated to 55˚F in winter

Air-to-Water System

- Previous energy usage was 3,187 gallons/yr of fuel oil, resulting in 71,389 lbs/yr of CO2 emissions
- Mid-May 2012 – mid-May 2013 energy usage was 10,740 kWh into the heat pumps, 7,651 kWh into the electric boilers, and 1,738 kWh into the electric DHW tanks – total of 19,859 kWh/yr. Using eGrid value of 728 lbs of CO2 per MWh for NEWE region, CO2 emissions were 14,457 lbs/yr, an 80% reduction. Fuel cost reduction was 70%.

Air-to-Water System

- Altherma heats DHW indirectly, sacrificing efficiency
- Guest House made DHW at 0.13 kWh/gallon (mixed value, hp plus electric resistance)
- Newer and smaller Althermas are rated at higher efficiencies and less reduction in output at low temperatures
- Best suited with radiant floors or any low temperature delivery system
- Expensive and much more complex than air-to-air minisplits

Heat Pump Water Heaters

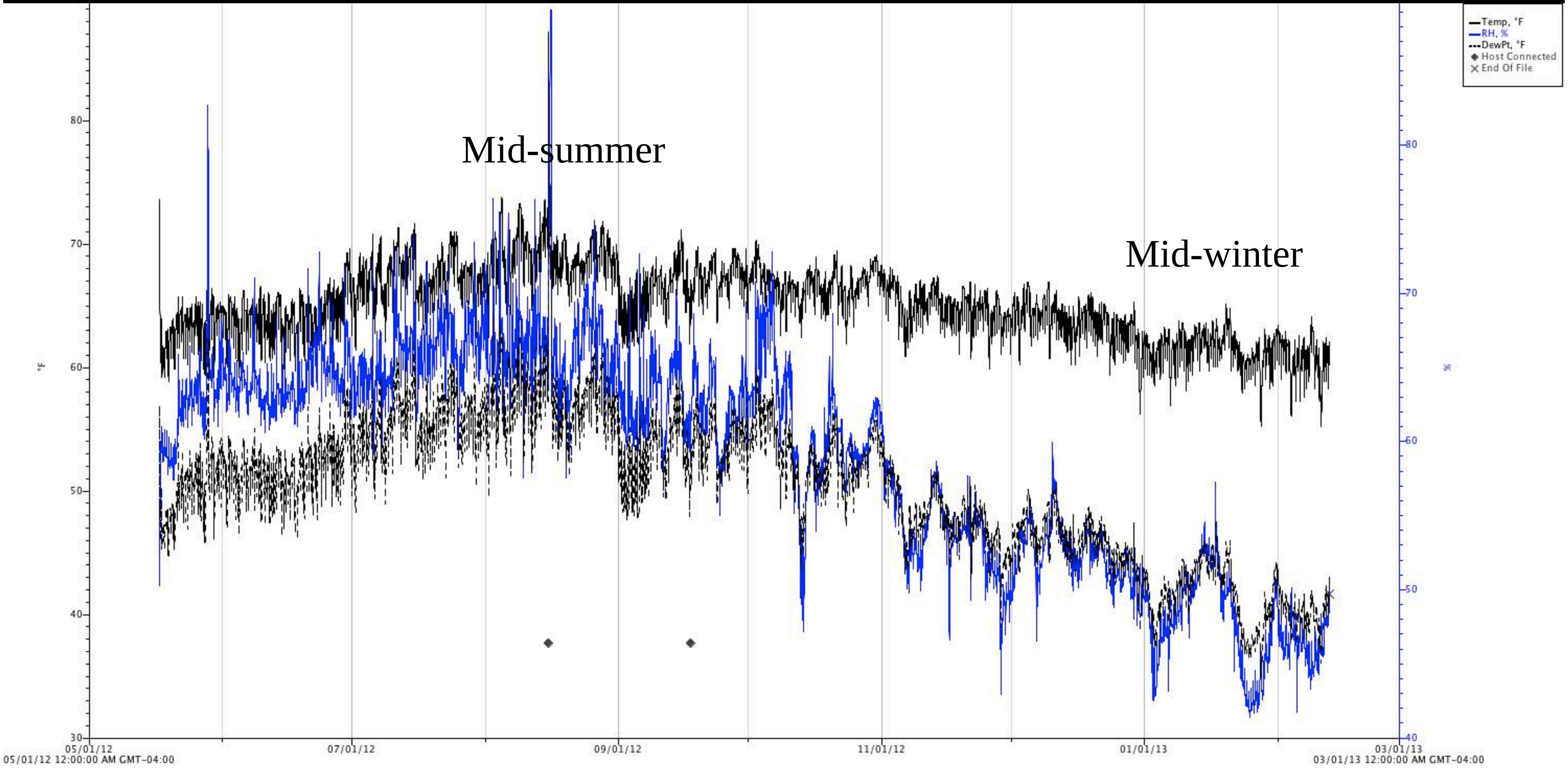
Heat Pump Water Heaters

- HPWHs pull air from the space they are in, and extract heat which is deposited to the water in the storage tank
- Unitary products (HP plus tank) range from 50 to 80 gallons in size
- Electric resistance back-up elements are included for periods of high demand, as the heat pump recovery rate is slow
- HPWHs usually move 300-400 CFM, need to be located in a space large enough to extract heat without excessive cooling off (100 sf minimum spec is common)
- There are models that can be ducted a short distance
- Beware of sound – fan and compressor
- During the heating season, they pull heat from the space which may need to be made up by the heating system

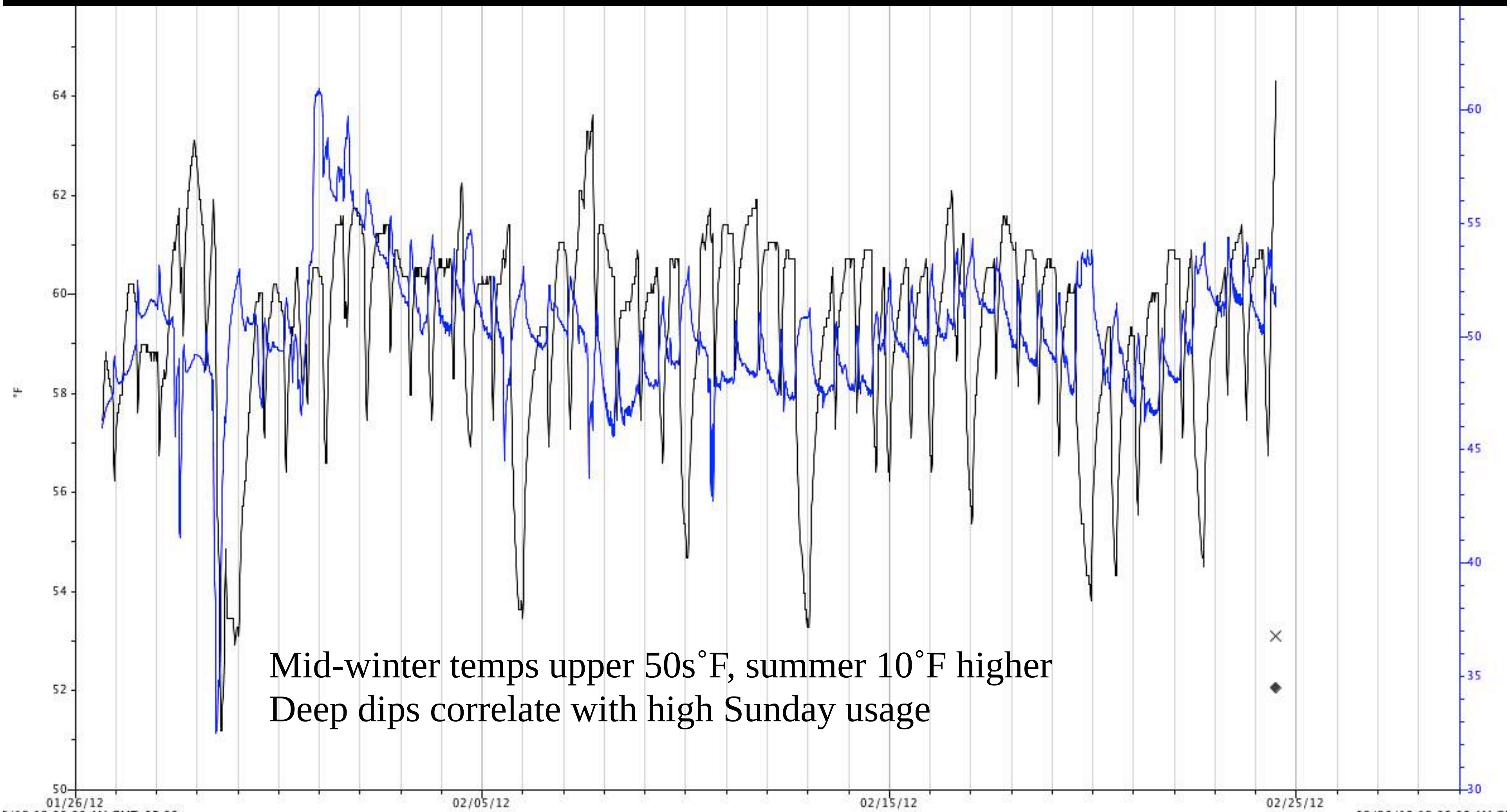
Stiebel Eltron

- Three installations of Stiebel Eltron Accelera HPWHs
- 80 gallon tank, 5-600W HP, 1,700W electric resistance back-up
- Heating coil wraps the tank (no water pump)
- Water meters on cold water inlets to tanks
- Case 1 in year-round DER with 42 gpd, Case 2 in seasonally occupied uninsulated basement with 49 gpd estimated, Case 3 in year-round DER with 15 gpd
- Baseline is 50 gallon Marathon electric resistance water heater which uses 0.21 kWh/gallon
- In Case 1, HPWH consumed 0.062 kWh/gallon
- In Case 2, HPWH consumed 0.070 kWh/gallon
- In Case 3, HPWH consumed 0.013 kWh/gallon (one winter month)

Stiebel Eltron

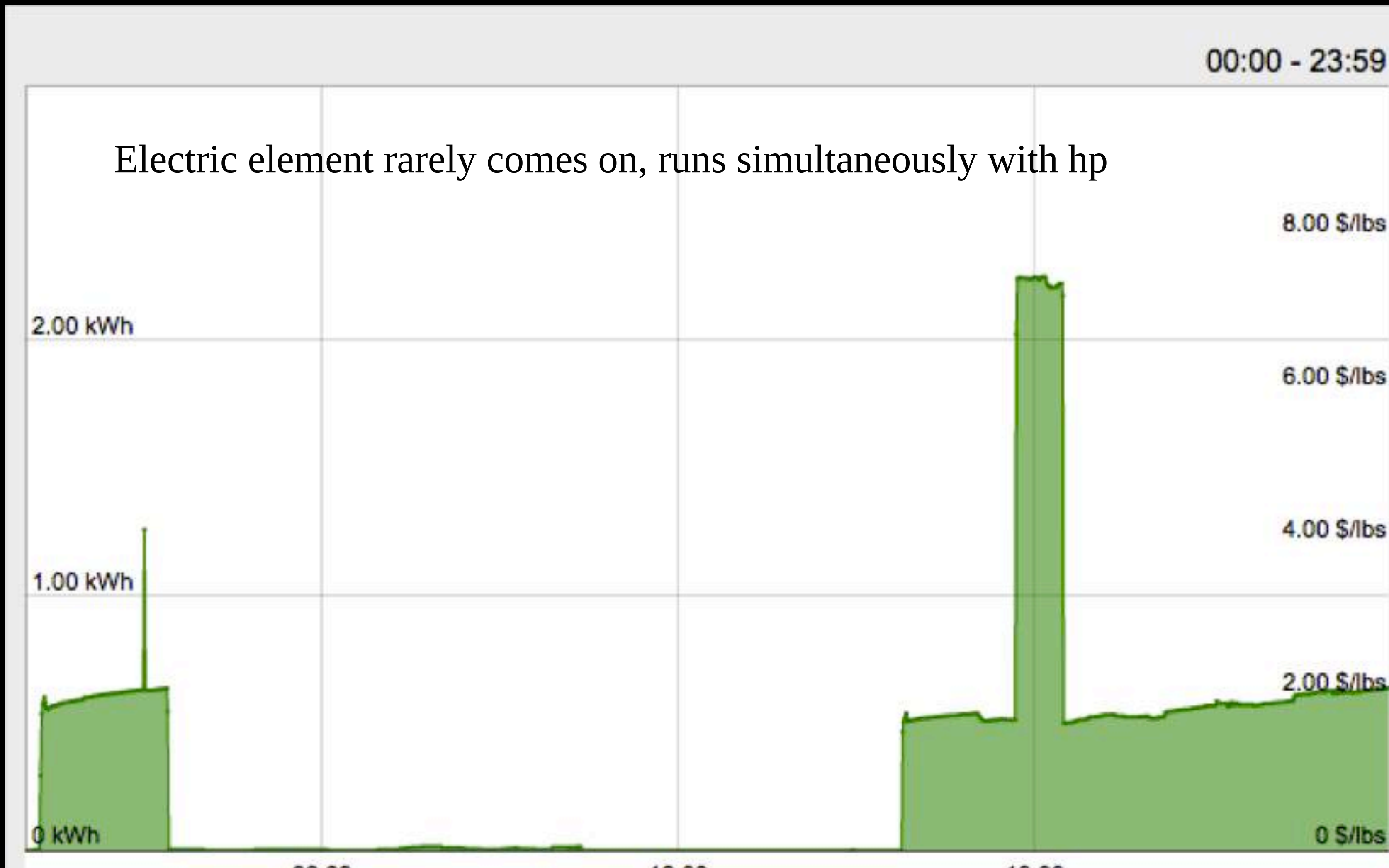


Stiebel Eltron

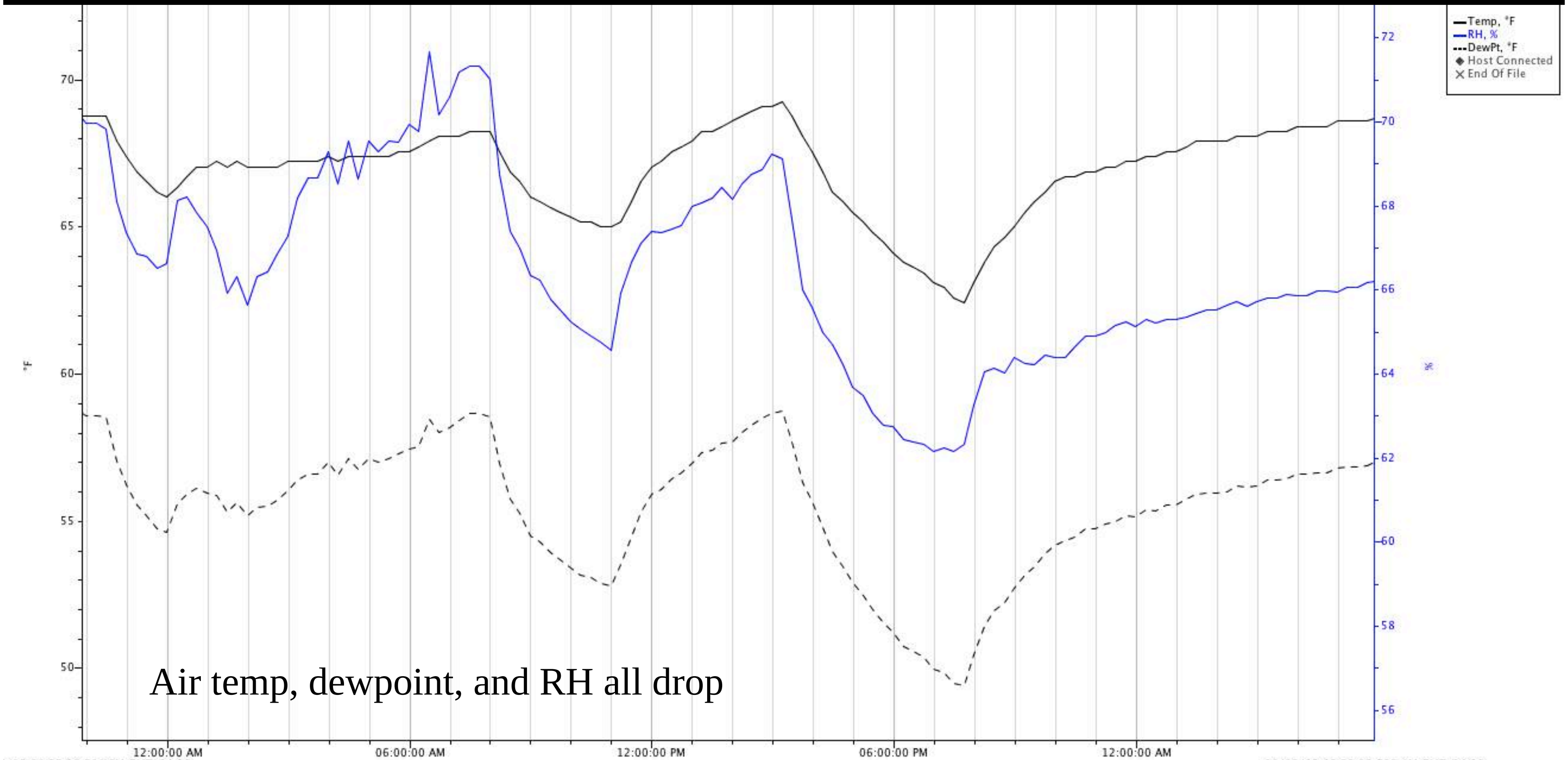


Mid-winter temps upper 50s˚F, summer 10˚F higher
Deep dips correlate with high Sunday usage

Stiebel Eltron



Stiebel Eltron



Air temp, dewpoint, and RH all drop

Stiebel Eltron

- In Case 2, the HPWH replaced an old oil boiler with a tankless coil and an 80 gallon DHW storage tank. Summer oil usage was approximately 1.05 gpd
- Estimated CO_2 emission reduction was 89%

Stiebel Eltron

No filter!

AO Smith Voltex

- 60 gallon tank (80 gallon available)
- Heating coil wraps the tank
- 4,500W upper electric element, 2,000W lower electric element
- 4 modes – HP only, hybrid, electric only, vacation (60F)
- July through January, 21 gpd, 0.075 kWh/gallon

Heat Pump Pool Heaters

- Heat pump pool heaters operate at COPs of 4-5
- Coupled with a solar electric system, they heat the pool on demand and power the pool pump, while exporting excess electricity during the rest of the year
- Compare an LPG heater at 80% efficiency with a HPPH at a COP of 4.5. In NEWE grid region at 0.728 pounds CO_2 per kWh, and propane at 12.6 pounds CO_2 per gallon, CO_2 reduction is 72%

Thank you

http://www.energysmiths.com/
http://thrivingonlowcarbon.typepad.com/
http://www.southmountain.com/

Zero Net Energy Homes Online Course

- A 10 Week NESEA Building Energy Masters Series Online Course, covering building science fundamentals, superinsulated construction, mechanical systems, and renewable energy systems
- Learn to calculate heat loss, solar gains, hot water loads, and annual energy usage with simple Excel-based calculators
- 12 CEUs for completing the Capstone Project

http://bit.ly/marczneh (For the full course)

http://bit.ly/znehtestdrive (For the free test drive)

For a look at the course, come to the Meetup at Demo Stage 1 5:30 pm on Wednesday

Questions?

This concludes the American Institute of Architects Continuing Education Systems program. You may all wake up now.