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Heat Pump Control Strategies and Best Practices

Overview, Potential and Ameren Illinois Support

Zak Paine and JT Stewart

Agenda

- Controls overview
- Proprietary systems
- All-electric air source heat pumps (ASHP)
- Dual-fuel ASHPs
- Balance point definitions and uses by application
- Multi-system controls
- Standing out in heat pump maintenance

Goals

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- What do electric systems require for auxiliary heat?
- Which balance point should be used to configure aux heat?
- What tools are good for finding balance point and economic switchover temps for dual fuel controls?
- What types of sensors do dual fuel systems need to operate at their best?
- How should multi-system heat pumps be controlled?
- What should the Droop be when using two controls?

Controlling the Heat Pump

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Ductless Wand/Remote

Wall Thermostat

Mobile App

Smart Wall Thermostat

Thermostat Selection and Configuration is a Critical Difference Between Heat Pumps and ACs

Not all thermostats are dual-fuel compatible.

Selecting a heat pump compatible thermostat is **not** enough.

You can find the Smart Thermostat Approved Product list at https://amerenillinoissavings.com/ally/existing-program-allies/residential-program-ally-resource-page/

Thermostat Features to Look for:

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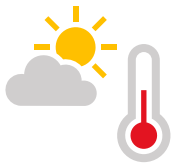
Four or more wires / wireless

- Must be able to control the heat pump reversing valve to operate both heating and cooling modes.
- Wireless thermostat models exist.

Dual-fuel controls software

- Some thermostats can control a heat pump but not a heat pump with a backup heat source.



Outdoor air temperature monitoring

- Can be a hardwired sensor, wireless sensor, or Wi-Fi connectivity to a local weather station.
- Required to set a condenser lockout temperature.

Multi-stage heating controls

- Optional, but may improve comfort or eliminate condenser lockout at low temperatures.

Configuring the Thermostat for Heat Pumps

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- Most heat pumps activate the reversing valve in heating.
  - › Bosch IDS/Rheem are common exceptions to this rule, always check.
  - › Specific wiring instructions vary by heat pump model and number of wires from the thermostat.
- Some systems can call the backup heat during defrost events.
  - › Increases the supply air temperature during defrost cycles.

Configuring the Thermostat for Heat Pumps

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- Multi-stage blower speed must be set to the heat pump coil specs.
  - Multi-stage systems should also be configured for appropriate staging and droop settings.
- Dual-fuel thermostats have a lockout /switchover / balance point temperature to configure.
  - Determine when the heat pump should not be used for heating.
  - Select based on economics or the home heat load.

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Manufacturer Specific Proprietary Thermostats

Communicating Controls

- Proprietary systems that communicate between the thermostat, indoor unit and outdoor unit need a thermostat that can communicate to operate in the most efficient way possible.
- Fully modulating systems that can incorporate a staged thermostat can lose stages of operation due to the limited ability of the controls
- Unitary and ductless products are both affected by staged controls, check with your manufacturer representative before installing a staged thermostat.

ENERGY STAR® Smart Thermostat Specification Development

July 11, 2022 - Dear ENERGY STAR® Smart Thermostats Partner or Other Interested Party:

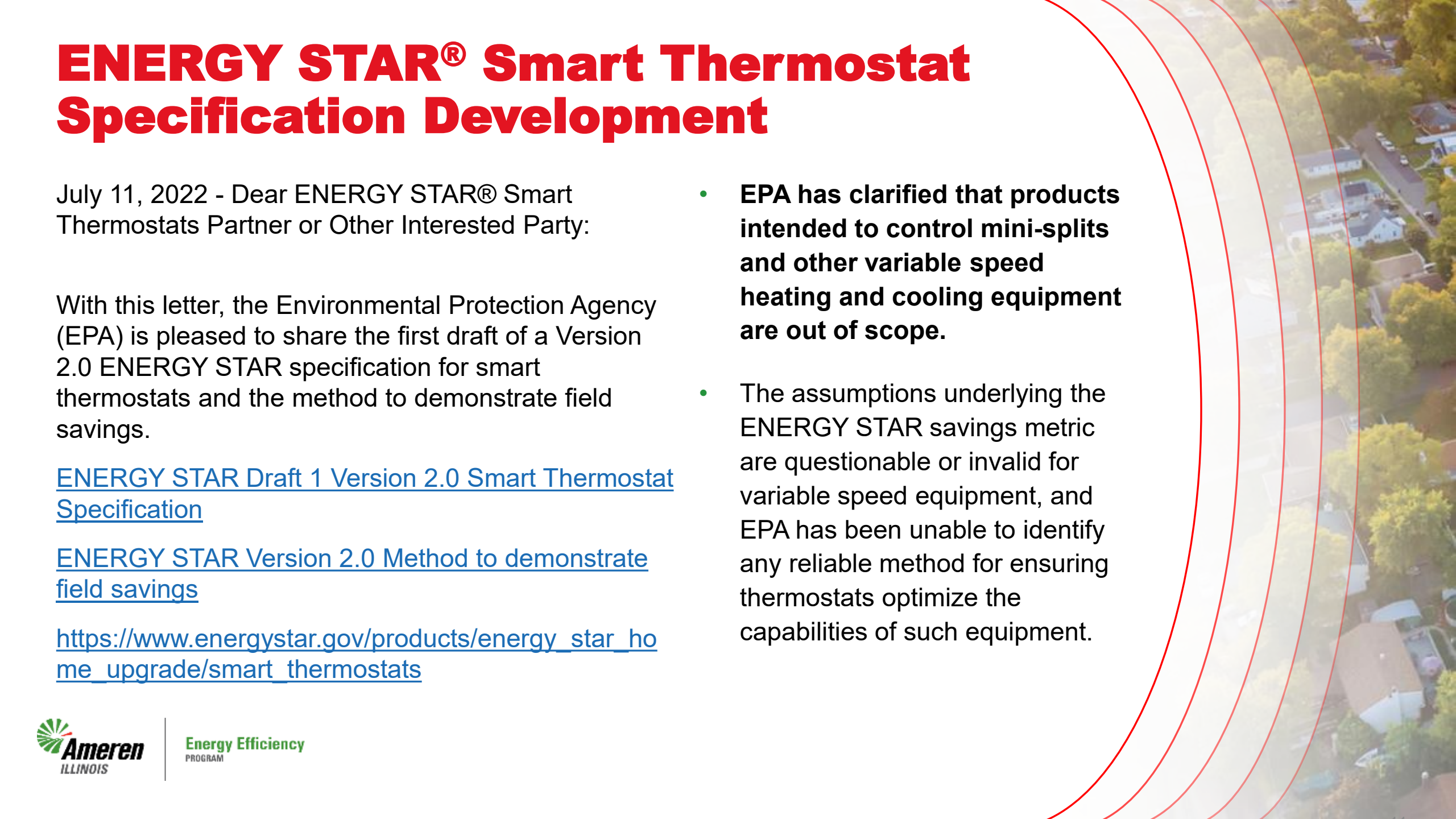
With this letter, the Environmental Protection Agency (EPA) is pleased to share the first draft of a Version 2.0 ENERGY STAR specification for smart thermostats and the method to demonstrate field savings.

ENERGY STAR Draft 1 Version 2.0 Smart Thermostat Specification

ENERGY STAR Version 2.0 Method to demonstrate field savings

https://www.energystar.gov/products/energy_star_home_upgrade/smart_thermostats

- **EPA has clarified that products intended to control mini-splits and other variable speed heating and cooling equipment are out of scope.**
- The assumptions underlying the ENERGY STAR savings metric are questionable or invalid for variable speed equipment, and EPA has been unable to identify any reliable method for ensuring thermostats optimize the capabilities of such equipment.



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Key Takeaways for Program Allies

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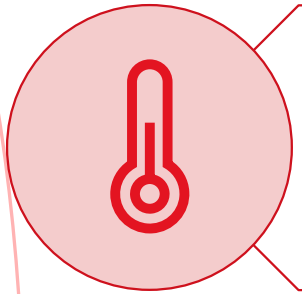
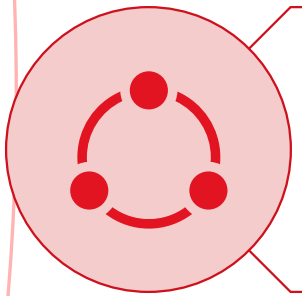
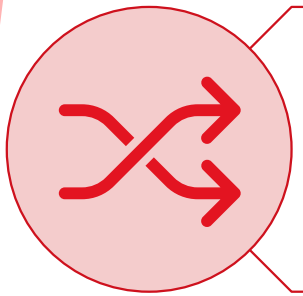


Modern dual fuel thermostats need outdoor or supply air temperature measurement.



Not all heat pump thermostats are dual fuel capable.



Heat pumps likely operate ideally with proprietary thermostats.

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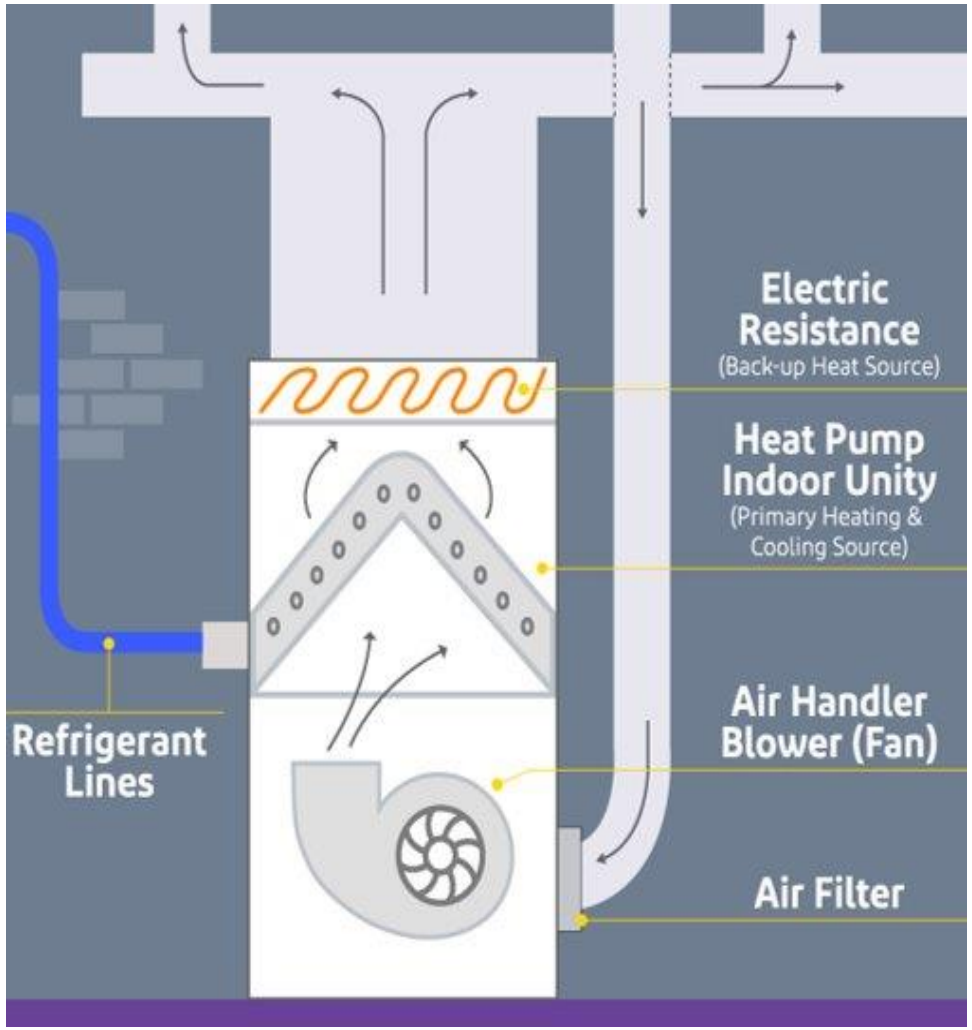
All-Electric Heat Pumps

Ducted All-Electric System

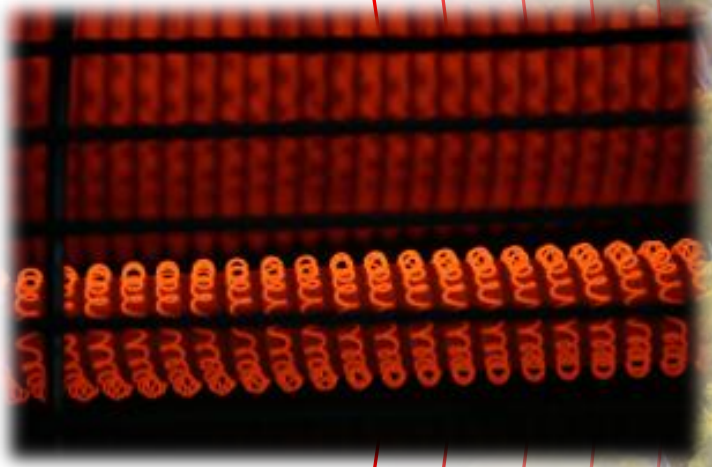
- These systems consist of three components:
  - The heat pump
  - The air handler
- Electric resistance heaters
  - Custom sized based on heat load
  - Multiple stages (e.g., 20KW has four stages or two stages)



Auxiliary Strip Heat Lockout Controls

Definition:

- Temperature ***above*** which the auxiliary electric resistance strip heat will ***not*** operate.
- Typically set in the range of 25°F – 35°F
- Capacity balance point plus 2°F
- Outdoor temperature sensor or weather station
- Defrost will not be affected by this setting



Benefits:

- Prevents use of electric resistance for recovery when not necessary

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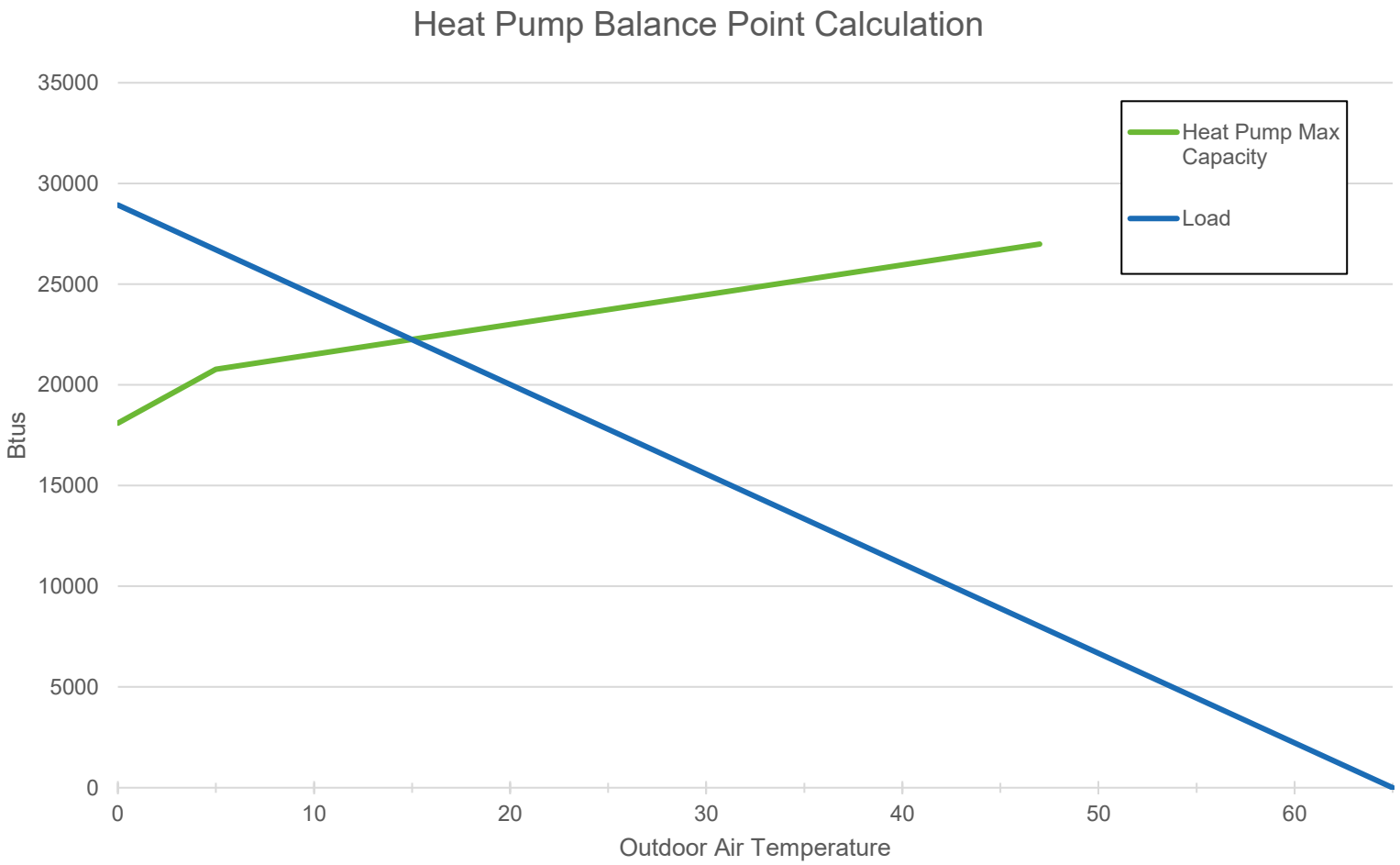
Determining the Capacity Balance Point



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Single and Two-Stage Wiring

Even with a lock out set, the defrost board can call on the auxiliary heat during a defrost demand.

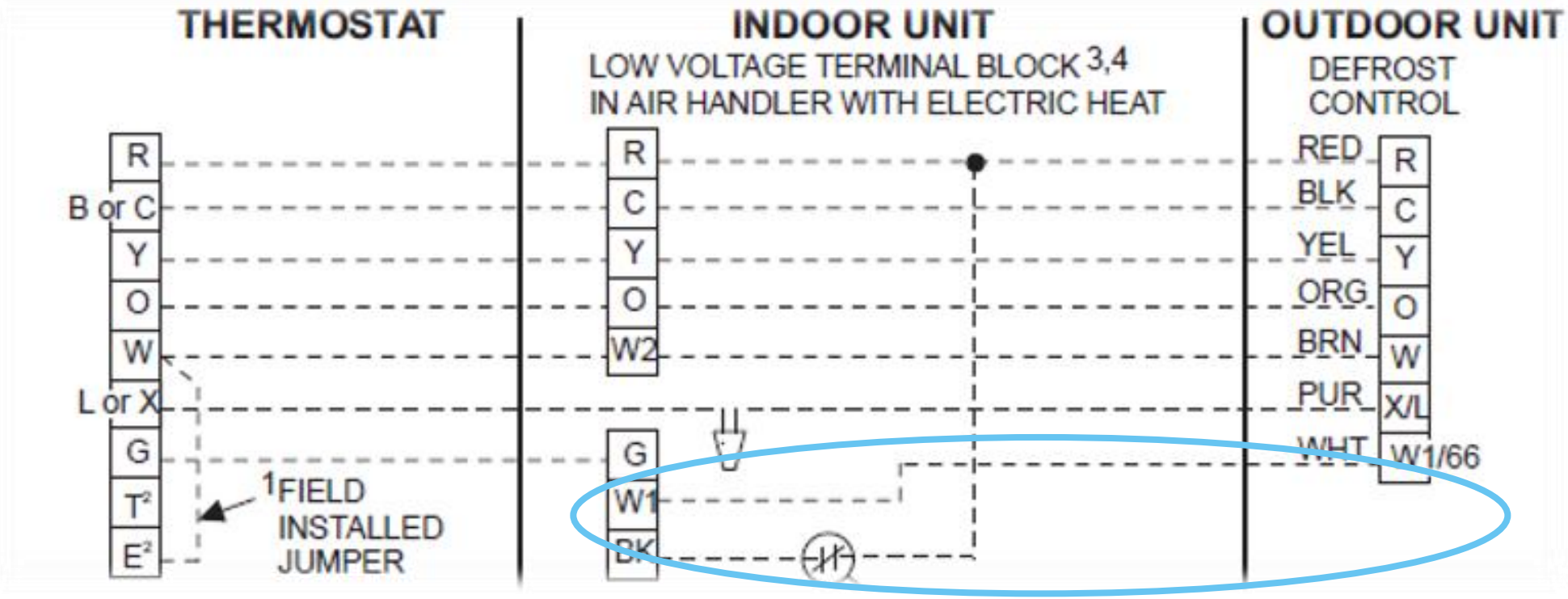
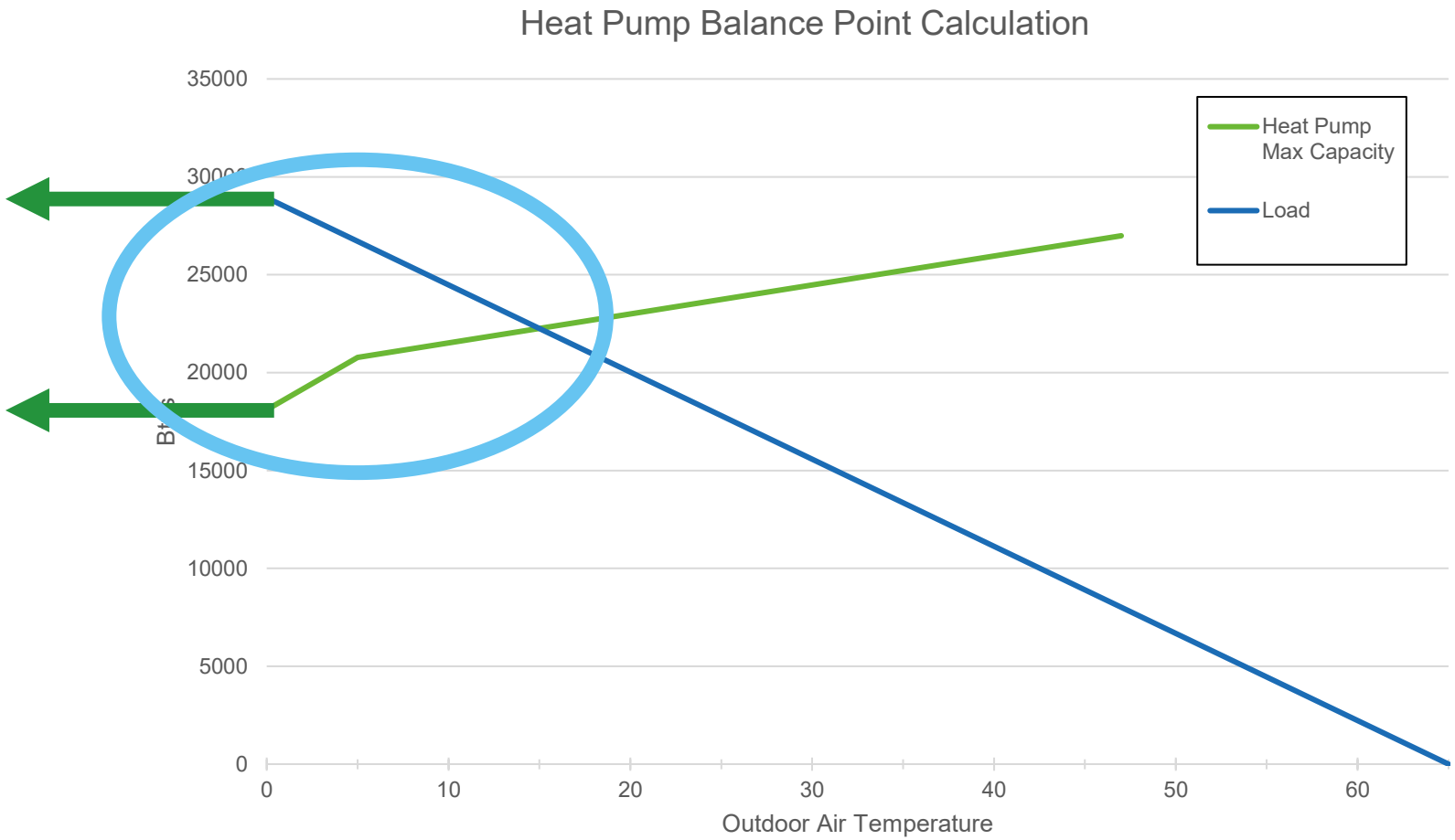


Image courtesy of Johnson Controls specification manual 632151-YTG-G-1214

Determining the Auxiliary Heat Needed and Capacity Balance Point



11,000 BTU (aux heat needed) / 3,412 BTU/KW = 3.22 KW AUX heat

Heat kits are often only available in 5KW increments

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Considerations for Electric Emergency and Supplemental Heat

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Size Limits for Electric Resistance Heating

Heat Pump - Supplemental Heat Only The *thermal balance point calculation* shall determine the required design *capacity* for use with heat pump *equipment*. (Use *size limits* below if electric heat strips will be sized to provide Supplemental Heat Only)		***Heat Pump Emergency Heat*** The design *capacity* for Emergency Heat shall be 85% of the Manual J *heating load*, unless superseded by local code. (Use *size limits* below if electric heat strips will be sized to provide Emergency Heat)	
Supplemental heating load	***Size limit***	**Emergency Heat Size**	***Size limit***
Supplemental heating load ≤ 15,000 BTU/h	Maximum Size = 5.0kW	*Emergency heating load* ≤15,000 BTU/h	Maximum=5.0kW
Supplemental heating load > 15,000 BTU/h *size factor*	Maximum = 1.75 Minimum = 0.95	*Emergency heating load* > 15,000 BTU/h *size factor*	Maximum = 1.75 Minimum = 0.95

Alternative Auxiliary Strip Heat Control

Supply air temperature sensor (SAT)

- Advanced air handlers have SAT terminals
  - 10-20K Ohm sensor
  - Typically dip switch controlled (on control board)
  - Set to 85 °F
- Location should be three feet away and out of line of sight from the resistance heat strips

Benefits:

- Turns on resistance heat when needed to maintain supply air temps

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Upstage Timers

Multistage heating is most economic when controlled in stages.

Upstage timers are timed options to engage additional stages of heat similar to upshifting a car.

- Built in dip switches on control board
- Set in thermostat

Longer run times are better

- Typical ASHP run time is 40 minutes per hour

You don’t have to sacrifice comfort!

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Upstage by Temperature (Droop)

What is "droop?"

Simply put, it's a temperature value that "droops" below standard heating setpoint and controls a backup or secondary heating system.

71°F

69°F

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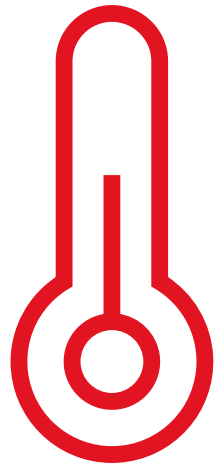
Upstage by Temperature (Droop)

- Thermostat offset determines staging
- Set temp – Room temp
- Two stage heat typically set to 2 °F
- The more stages the lower the stage temp can be set
- Thermostats can increase as little as ½ °F



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All-electric System Controls – Key Takeaways

- Use lock out to keep resistance heat off
  - Typically, 25 °F
- Determine the capacity balance point and stage auxiliary heat for the difference
- Supply air temperature sensors can control staging auxiliary heat
- Two methods for staging on AUX heat
- Time upstaging
- Temperature upstaging (Droop)

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Dual-Fuel Heat Pumps

Dual-Fuel System

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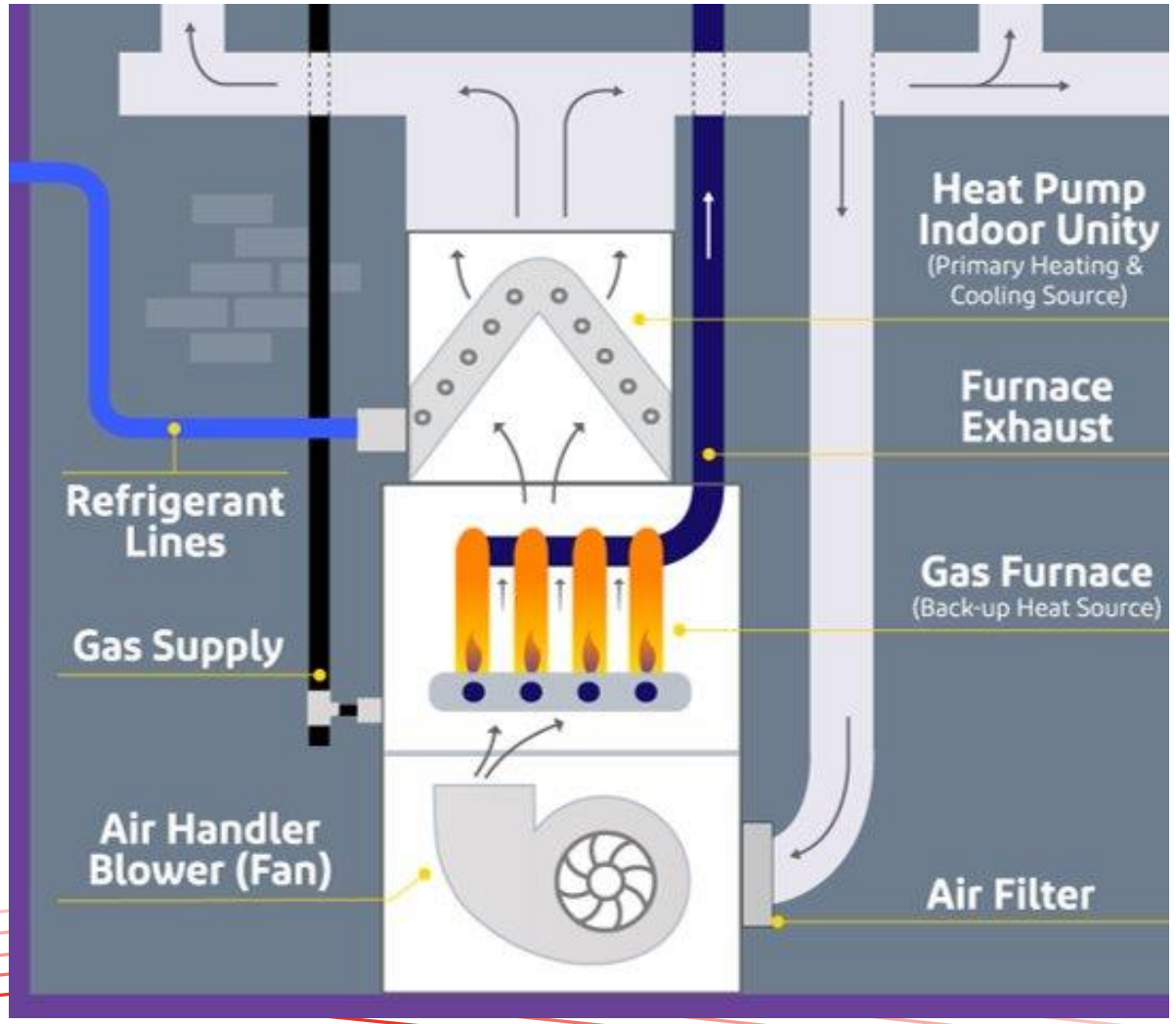
These systems consist of three components:

- The heat pump
- The indoor coil
- The furnace



Dual-Fuel Compatible Thermostats

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- Should have outdoor temp sensor or Wi-Fi connectivity to access local weather data
- Multistage heating control is beneficial (two-stage can be done without it)
- Wireless is an option

Compressor Lockouts

Definition:

- Temperature ***below*** which the heat pump's compressor will ***not*** operate
  - › Follow manufacturer guidelines
  - › Disable for most cold climate heat pumps
  - › If used, 5°F or lower

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Definitions for Switchover Temperature / Balance Point

The balance point is a TEMPERATURE at which switch over happens

Thermal Balance Point

- The outdoor temperature at which the heat pump can no longer produce the heat needed for the home.
- Also called Capacity Balance Point.

Economic Balance Point

- The outdoor temperature at which the cost to heat the home with the heat pump is more expensive than the back up heat cost.
- Relies on the back up heat fuel cost.

Comfort Balance Point

- The outdoor temperature at which the homeowner experience discomfort when running the heat pump.

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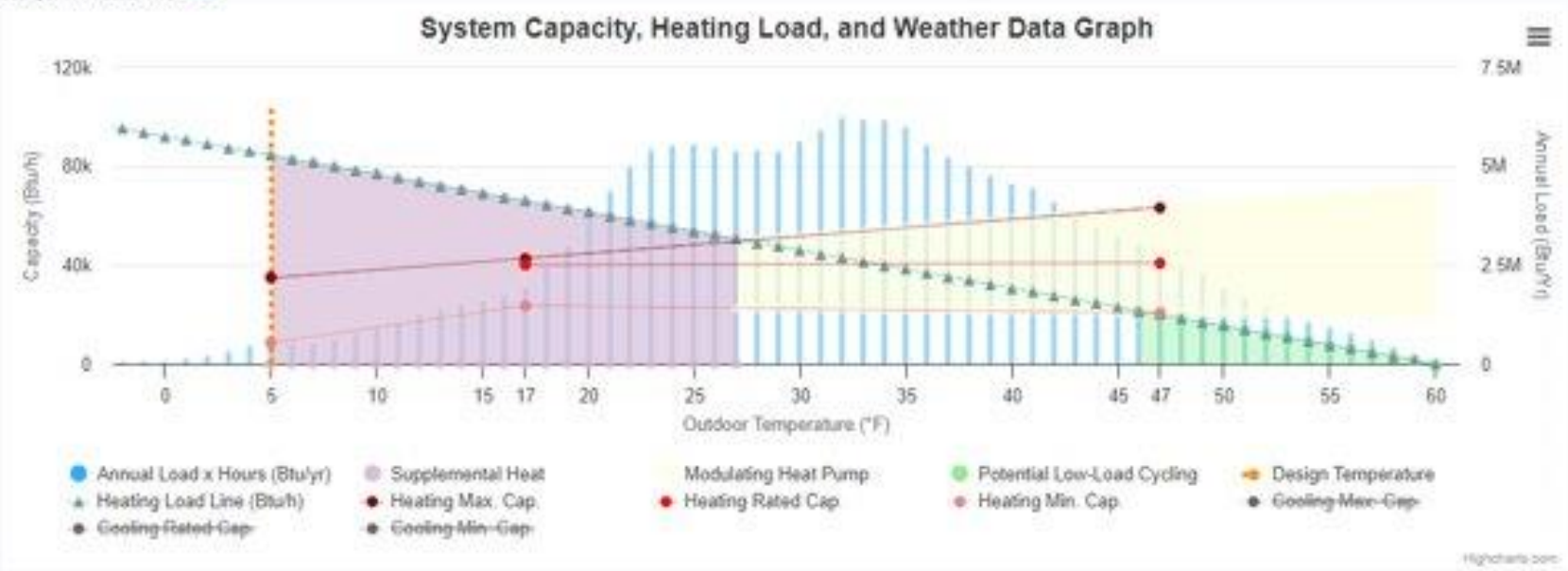
Capabilities of Heat Pumps

	Single stage	2 stage	Modern-inverter system	Stand-alone add-on inverter	Multizone inverter system
Gas furnace match	Single stage or better	2 stage or modulating	Communicating	Any	2 stage or modulating
Typical control type	24V w/ temp sensor	2 stage or communicating	Communicating	24V w/ temps sensor	Any
Examples	All manufacturers	Most manufacturers	Top tier all manufacturers	Bosch IDS Gree Flex Daikin Fit Mitsubishi Intelli-heat	Daikin VRF Mitsubishi Intelli-heat Carrier Bryant coming soon!
Largest sizing choice	Cooling load	Cooling load at low stage	Heating load	Heating load	Heating load
Switch over temp	Thermal BP	Thermal BP	Economic BP	Economic BP	Economic BP

Determining the Thermal/Capacity Balance Point with the NEEP Tool

This is the best place to guess and check on capacity balance points! Your customer may not be as forgiving as this tool.

Graph Information



Product Sizing For Heating

Field Information

Capacity Balance Point (°F)	27
Minimum Capacity Threshold (°F)	46
Maximum Capacity at Design Temp (Btu/h)	0
Percent Design Load Served	0.0%
Annual Heating Load (MMBtu)	175.5
Percent Annual Heating Load Served	67.5%

Field Information

Annual Btu's Covered by Supplemental Heat (MMBtu)	57.1
Hours Requiring Supplemental Heat	936
Percent Hours Requiring Supplemental Heat	16.5%
Percent Annual Load Modulating	86.9%
Percent Annual Load with Low-Load Cycling	10.5%

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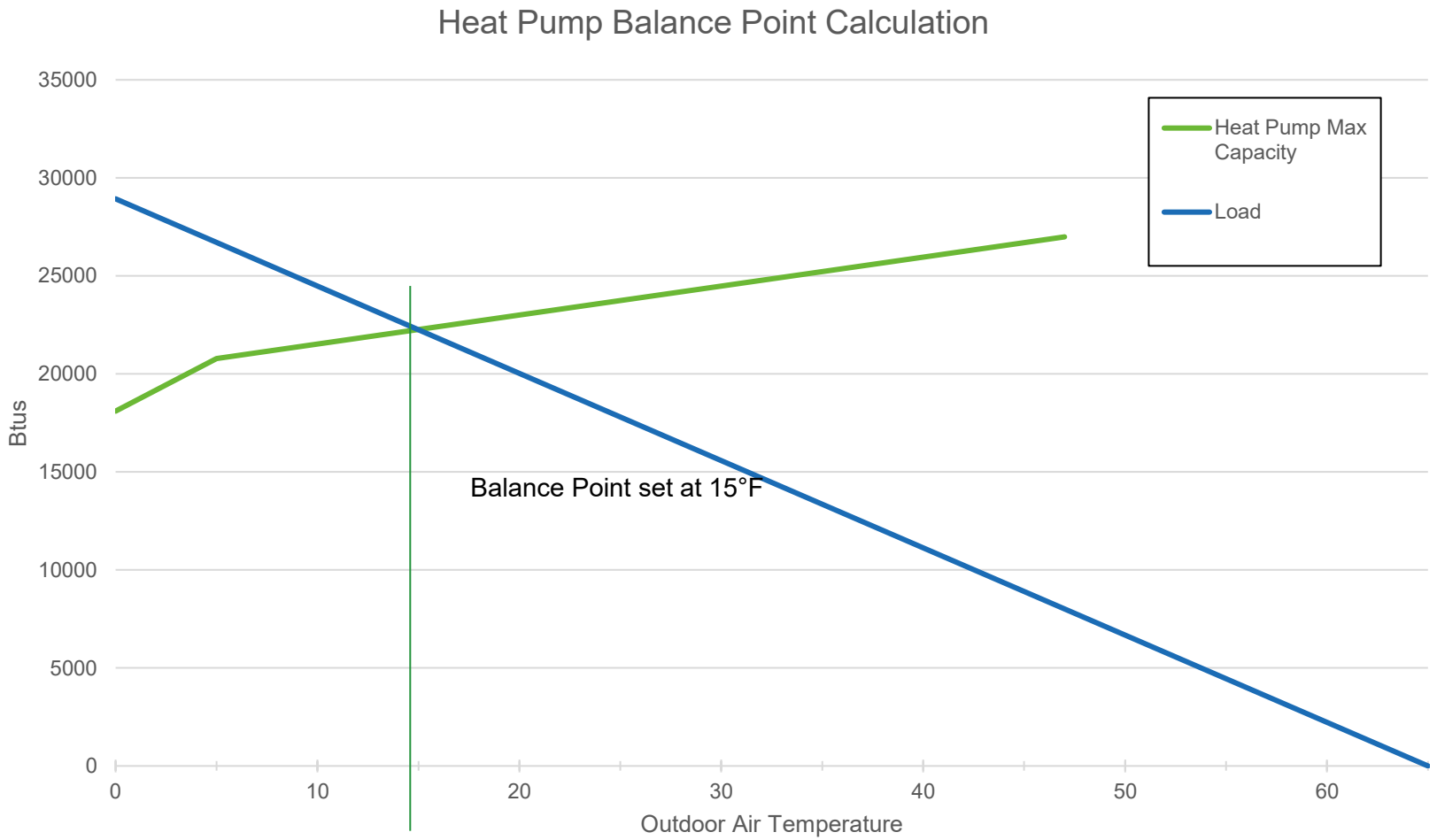
Determining the Capacity Balance Point



Economic Switchover Temperature

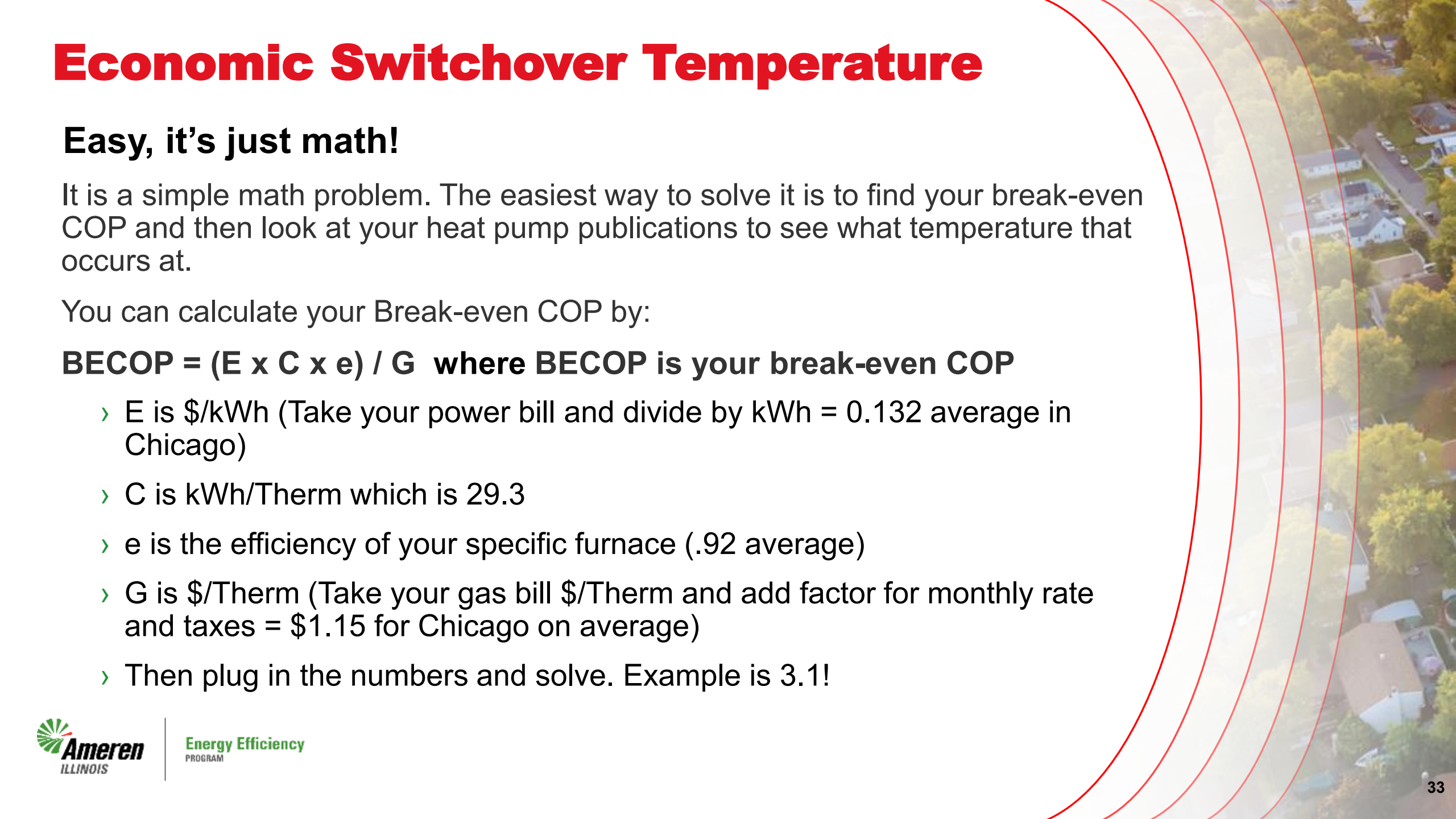
Easy, it's just math!

It is a simple math problem. The easiest way to solve it is to find your break-even COP and then look at your heat pump publications to see what temperature that occurs at.

You can calculate your Break-even COP by:

BECOP = (E x C x e) / G where BECOP is your break-even COP

- E is $/kWh (Take your power bill and divide by kWh = 0.132 average in Chicago)
- C is kWh/Therm which is 29.3
- e is the efficiency of your specific furnace (.92 average)
- G is $/Therm (Take your gas bill $/Therm and add factor for monthly rate and taxes = $1.15 for Chicago on average)
- Then plug in the numbers and solve. Example is 3.1!



Breakeven Coefficient of Performance Calculated

BeCOP	=	(E	X	C	X	Ef)	/	G
Break even COP	=	$ / Kwh	X	kWh / Therm	X	Efficiency of furnace	/	$ / Therm Gas
3.1	=	.132	X	29.3	X	92%	/	1.15

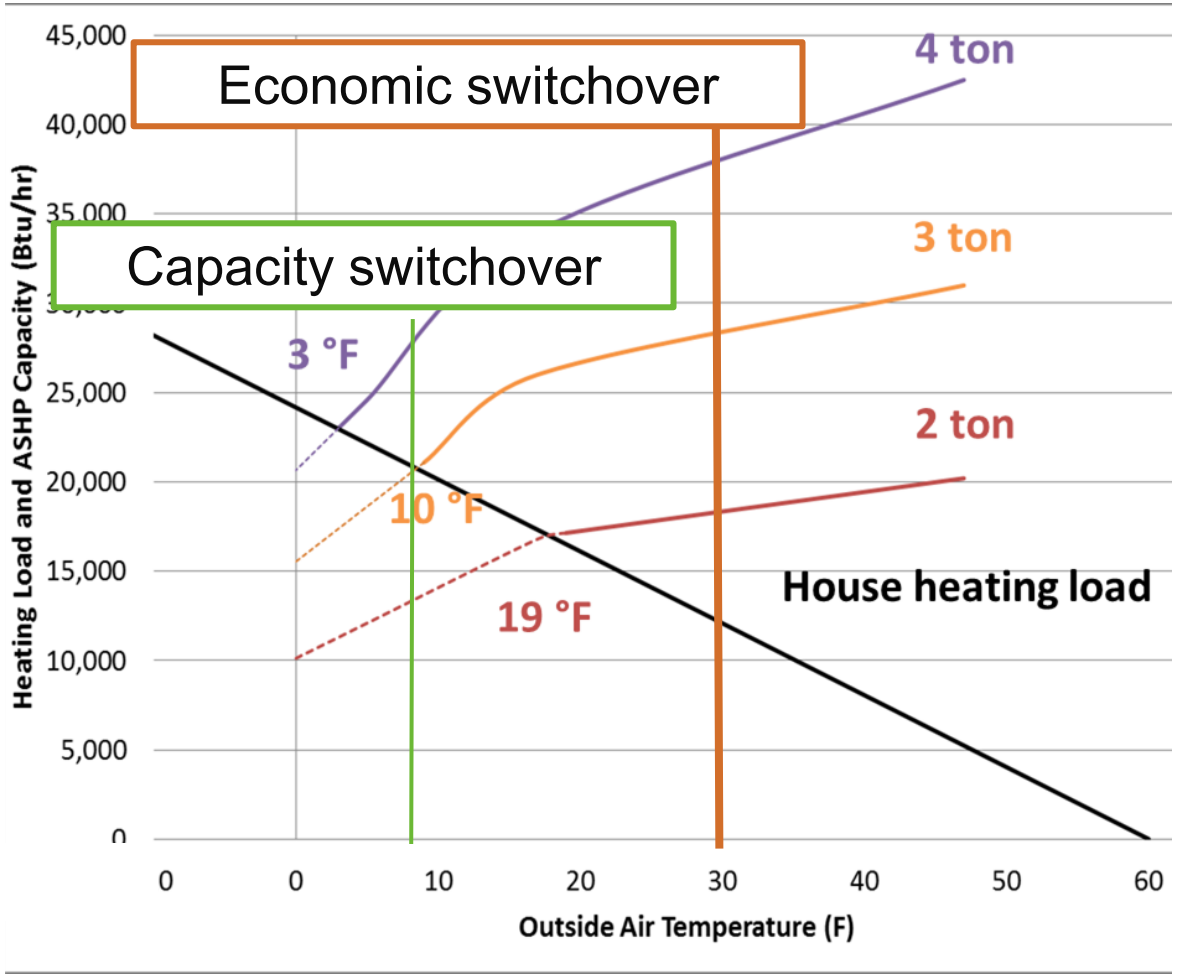
Determining the Switchover Temp with the BeCOP

- If the BeCOP were 3.1, the likely outdoor dry bulb temp that would align would be around 32 °F.
- Using Manufacturer Extended Performance Data is more accurate!

Performance Specs

Heating / Cooling	Outdoor Dry Bulb	Indoor Dry Bulb	Unit	Min	Rated	Max
Cooling	95°F	80°F	Btu/h	18,000	42,000	42,000
			kW	1.78	4.27	4.27
			COP	2.96	2.88	2.88
Cooling	82°F	80°F	Btu/h	19,000	-	47,000
			kW	1.3	-	4.2
			COP	4.28	-	3.28
Heating	47°F	70°F	Btu/h	22,000	48,000	54,000
			kW	1.59	4.01	4.87
			COP	4.06	3.51	3.25
Heating	17°F	70°F	Btu/h	17,000	42,000	48,000
			kW	1.85	4.99	6.7
			COP	2.69	2.47	2.1
Heating	5°F	70°F	Btu/h	12,000	-	48,000
			kW	3.06	-	7.36
			COP	1.15	-	1.91

Economic Switchover ≠ Capacity Switchover



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Dual-Fuel System Controls - Key Takeaways

- Must be dual fuel capable thermostat and have outdoor temp sensor or Wi-Fi connectivity to access local weather data.
- There are three balance points:
  - Thermal / capacity
  - Economic
  - Comfort
- Balance points change based on system capabilities, utility rates, and customer goals.
- Use the NEEP tool to guess and check when available for thermal balance point and the BeCOP for economic balance point.

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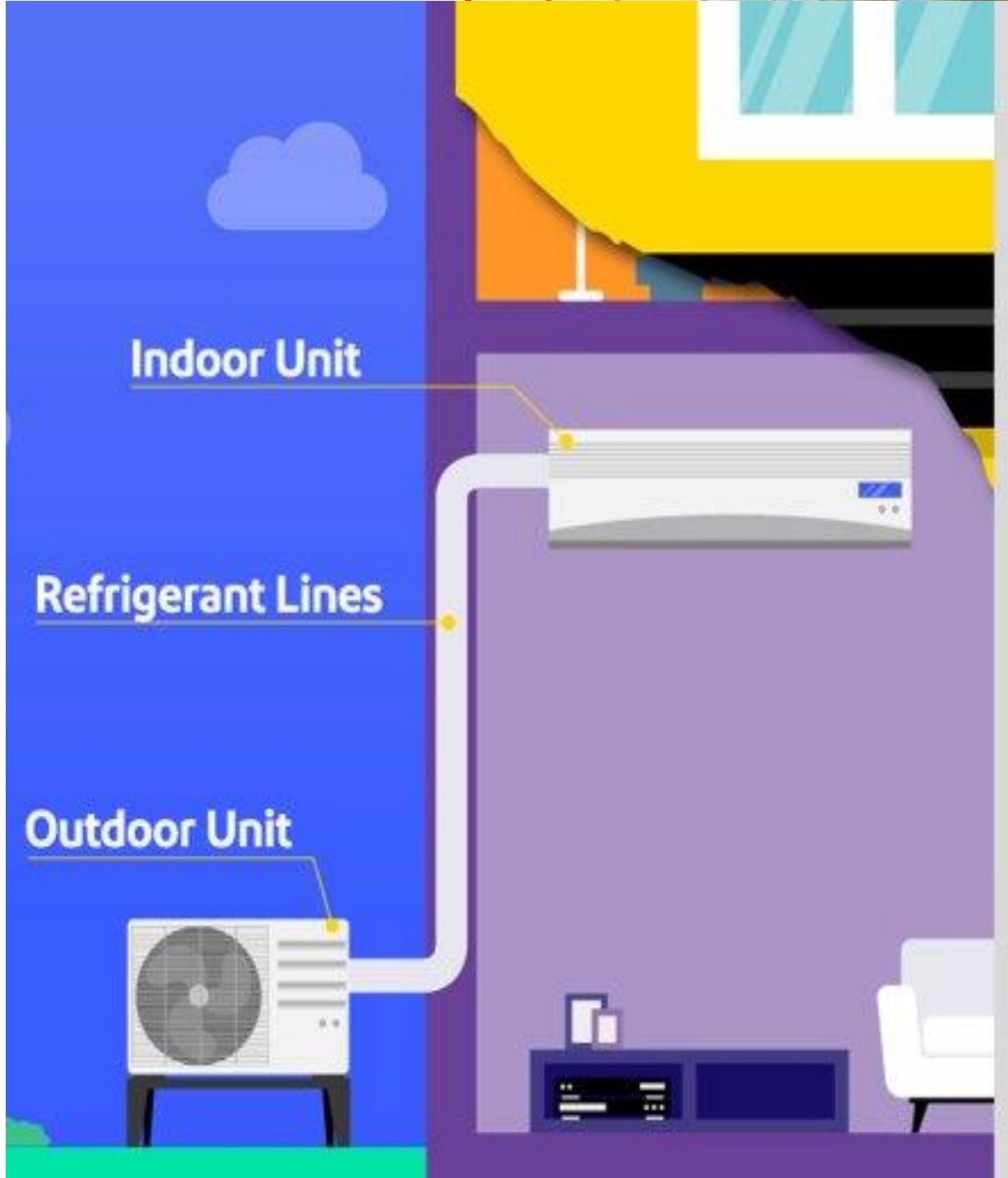
Multi-System Heat Pumps

Ductless Systems with Non-Connected Back-up

These systems consist mini- / multi-split and a non-connected heat source:

- Electric base board
- Boiler
- Wall furnace



Controlling the Supplemental Heat

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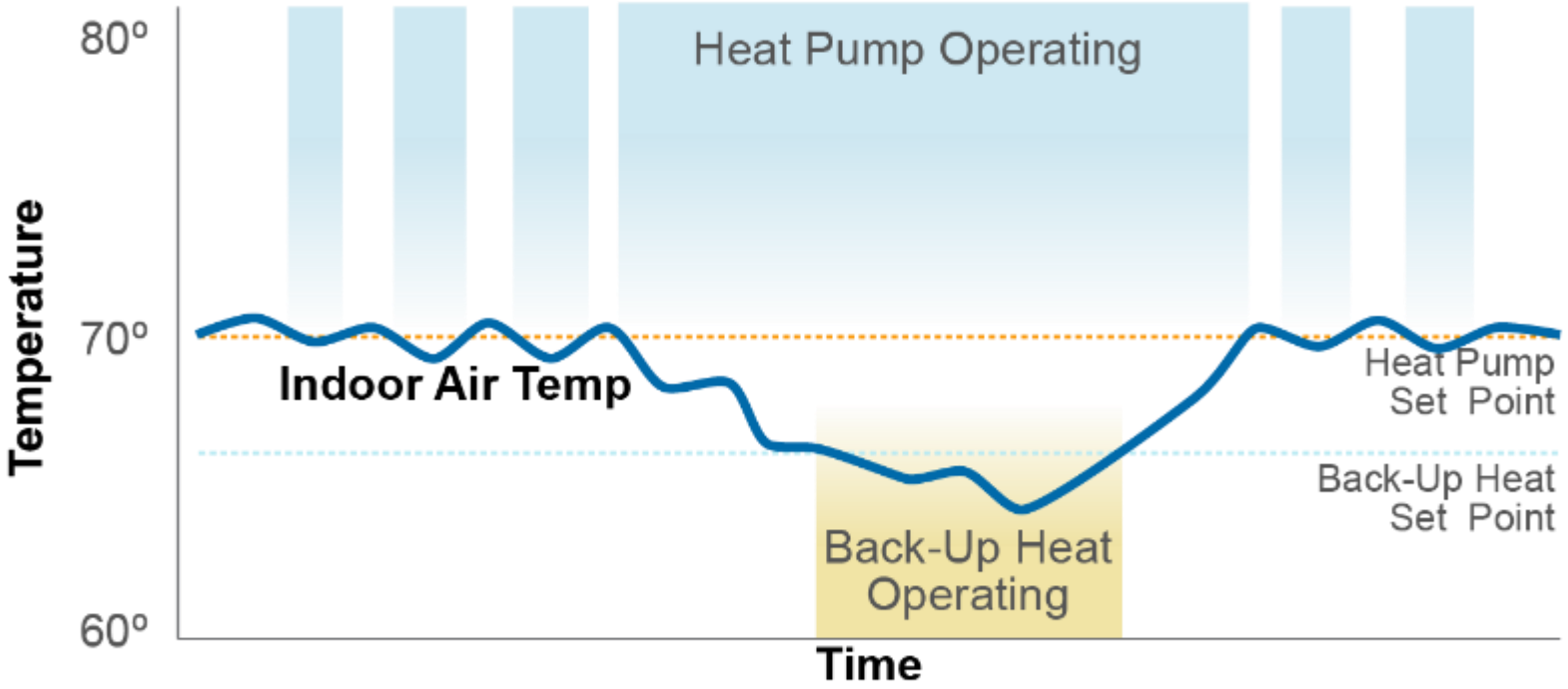
Separate Controls

- Supplemental thermostat located in the supplemental zone.
- May be viable for a small ***droop***—2°F to maximize heat pump use on mild days.

Simultaneous or Droop Method



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Ductless Systems with a Separate Heating System - Key Takeaways

- Keep back up heat OFF as long as possible!
- Two methods for controlling both systems:
  - Separate controls and droop of 2 °F
  - Integrated controls
- Integrated controls can affect heat pump performance. Check with your distributor before utilizing them.

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How to Stand Out in Heat Pump Maintenance

Maintenance Visits

Standing out may be easier than you think…

- Start at the thermostat
- Ask questions about recent utility bills
- Don’t be afraid to adjust the balance point (rates for fuel will change)
  - If gas bills went up or electric rates went down – adjust switchover to a lower temperature
  - If gas bills went down or electric rates went up – adjust switchover to a higher temperature

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What We Covered …

- Controls overview
- Proprietary / communicating controls
- All electric system controls
- Dual-fuel controls
- Ductless systems with separate system controls
- Balance point definitions and uses by application

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Thank you!