Having Success with Cold Weather Heat Pumps

Considerations for duct, envelope, and system performance

Bill Graber and Jake McAlpine
The Energy Conservatory

Energy Design Conference
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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 code/energy hours of credit toward Building Officials and Residential Contractors continuing education requirements."

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MINNEAPOLIS
BLOWER DOOR™

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GRID

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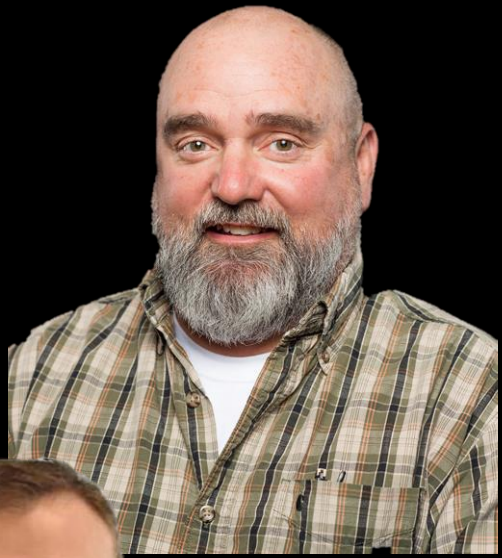


Making it Easier to do it Right™

TEC Industry Support

Gary Nelson

- Founder (40+ years)
- Physicist & Engineer from St. Olaf
- Inventor of Minneapolis Blower Door™, Ductblaster®, TrueFlow®
- Member of numerous committees (ASHRAE, RESNET, BPA)

Steve Rogers

- President
- 25+ years in pressure & flow with Emerson
- Mechanical Engineer from BYU
- Inventor of Digital TrueFlow®
- Member of ASME, ISO, ASHRAE committees.

Collin Olson

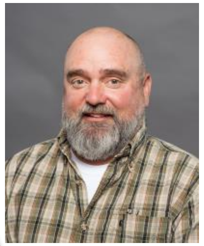
- Senior Staff Physicist
- 25+ years experience in building science & performance
- Ph.D. from Univ. of Wisconsin, Madison
- Member of several committees: ASHRAE 193,162, 62.2 & ABAA.

Jake McAlpine

- Technical Support Lead
- 13+ years experience in building diagnostics
- Residential Building Science Degree from Minnesota

Chris Hughes

- HVAC Business Development
- 18+ years experience as Mechanical Contractor
- Experience in air flow design, refrigeration, DDC & Pneumatic controls, VFD's, VRV/VRF Technology



Ed Janowiak

- TEC HVAC Design Consultant
- Manager of HVAC Design Education for ACCA
- 35+ years' experience in the HVAC industry

Bill Graber

- Marketing, Partner
- 25+ years in pressure & flow with Emerson
- Mechanical Engineer/MBA from Minnesota

Nearly 200 Years Experience

Cold Climate Heat Pumps - Key Messages

- CC Heat pumps are a **great opportunity.** In many cases in Upper Midwest, these will be **ducted systems**.
- **Look beyond COP** to have a successful heat pump install. Goals include **comparable comfort, costs and durability.**
- Several factors influence a **retrofit project success** – including **air flow**, **duct condition**, and **building envelope condition.**
- There are **many great resources** for homeowners and contractors, including **CEE, Slipstream, NEEP**, and others.

We will review two houses ("Good/Tight" & "Bad/Leaky") to show how these factors interact to impact the success in a ducted retrofit application

Agenda

- Intro: Success with a 1.5-ton heat pump in Minnesota
- Why Cold Weather Heat Pumps?
- Sizing a Heat Pump for Success
  - Minneapolis Example
    - Impact of Air Flow
    - Impact of Building Envelope
    - Impact of Ductwork
- How to Achieve Good Envelope and Ducts
- Final thoughts & Summary

Having Success With Cold Weather Heat Pumps

- This session will review a case study project of installing a 1.5-ton heat pump (with no backup!) on a Minneapolis home.
- Learn details of what was considered and what work was done to make this project a success.
- Learn about what broader lessons we can apply as customers look to install more cold-weather heat pumps in our region.

Gary completed a renovation in 2017 and has a very "Good House"

We will Touch on Gary Nelson's Project, but then Focus on Broader Topics

Can a Heat Pump Work in Minnesota?

First, fix the building enclosure!

Details of Gary's 2017 Renovation Project

- **Infiltration:** 1 ACH50 (air change per hour at 50 Pascals)
  500 cubic feet per minute at 50 Pa (cfm50)
- **Walls:** R-30 to R-40
- **Ceiling:** R-50
- **Floor:** R-0 (old part), R-20 foam under addition
- **Windows:** Triple pane, argon-filled, 3 low-e coatings

The result of improving the enclosure so much is that the **heating load is very low**. Minneapolis design temp -10F, needed a heat pump with a capacity of **18,000 BTU/hr.**

Can a Heat Pump Work in Minnesota?

energy vanguard

1.5 Ton Heat Pump

- Replaced heating system with 1.5-ton Fujitsu ducted mini-split heat pump
- Moved heat pump higher after first winter to avoid ice build-up
- Winter #2: Moved higher
- Winter #3: Added a plexiglass shed roof to keep snow off

Can a Heat Pump Work in Minnesota?

Heating Performance

- **Winter 2017-18**: Low in Minneapolis was -15° F. The system performed very well and held the house at their 72° F setpoint.

- **Winter 2018-19**: Coldest was -27°F, house got down to 62° F…but they were away in Australia at the time. Nelson believes they would be closer to 70° F with body heat and by baking some cookies.

- **Winter 2019-20**: Nothing remarkable to report. They didn't have any weather cold enough to call for any kind of auxiliary heat.

Can a Heat Pump Work in Minnesota?

Heating Performance at -27F

- The heat pump capacity was 8,597 BTU/hr (2.52 kilowatts) and the power consumption was 1,834 watts (W). **The coefficient of performance was 2.52 ÷ 1.834 = 1.37**. For comparison, electric resistance heat has a coefficient of performance of 1.

- When the temperature **rose to -17° F**, the heat pump output rose to 13,000 BTU/hr and the power consumed to 1,959 W. The resulting **coefficient of performance was nearly 2.**

Historically, some HVAC techs would tell people to switch to emergency heat when the outdoor temperature drops into the 30's!

Can a Heat Pump Work in Minnesota?

Heating Performance

- **Winter 2020-21: Few days in a row where it didn't get above 0° F and down around -17° F** at night. And very little sun, which I think is unusual when it's this cold.

- Ran about flat out for 3 or 4 days and didn't quite meet the setpoint. The third morning, I **turned on the [electric] oven for an hour** or so with the door open and then set it to 350° F with the door closed for much of the day. I'd guess we probably **used < 40 kWh of resistance heat.**

40 kilowatt-hours of supplemental electric resistance heat he used might have **added about $5 to his electric bill**.

Can a Heat Pump Work in Minnesota?

Cooling Performance

- Nelson's heat pump is sized just about perfectly for heating. That means it's oversized for cooling. As a result, the house **can stay at the setpoint temperature easily but doesn't get dehumidified enough**.
- After two summers, he **installed an Ultra-Aire dehumidifier** in the summer of 2020. As a result, he "enjoyed much better humidity control" during the cooling season.

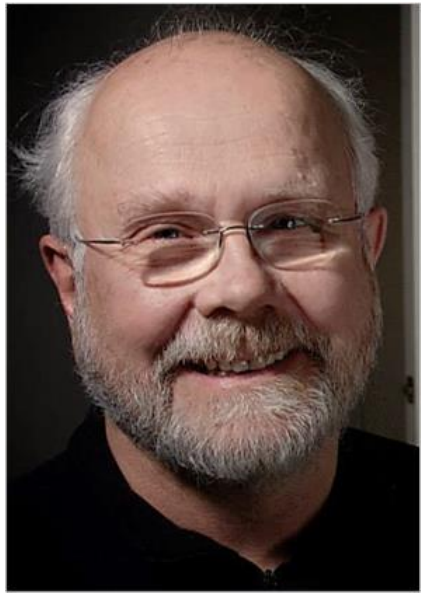
Can a Heat Pump Work in Minnesota?

Cooling Performance

- Last year, Gary **established a new (manual) process to control** the performance in Summer.
- He adjusted his fan speed to as low as it would go and operates in “dry mode”.
- He adjusts the thermostat down to 72F (from 74F) at night to ensure it operates over a longer run time. This allows it to run efficiently at night. He then turns it back up to 74F in the morning. Even though it was a warm and humid summer, **he did not need the dehumidifier in 2022.**

Improved (and simplified) controls is a key need to deliver the best performance from heat pumps

Can a Heat Pump Work in Minnesota?



Key Lessons from Gary's Project

1. **Cold climate heat pumps can be successful** in covering the heating load – even as a retrofit!
2. It is important to understand and **minimize the heating load through house envelope improvements**
3. If the heat load is low enough **electric resistance** may be a viable option for supplemental heating. In other cases, **dual fuel** may be appropriate.
4. **A key question: Can the grid handle the peak** if everyone flipped to electric resistance at the same time?
5. If you cover the heat load, you may need additional dehumidification in cooling season – but **improved controls** may also address this issue.

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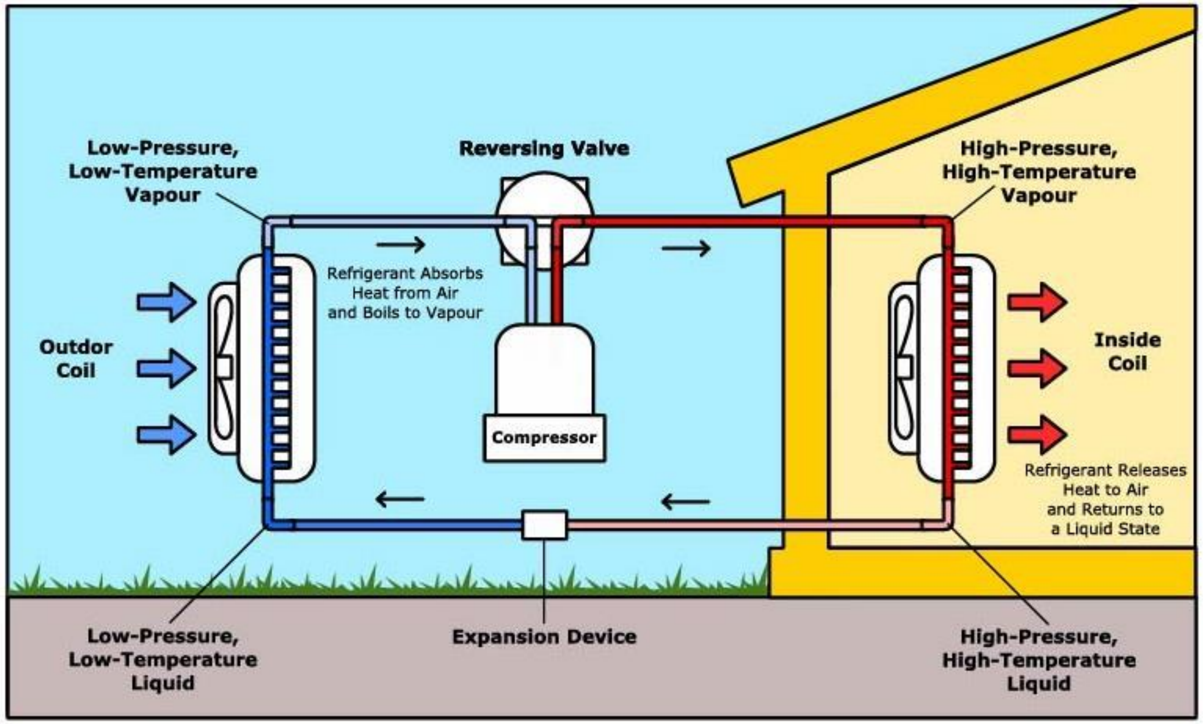
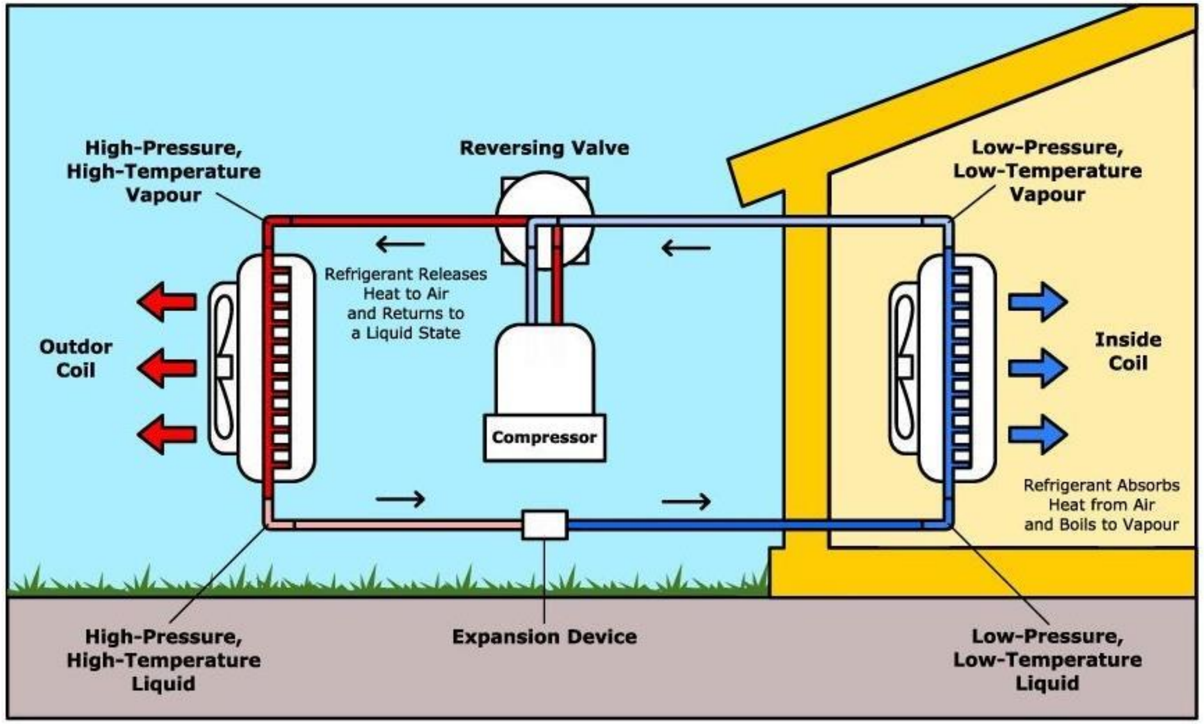
Air Source Heat Pump Operation

Source: DOE Energy Star

Heating Cycle



Cooling Cycle



Heat Pump Resources

ASHP
air source heat pump collaborative

cee

NEEP'S COLD CLIMATE AIR SOURCE
Heat Pump List

slipstream

Energy Demand and Sources in 2050

General Direction to Move to Electric to Reduce Co2 Footprint

Source: NRDC

SCENARIO (Electricity Portion of Final Energy in 2015 & 2050)	Total Final Energy	Electric Load	Natural Gas	Economy Wide
CONSERVATIVE (21% & 32%)	20%	24%	33%	19%
REFERENCE (21% & 36%)	22%	32%	40%	20%
PROGRESSIVE (21% & 39%)	27%	35%	31%	57%
TRANSFORMATION (21% & 47%)	32%	52%	18%	67%

What does it Mean to Have Success?

Source: Energy.gov

Government Funding Goals

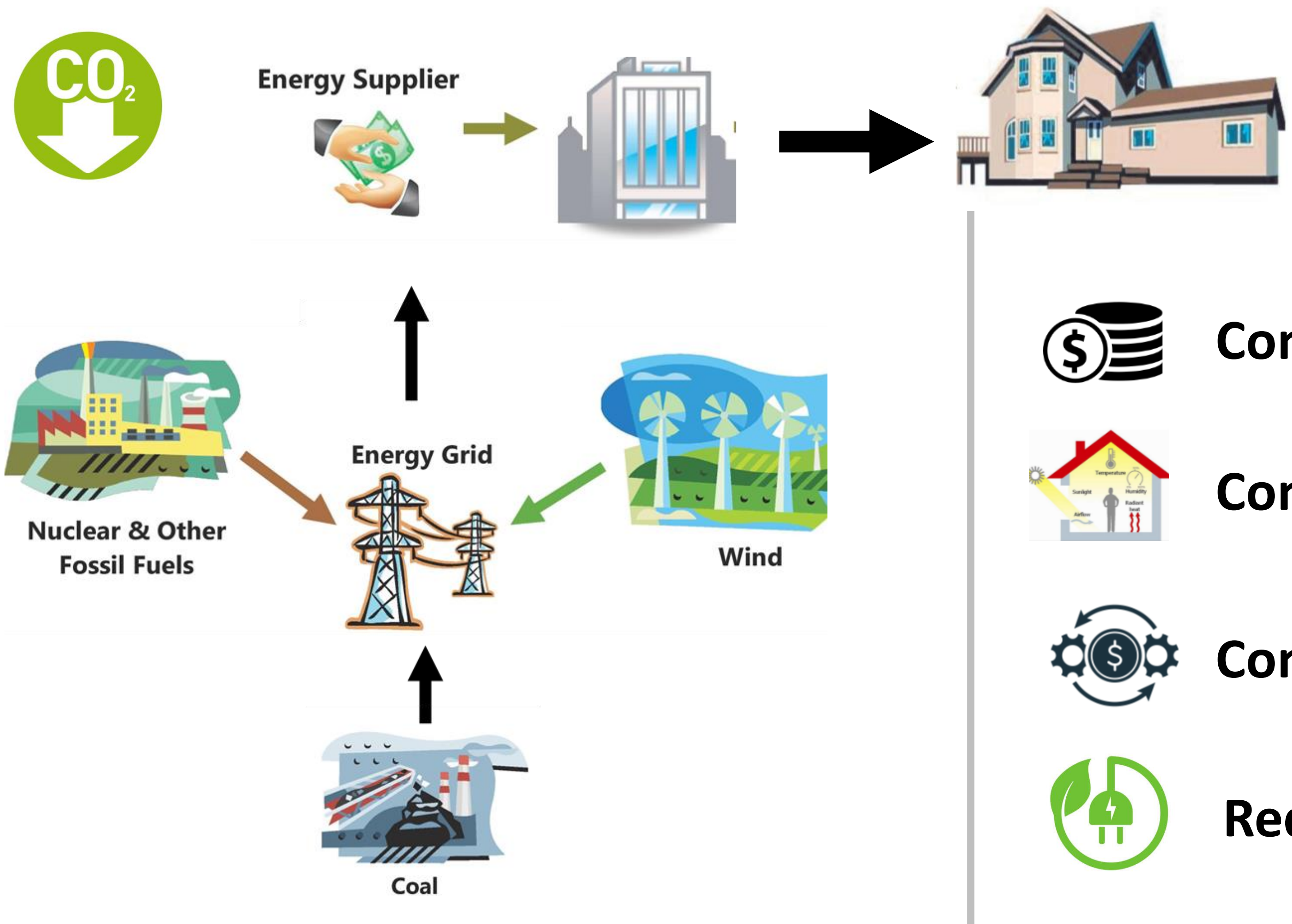
The Inflation Reduction Act (IRA) of 2022 makes the single largest **investment in climate and energy** in American history, enabling America to **tackle the climate crisis**, advancing **environmental justice**, securing America's position as a world leader in domestic **clean energy** manufacturing, and putting the United States on a pathway to achieving the Biden Administration's climate goals, including a **net-zero economy by 2050**.

Inflation Reduction Act Summary

Policy	Cost (-)/Savings (2022-2031)
Energy and Climate	**-$386 billion**
Clean Electricity Tax Credits	-$161 billion
Air Pollution, Hazardous Materials, Transportation and Infrastructure	-$40 billion
Individual Clean Energy Incentives	-$37 billion
Clean Manufacturing Tax Credits	-$37 billion
Clean Fuel and Vehicle Tax Credits	-$36 billion
Conservation, Rural Development, Forestry	-$35 billion
Building Efficiency, Electrification, Transmission, Industrial, DOE Grants and Loans	-$27 billion
Other Energy and Climate Spending	-$14 billion
Health Care	**-$98 billion**
Extension of Expanded ACA Subsidies (three years)	-$64 billion
Part D Re-Design, LIS Subsidies, Vaccine Coverage	-$34 billion
Total, Spending and Tax Breaks	**-$485 billion**

What does it Mean to Have Success?

Source: Energy.gov



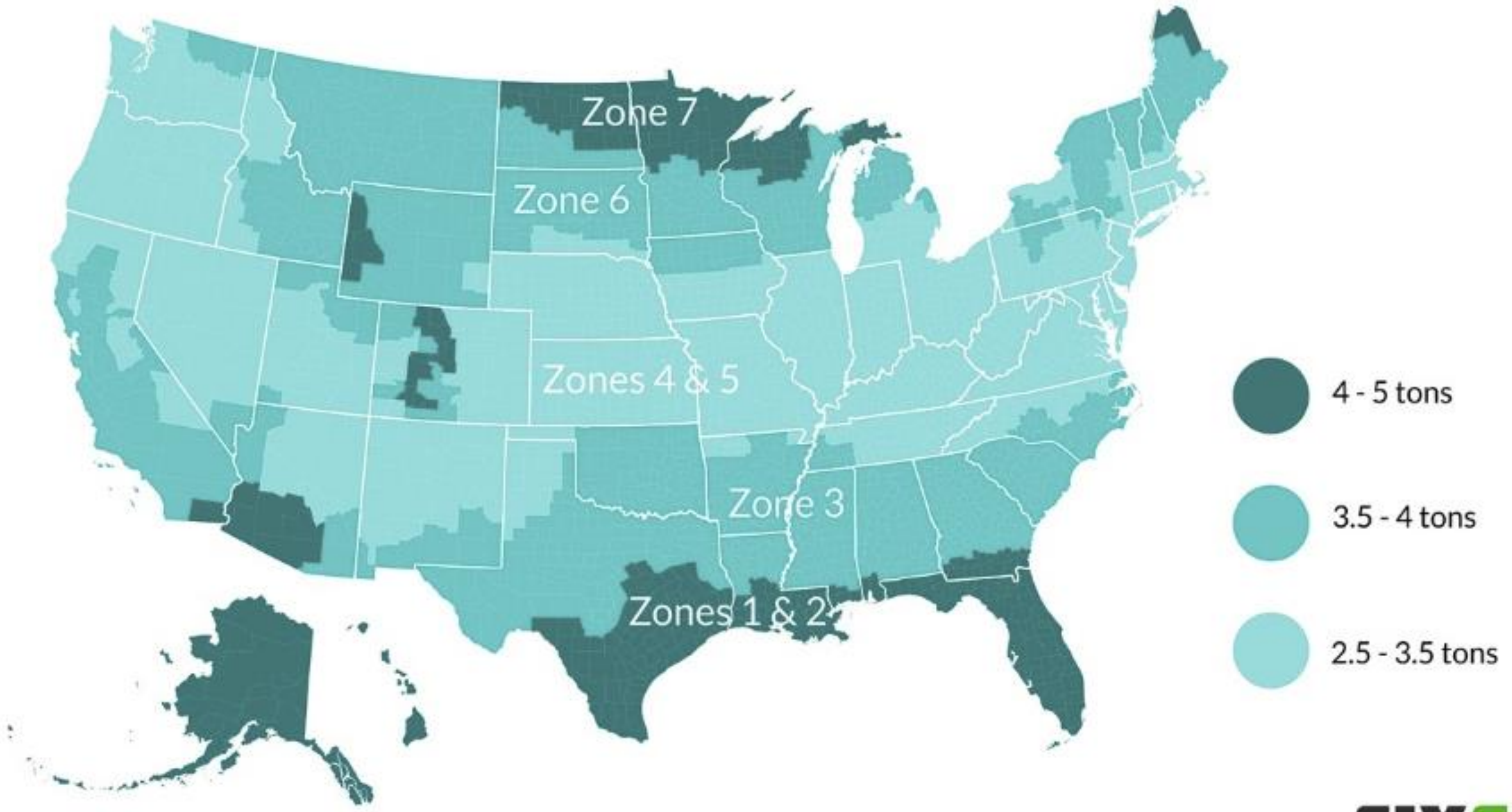
Homeowner/Contractor Goals

- Comparable Initial Cost
- Comparable Comfort
- Comparable Operating Cost
- Reduce Energy (Carbon) Consumption
- Comparable Expected Life / Durability

Selecting Heat Pump can be Over-simplified

Success Factors
Comparable Initial Cost
Comparable Comfort
Comparable Operating Cost
Reduce Energy CO_2 Consumption
Comparable Durability

To heat and cool a 2,000 sq.ft. home in each zone, you need the following sized heat pumps:



Source: FIXR

FIXR

Selecting Heat Pump can be Over-simplified

Success Factors
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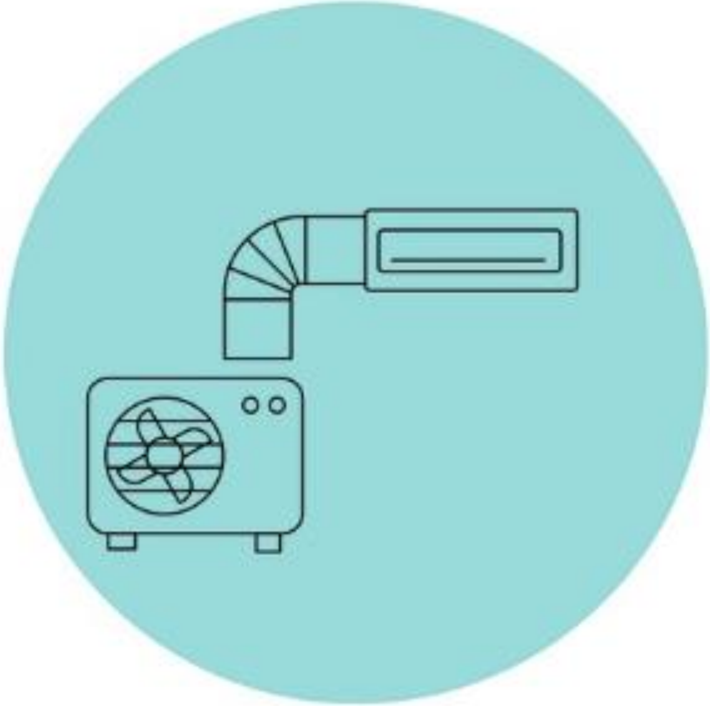
Air Source Heat Pump Styles

Source: FIXR

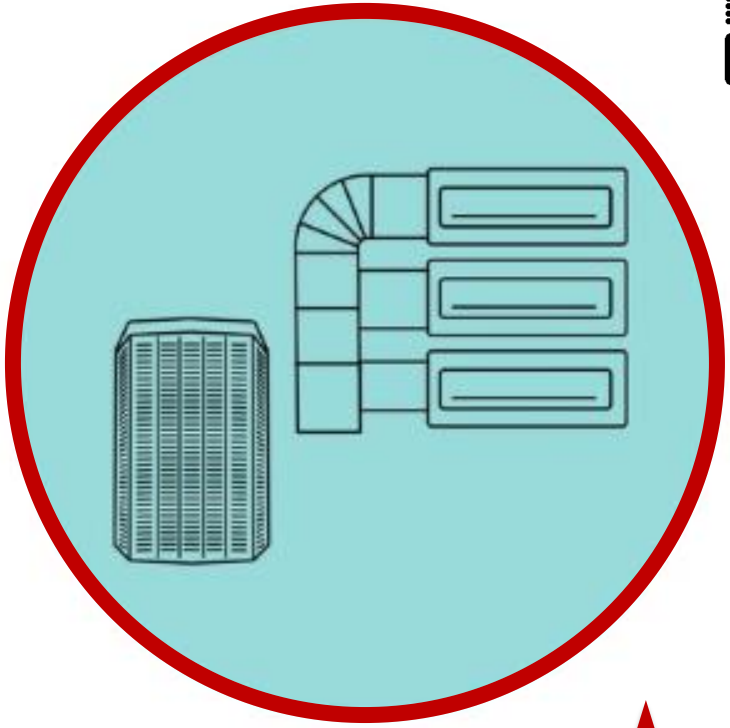
$900 - $5,000

Ductless



$2,000 - $8,000

Ducted Mini-split

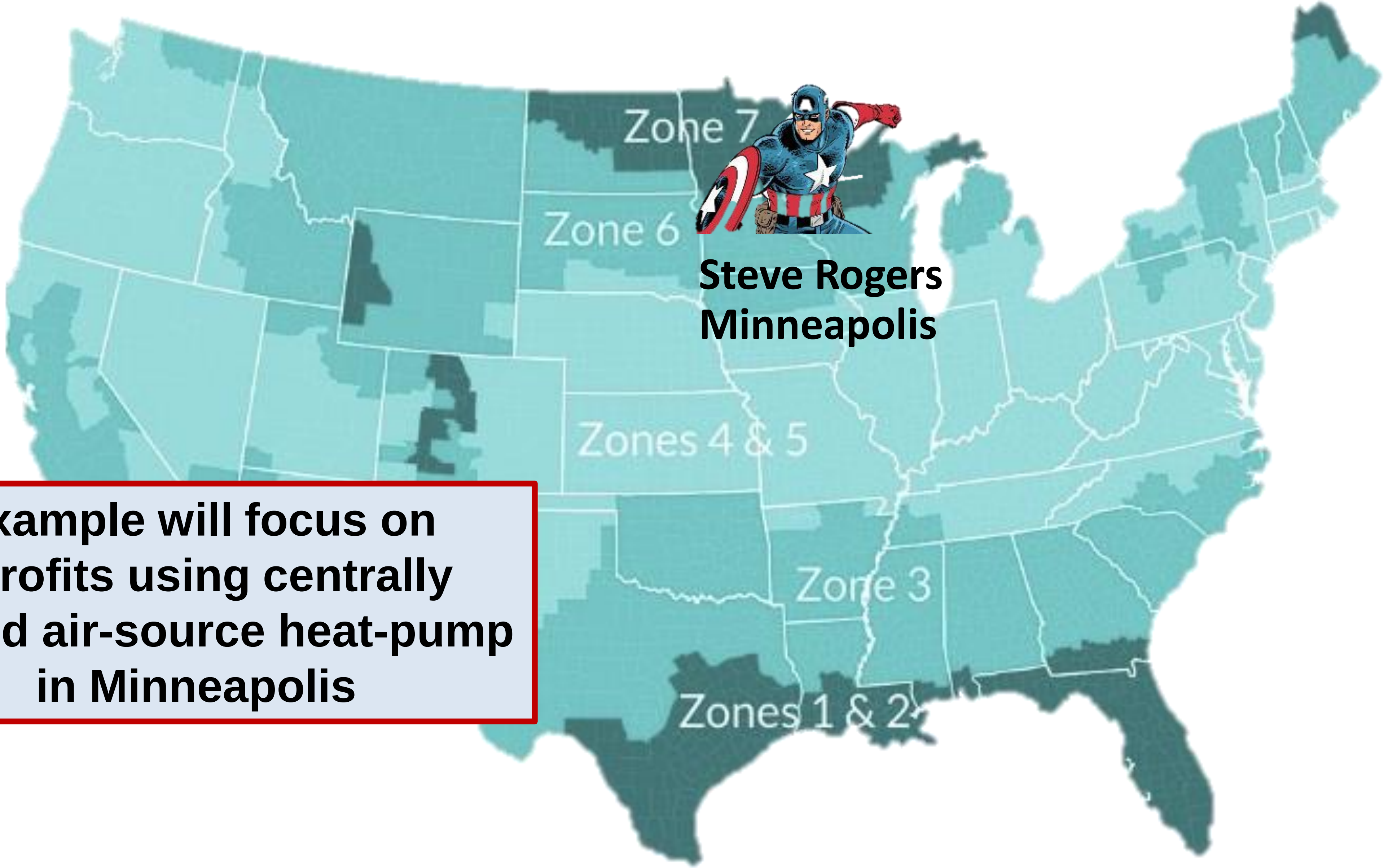


$2,000 - $8,000 ★

Ducted / Central

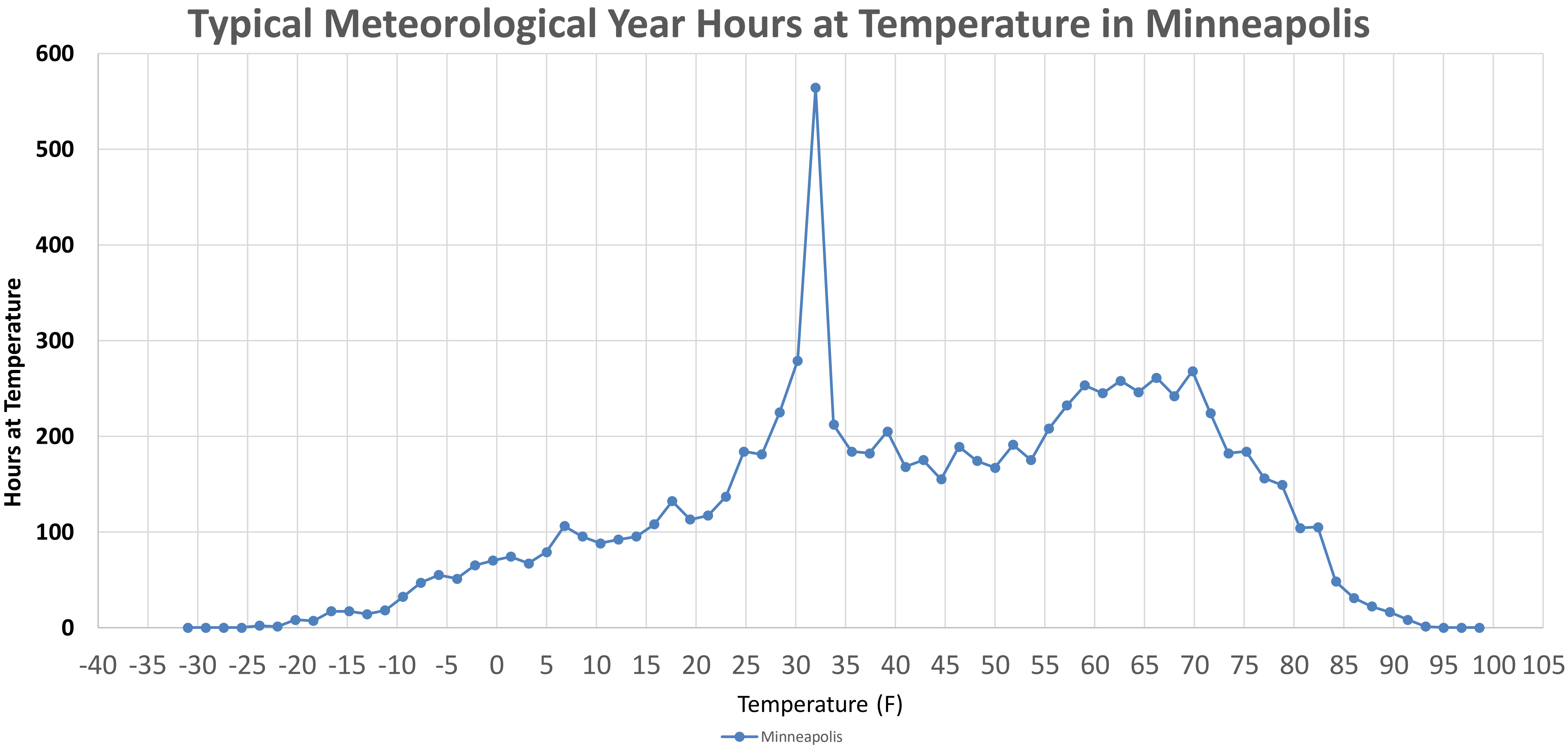
Retrofit Ducted Systems will be Most Challenging

Let’s Look at some Examples - Meet the Rogers…



Example will focus on retrofits using centrally ducted air-source heat-pump in Minneapolis

Minneapolis House



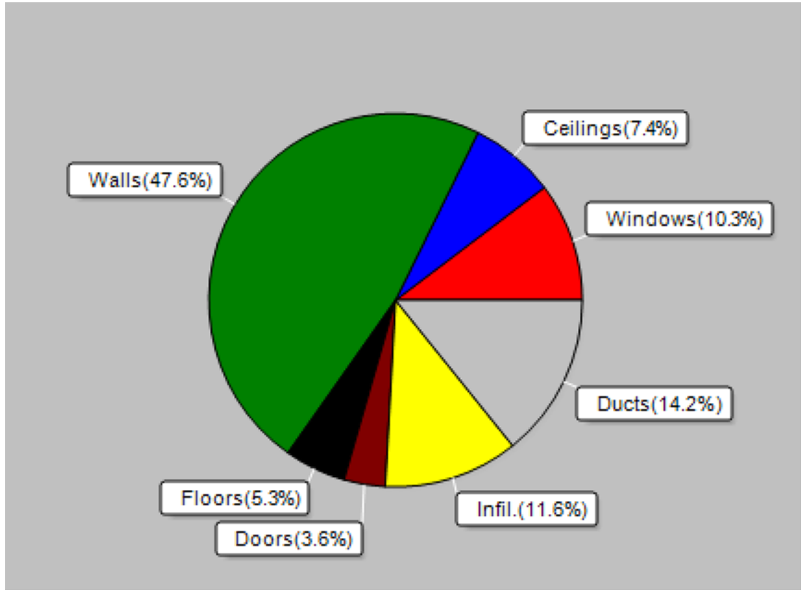
Example Minneapolis House

Let's Size a Heat Pump for Success!

Retrofit

- 1 Story, ~1500 Sq Ft Home
- 95% Gas Furnace, 2-ton AC

Success Factors
Comparable Initial Cost
Comparable Comfort
Comparable Operating Cost
Reduce Energy CO2 Consumption
Comparable Durability



Complete load calcs to understand & address specific home needs

Example Minneapolis House

Let's Size a Heat Pump for Success!

Retrofit

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Success Factors

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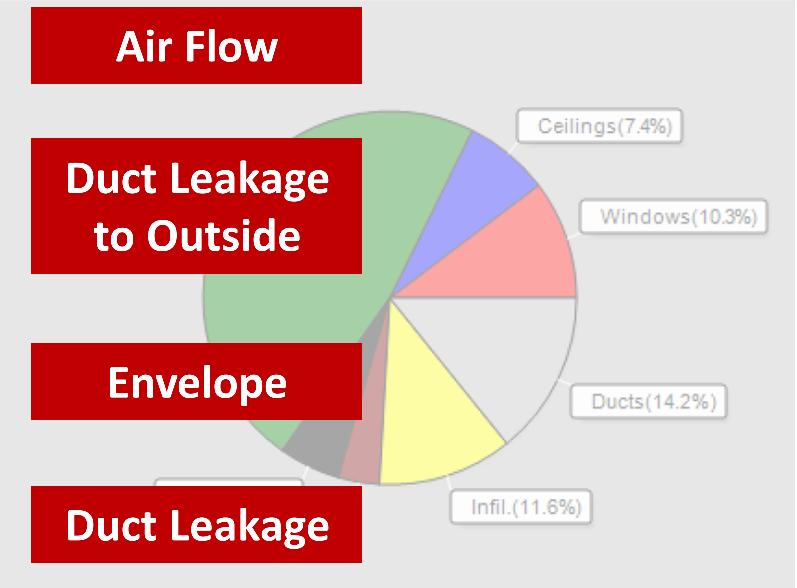

We will use examples of a "leaky house" and "tight house" to show impact of these items

Example Minneapolis House

Let's Size a Heat Pump for Success!

Retrofit

- 1 Story, ~1500 Sq Ft Home
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Success Factors
Comparable Initial Cost
Comparable Comfort
Comparable Operating Cost
Reduce Energy CO2 Consumption
Comparable Durability

Air Flow

Duct Leakage to Outside

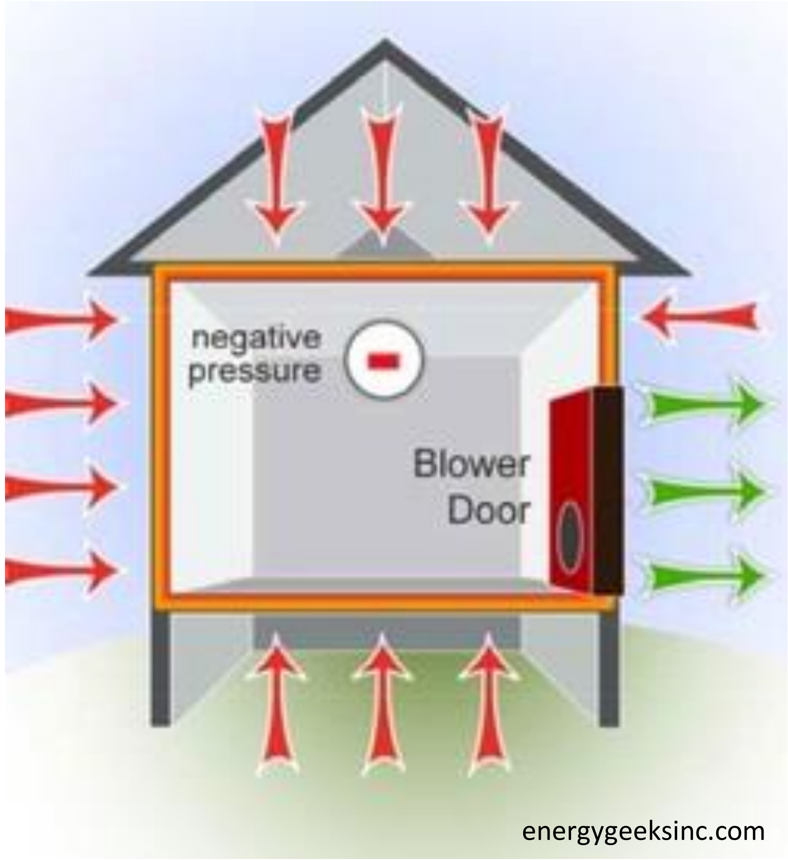
Envelope

Duct Leakage

Versions	Envelope	HVAC TESP	HVAC Air Flow (heat)	Duct Leakage to Outside
Leaky House	11 ACH50	0.8 inH2O	900 cfm	8%
Tight House	2 ACH50	0.5 inH2O	1000 cfm	0%

What Happens During a Blower Door Test?

- A blower door test is typically done at an induced pressure difference of 50 Pascals(Pa)*
- The fan is turned on and adjusted to change the pressure difference between inside and outside the building by 50 Pa and the flow is measured.
- Pascal's principle says the interior pressure changes by the same amount everywhere.



A Blower Door Test induces a pressure difference between inside and outside

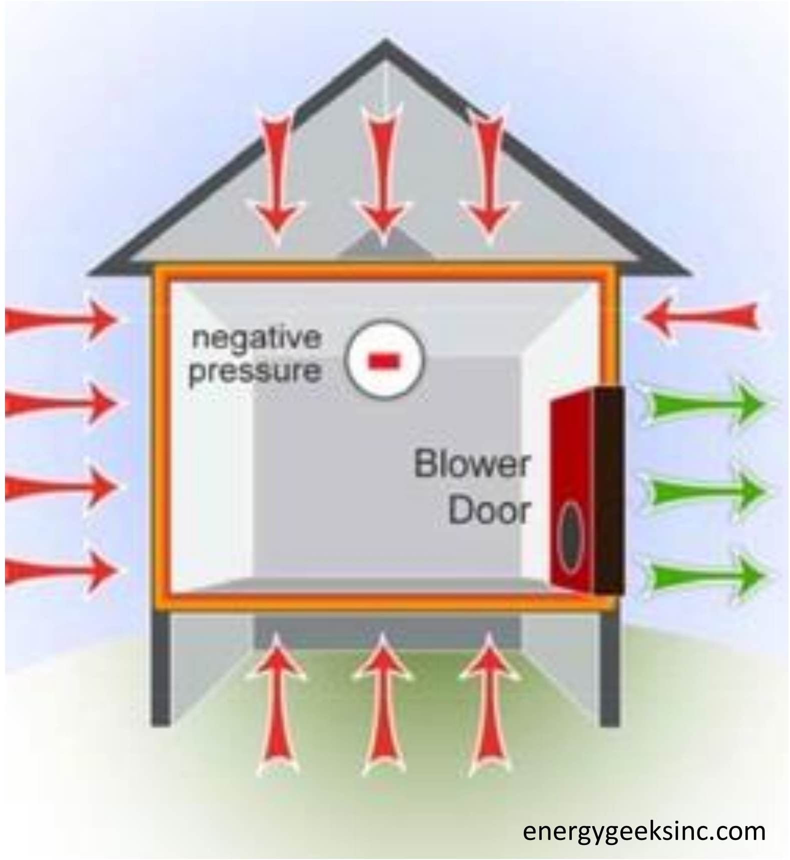
- - Note: To simplify the explanation, we will talk about a single point blower door test at 50 PA. The same principles hold for multi-point tests using different pressures.

What Happens During a Blower Door Test?

- We measure the air flowing through the fan when pressurized to 50 Pa. This is noted as **cfm50** (cubic feet per minute at 50 Pa of pressure). This flow matches the flow through the leaks in the envelope

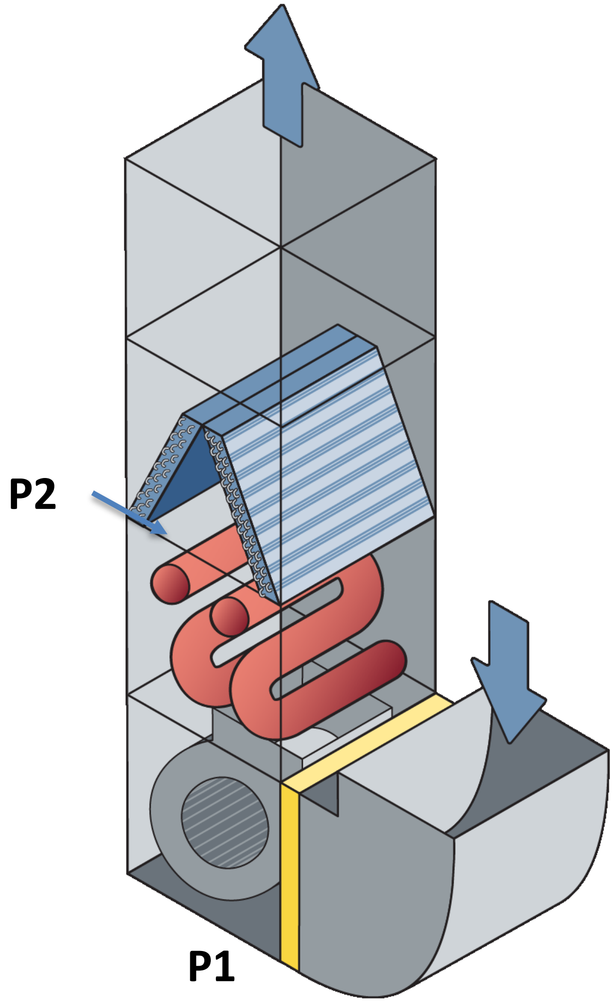
- We use this flow rate and the volume of the house envelope (LxWxH) in FT^3 to calculate how many times the volume of air would change over in 1 hour. This is called **ACH50 (Air changes per hour at 50 Pa).**

- Code for new construction in most northern climates is 3 ACH50. But older homes can be much worse than this

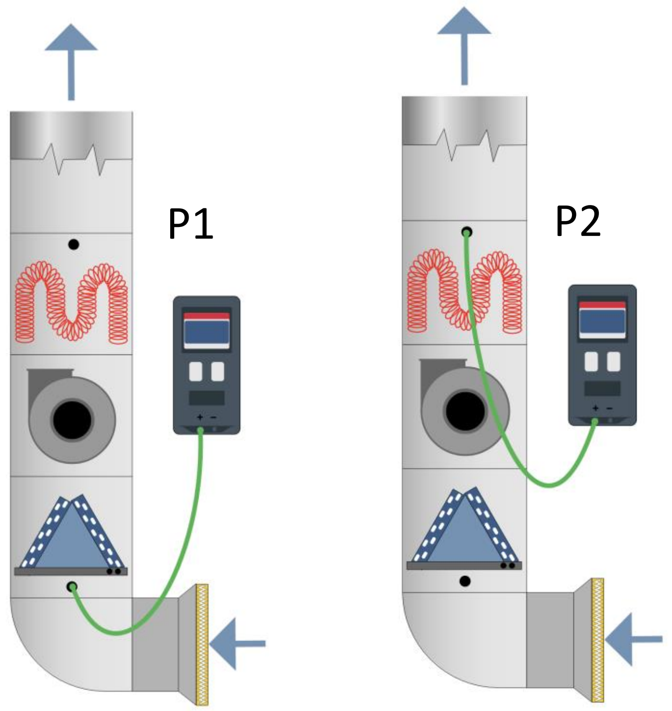


A Blower Door Test induces a pressure difference between inside and outside

Total External Static Pressure



TESP = Total External Static Pressure
= Exit Pressure – entrance pressure
= P2 – P1



Example Minneapolis House

Let's Size a Heat Pump for Success!

Retrofit

- 1 Story, ~1500 Sq Ft Home
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Success Factors

- Comparable Initial Cost
- Comparable Comfort
- Comparable Operating Cost
- Reduce Energy CO2 Consumption
- Comparable Durability

Air Flow

Duct Leakage to Outside

Envelope

Duct Leakage

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Leaky House	11 ACH50	0.8 inH2O	800 cfm	8%
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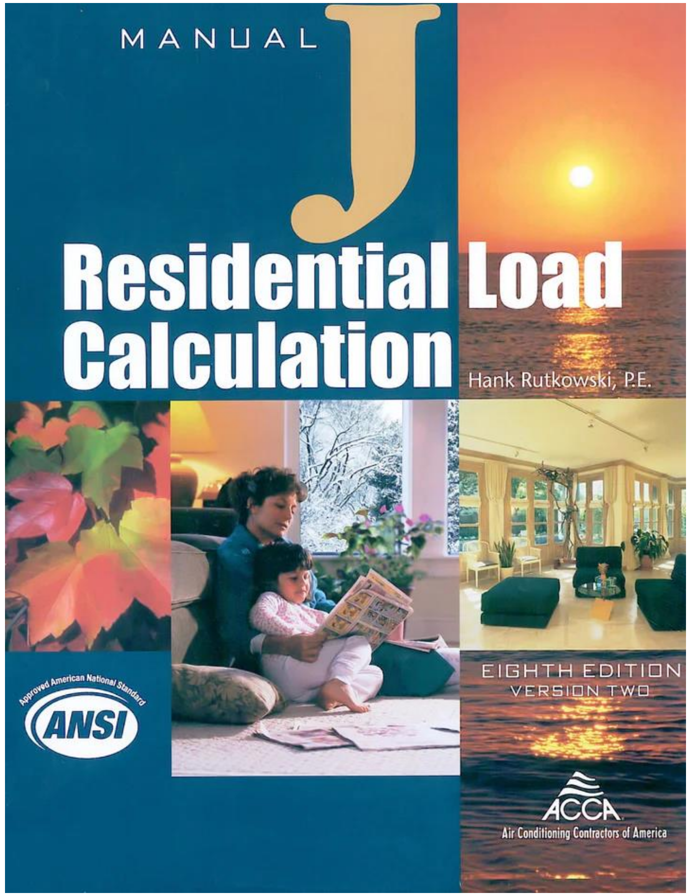
Minneapolis House

Heating Design Temp = -8F
Cooling Design Temp = 88F

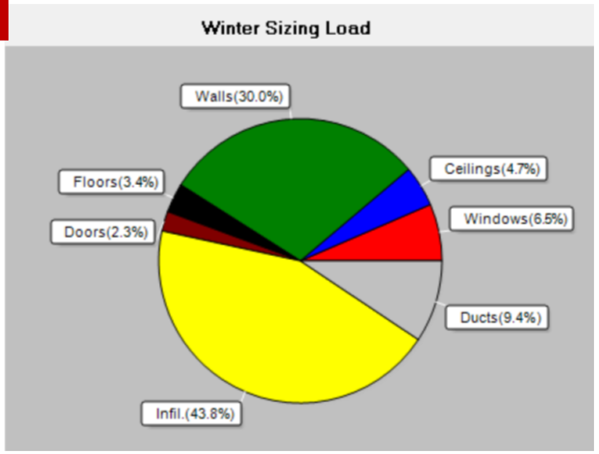
Manual J Load Calc Software



Envelope

Duct Leakage (Leakage to Outside)

Winter Delta Temp. (°F)	78
Winter Building Load (Btuh)	
Window Load:	4142
Wall Load:	19063
Ceiling Load:	2970
Door Load:	1435
Floor Load:	2134
Infiltration Load:	27780
Building Subtotal	57524
Duct Loss:	5955
Mech Ventilation Loss:	0
TOTAL HEATING LOAD	63479



Minneapolis House

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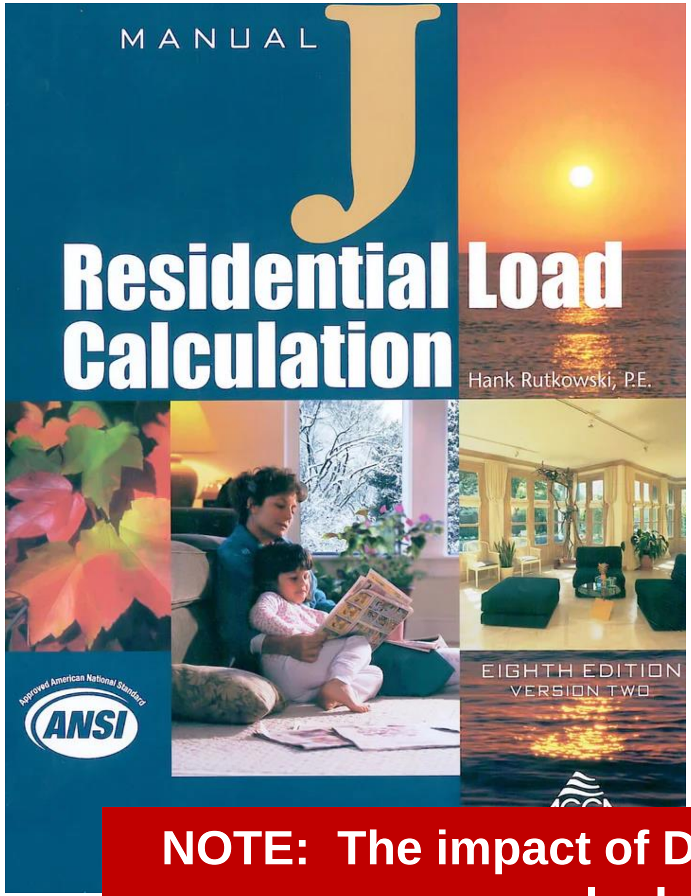

MiTek WRIGHTSOFT

KWIK MODEL3D

Cool Calc Manual J

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Envelope

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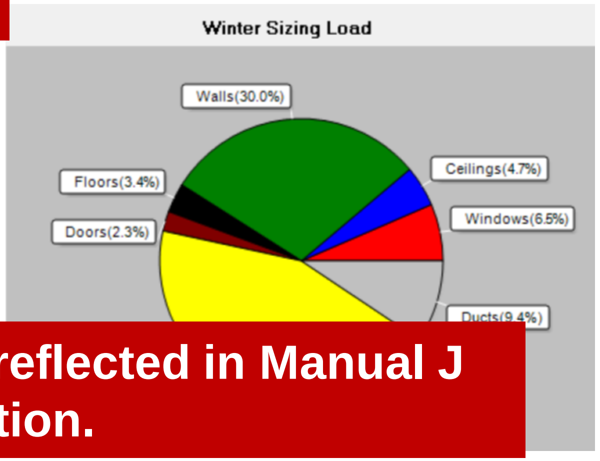
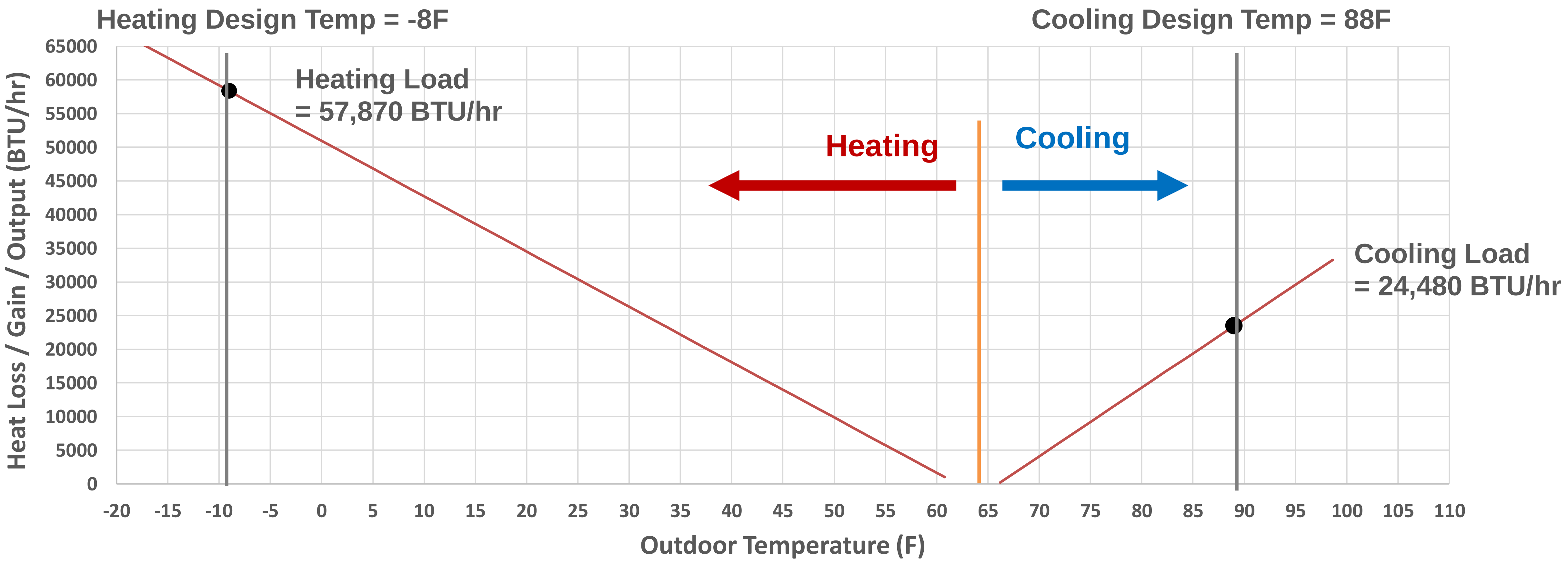


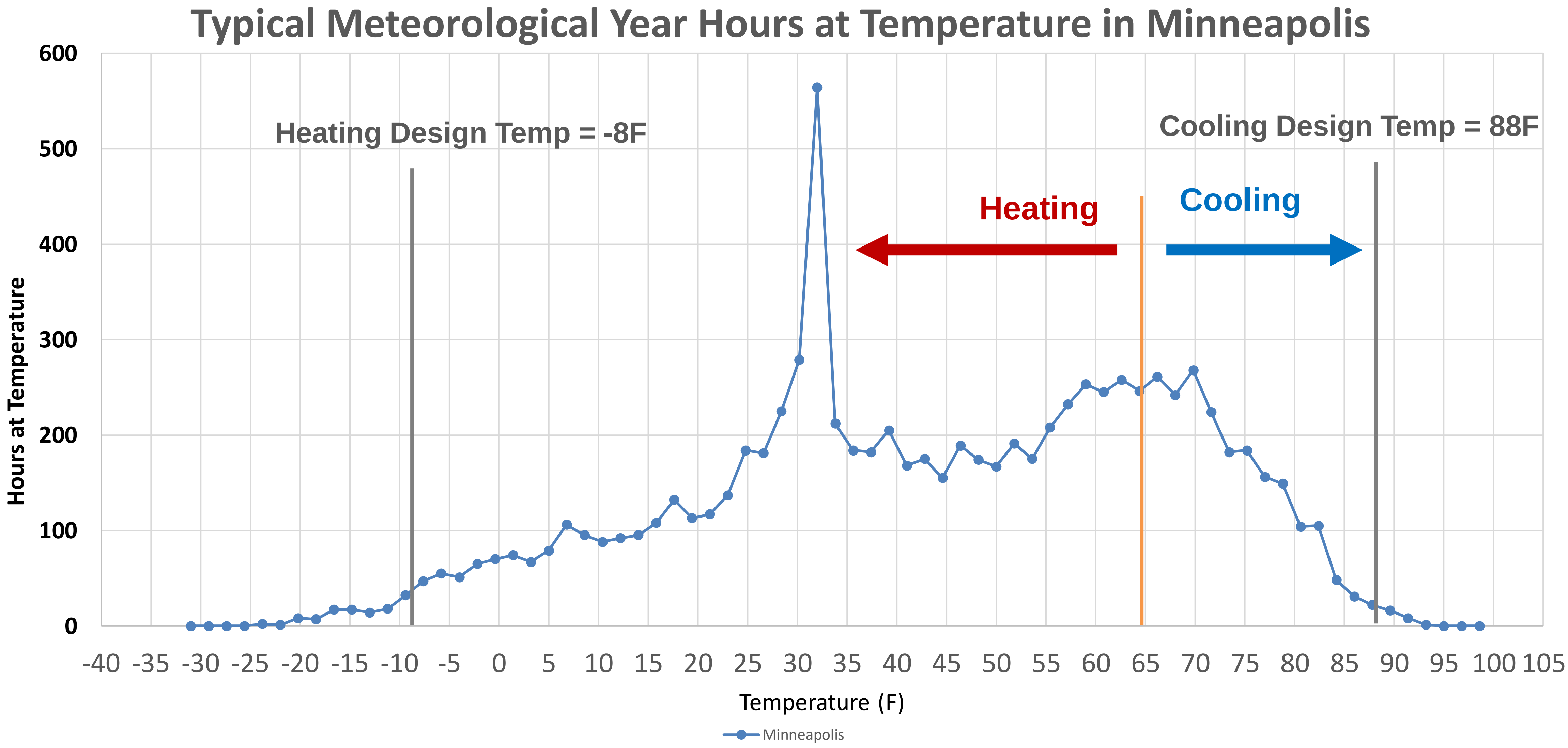
NOTE: The impact of Duct Leakage to Outside is larger than what is reflected in Manual J calculations. More on this topic later in the presentation.

Minneapolis "Leaky House"

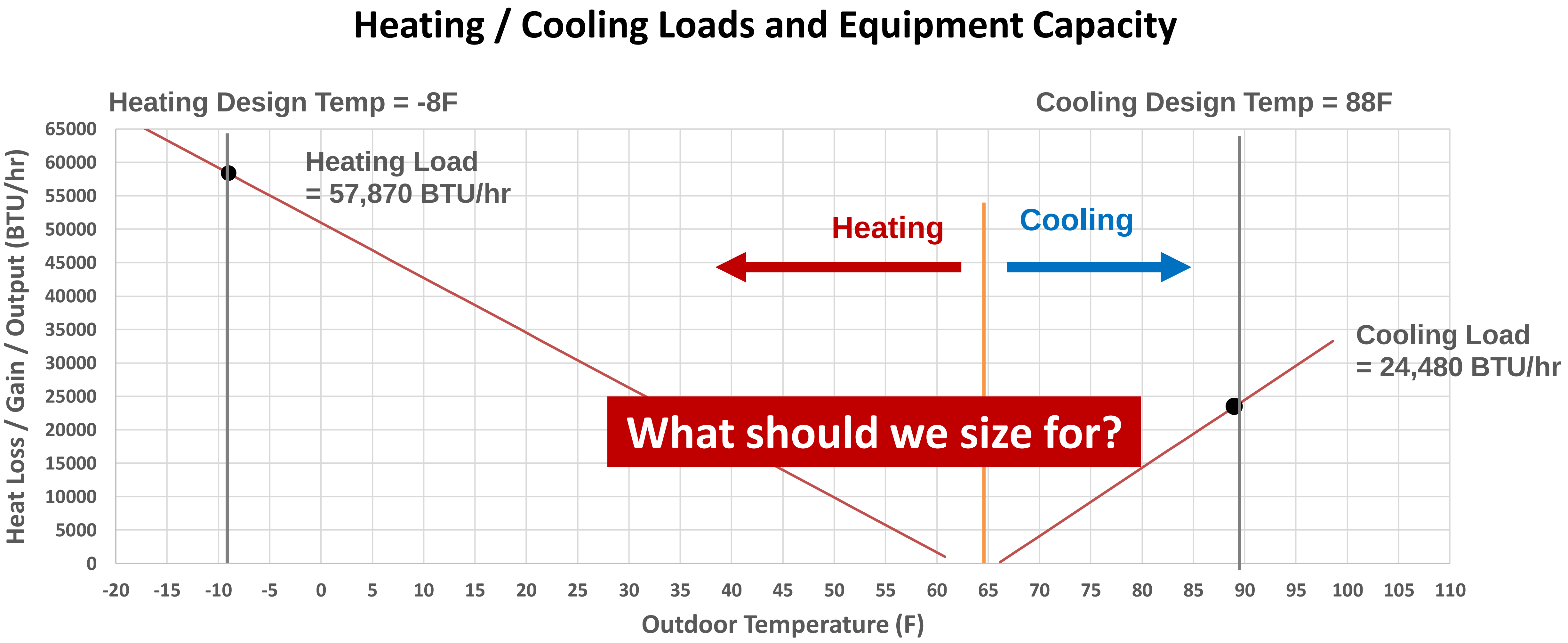
Heating / Cooling Loads and Equipment Capacity



Example Minneapolis House



Minneapolis "Leaky House"

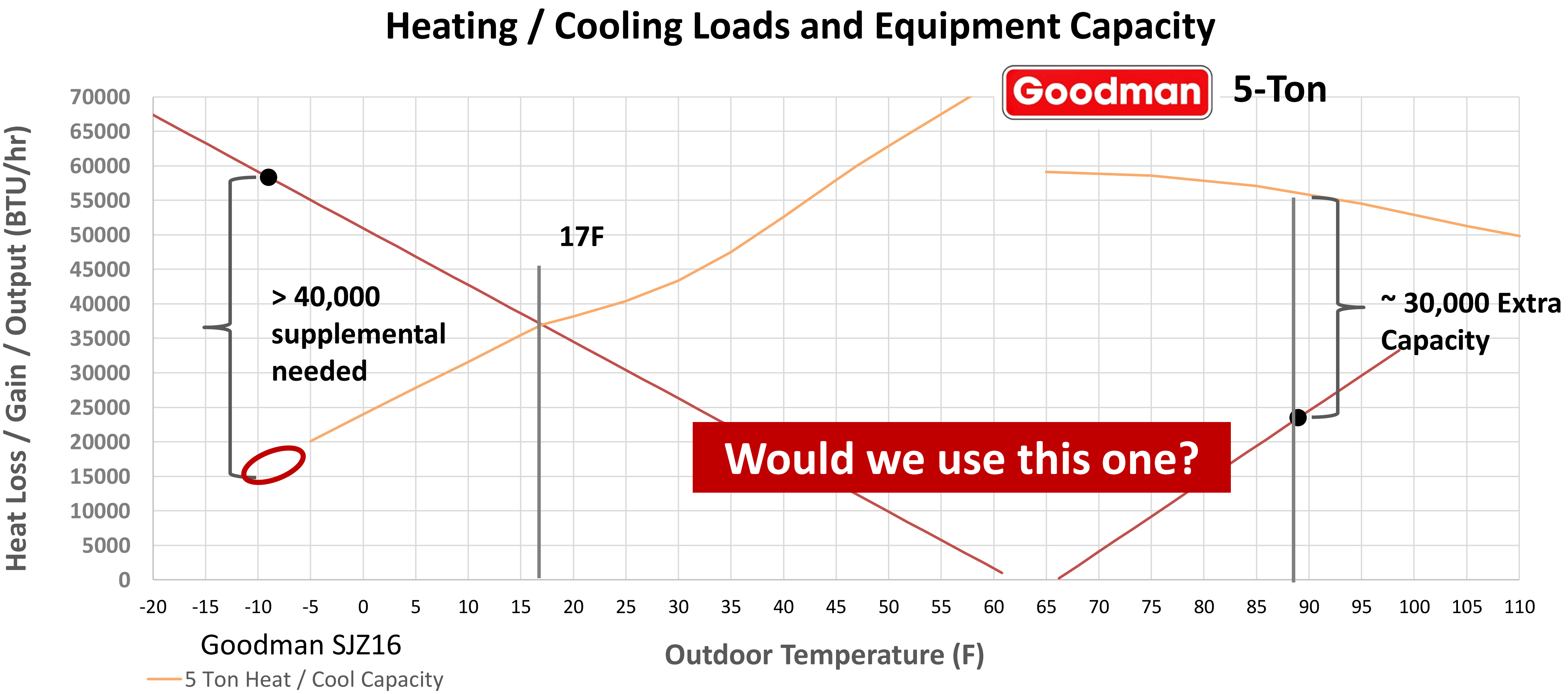


Minneapolis “Leaky House”

NEEP'S COLD CLIMATE AIR SOURCE
Heat Pump List

- Size a standard heat pump
- Size a cold climate heat pump

Minneapolis “Leaky House”



Thermal vs. Economic Balance Points

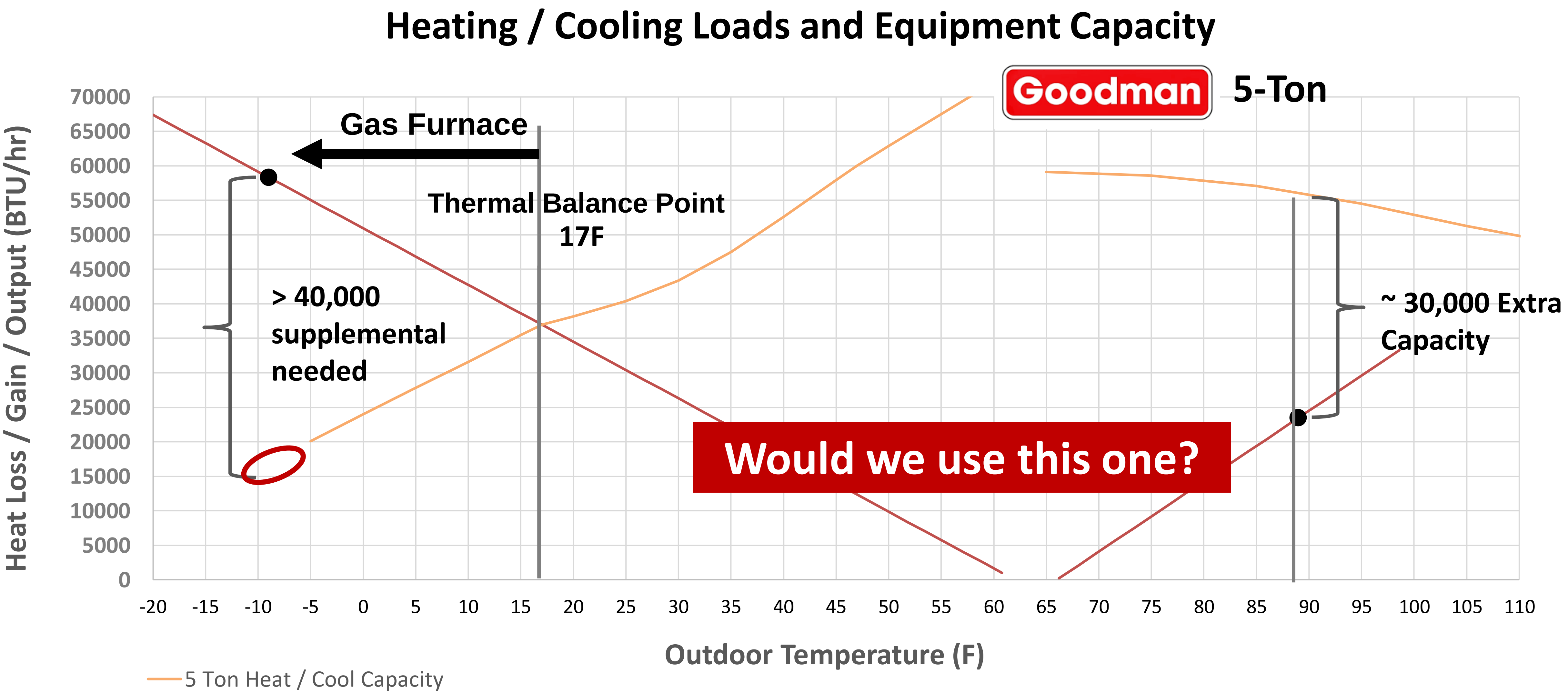
Thermal Balance Point

- **Lowest temperature at which the heat pump produces enough heat to cover the load.**
- Below the thermal balance point, supplemental heat is required
- Depends on what heat pump is selected to cover the load of the specific house

Economic Balance Point

- **Lowest temperature the heat pump is more cost-effective than an alternative heat source**
- Below the economic balance point, another heat source is more cost-effective
- Depends on the COP of the heat pump (which is dynamic with temperature) and the local cost of electricity and other heat sources (Natural Gas, Propane, electric resistance)

Minneapolis "Leaky House"

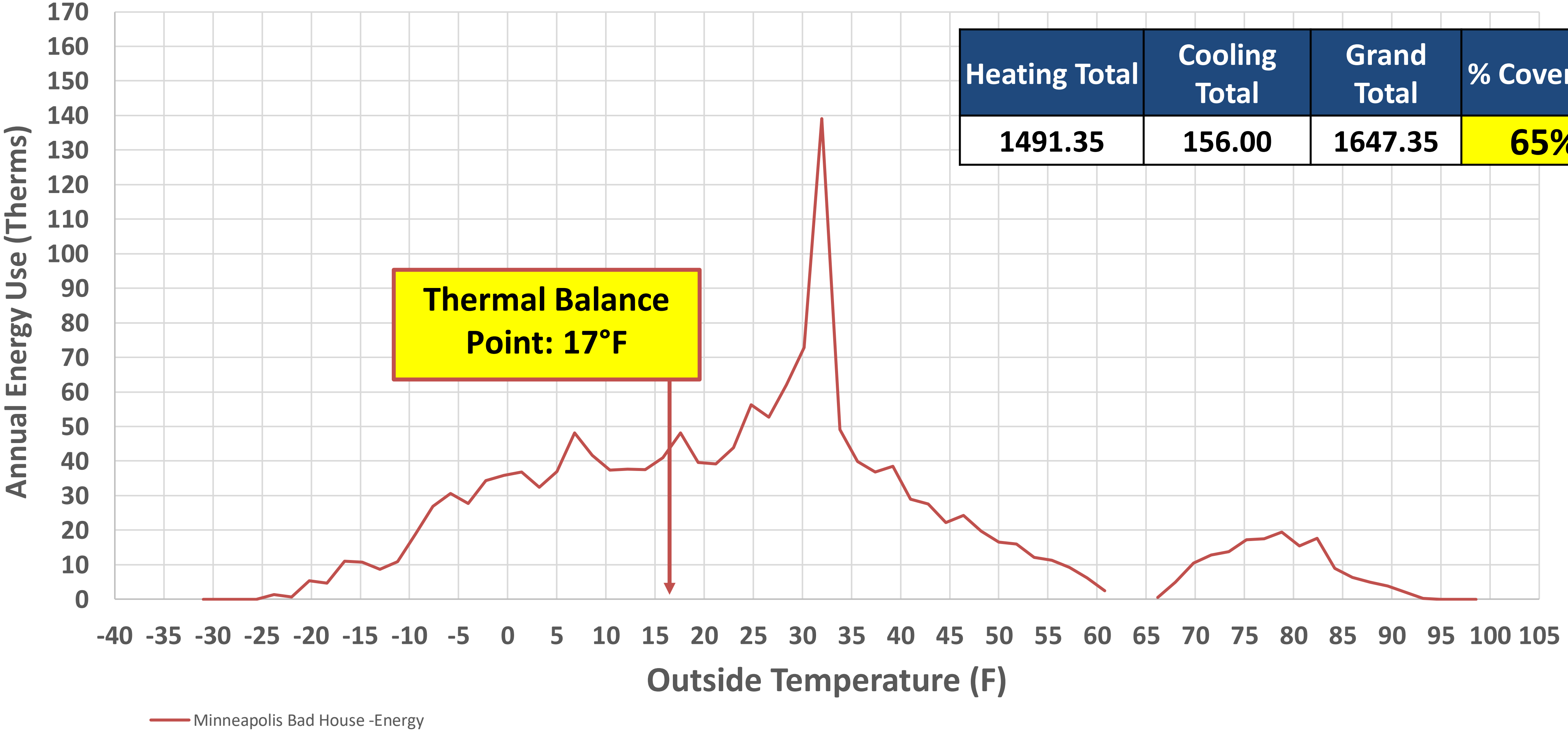


Minneapolis Leaky House

Goodman 5-Ton

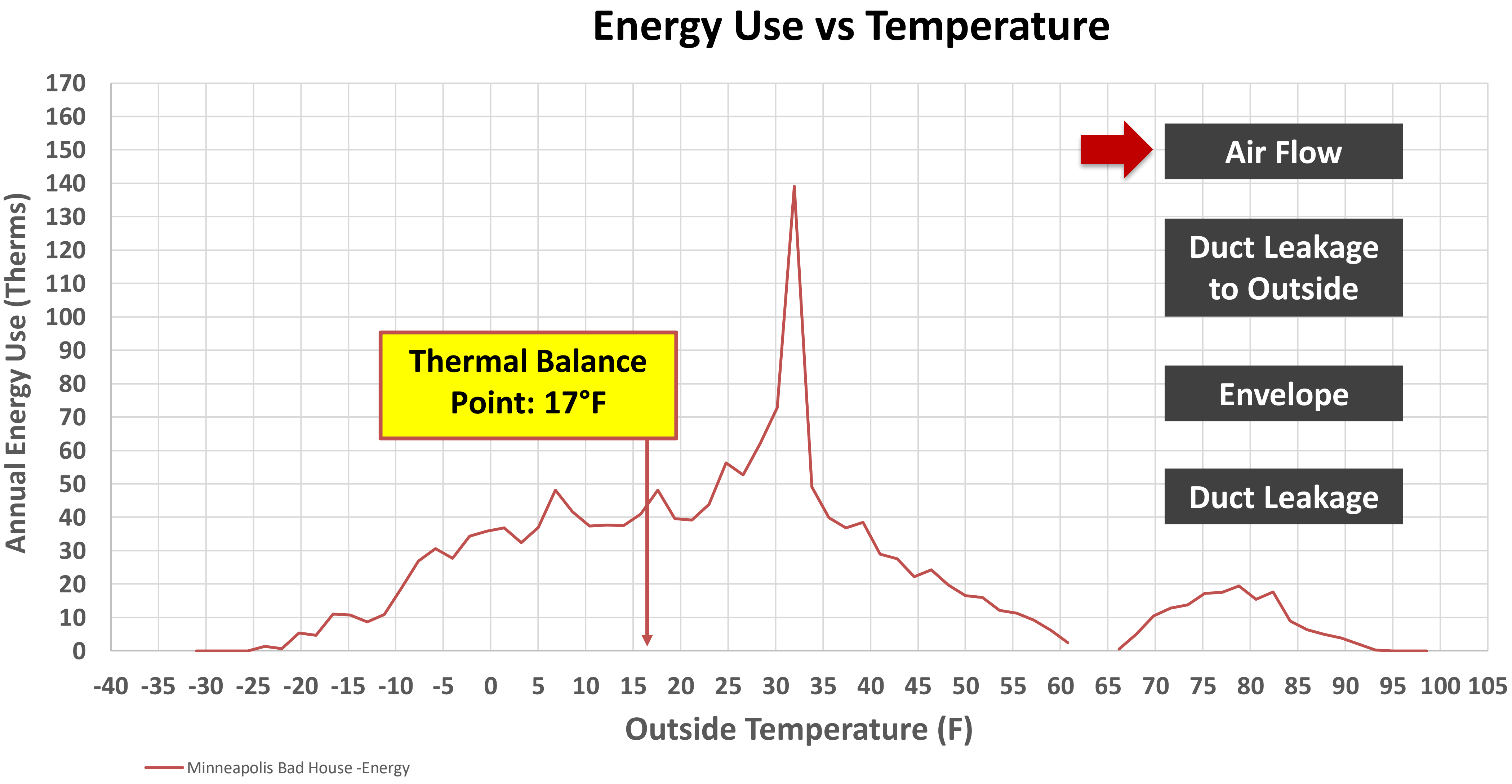
Energy Use vs Temperature

Heating Total	Cooling Total	Grand Total	% Coverage
1491.35	156.00	1647.35	65%



Minneapolis Leaky House

5-Ton



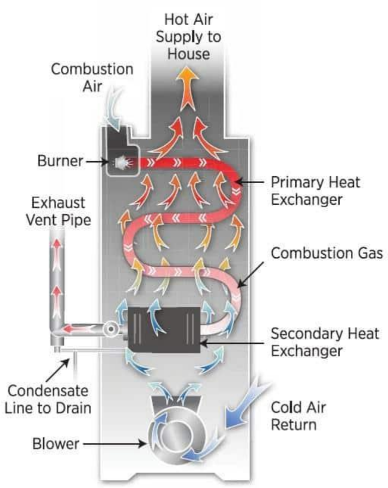
Leaky House Sizing for Heat Load

Goodman 5-Ton

Air Flow

95% Furnace

- 80,000 BTU
- Heat Rise = 35 – 50 F
- **Air flow = 800 cfm**
- **TESP = 0.8 inH2O**
- ~120 cfm/ton



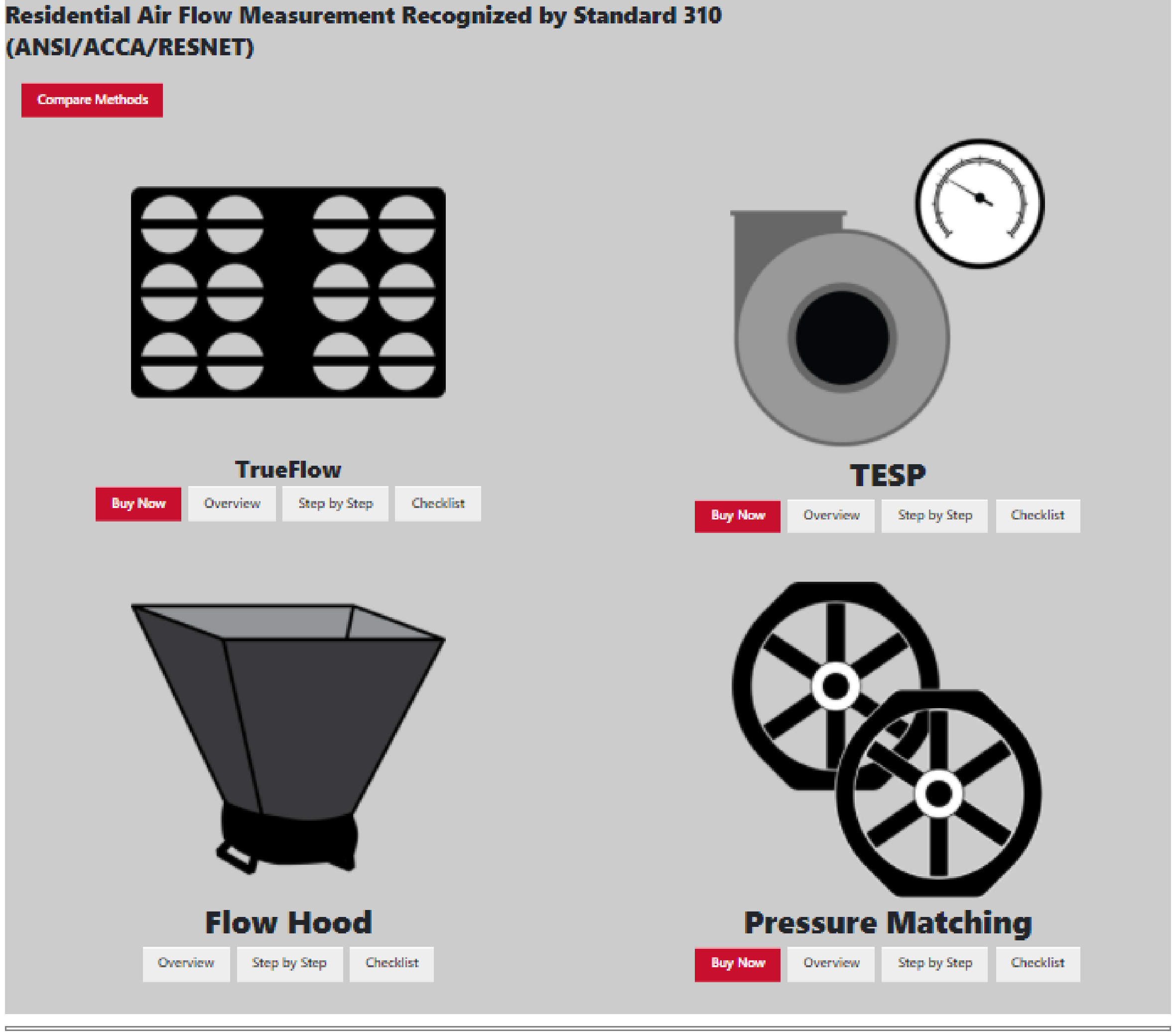
5-ton Heat Pump

- Design Heat Rise = 20 – 30 F (Typically lower than gas furnace)
- Required air flow = 2000 cfm (Typically, requires ~400 cfm/ton)
- ECM motor will try to push 2000 cfm at 5 inH2O.
  - **Won't happen.**
  - More likely to reach ~1.5 inH2O (or so) which will deliver ~1100 cfm (220 cfm/ton)
  - May hit refrigerant high-pressure limit and shut down heat pump, moving to back-up heat.

ANSI 310 Standard: Residential HVAC Systems

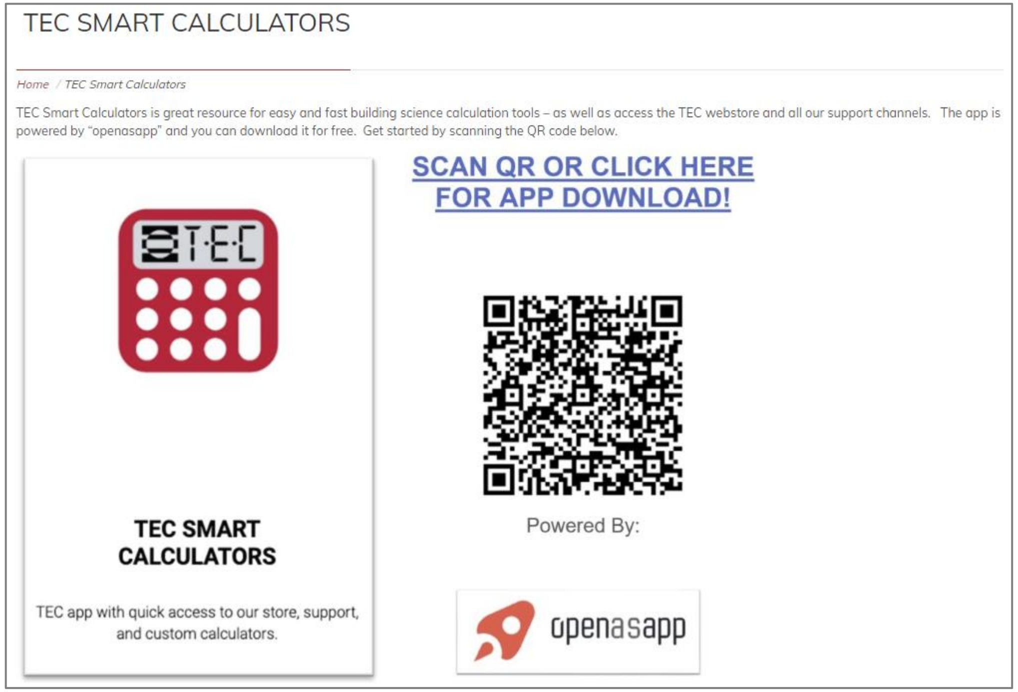
HVACAIRFLOW.com is a KEY resource

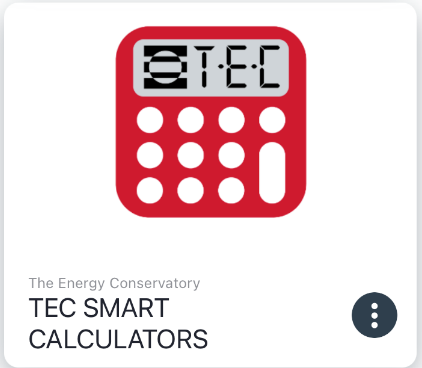
Air Flow

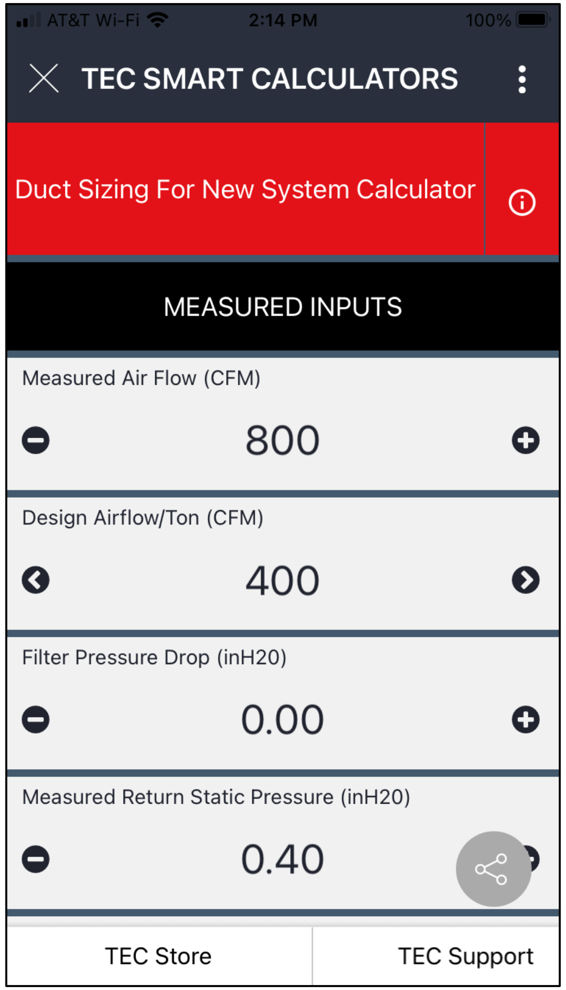


Smart Calculators Support Equipment Selection

Predicts Expected Pressure Drop for New System







Minneapolis Leaky Home with Goodman 5-ton

Success Factors	Bad Home Size for Heating
Comparable Initial Cost	Rebate
Comparable Comfort	Restricted flow limits conditioned air
Comparable Operating Cost	OK if Furnace High if electric resistance
Reduce Energy CO2 Consumption	No due to use of Nat Gas or electric resistance
Comparable Durability	ECM motor may be impacted by high static pressures

Goodman 5-Ton

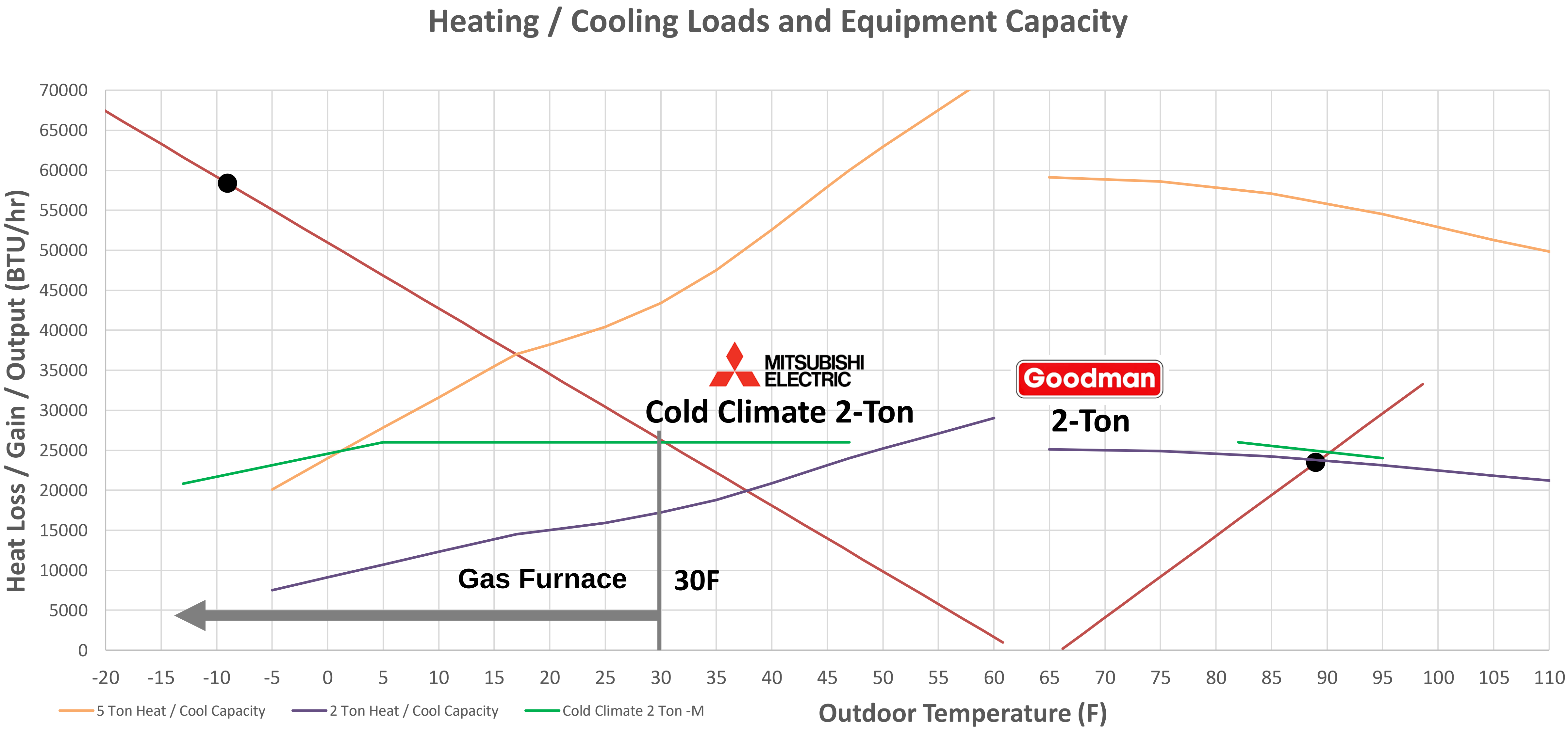
Not Successful

Requires Dual Fuel

Air Flow

Dehumidification in Cooling?

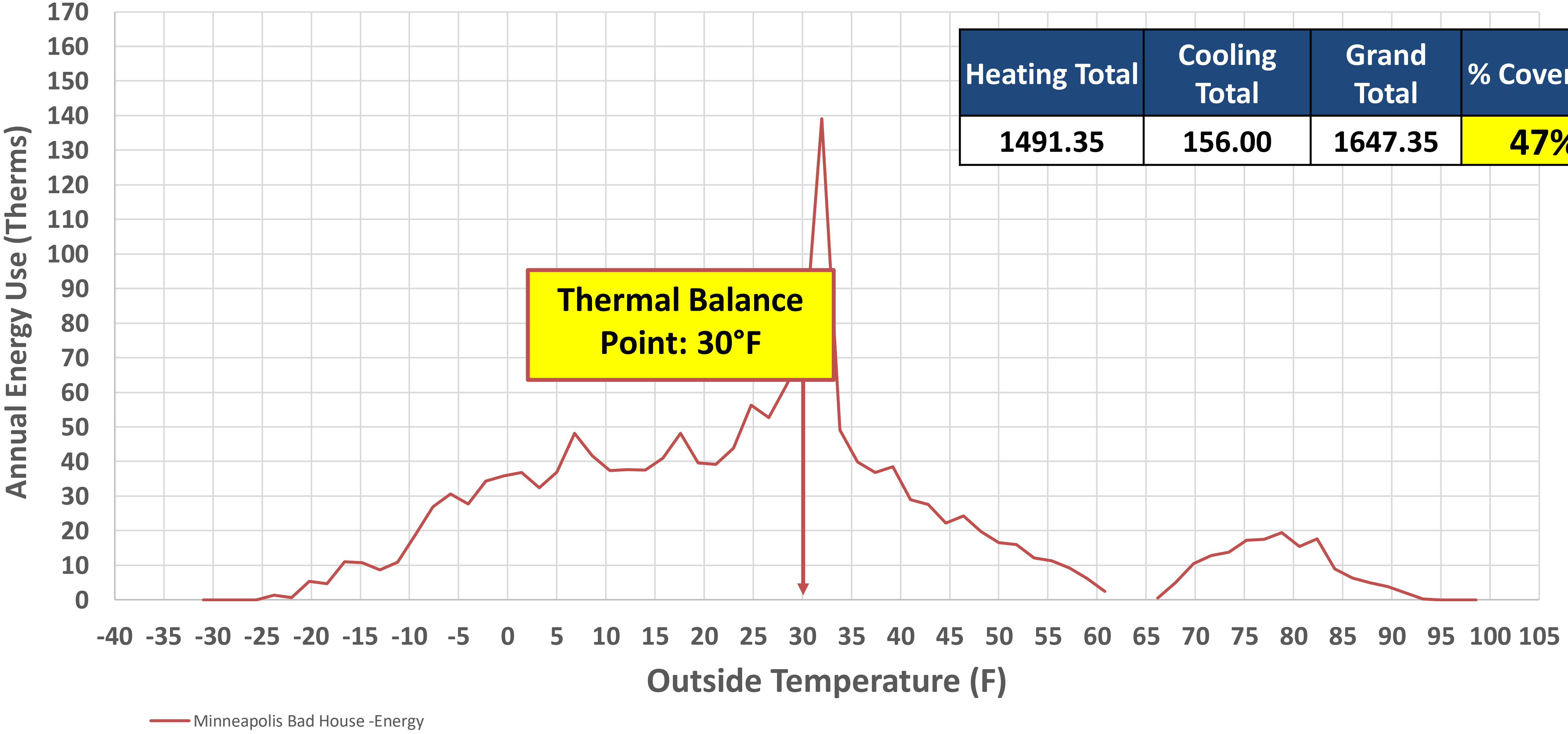
Minneapolis Leaky House – Cooling Load



Minneapolis Leaky House

MITSUBISHI ELECTRIC **CC 2-Ton**

Energy Use vs Temperature

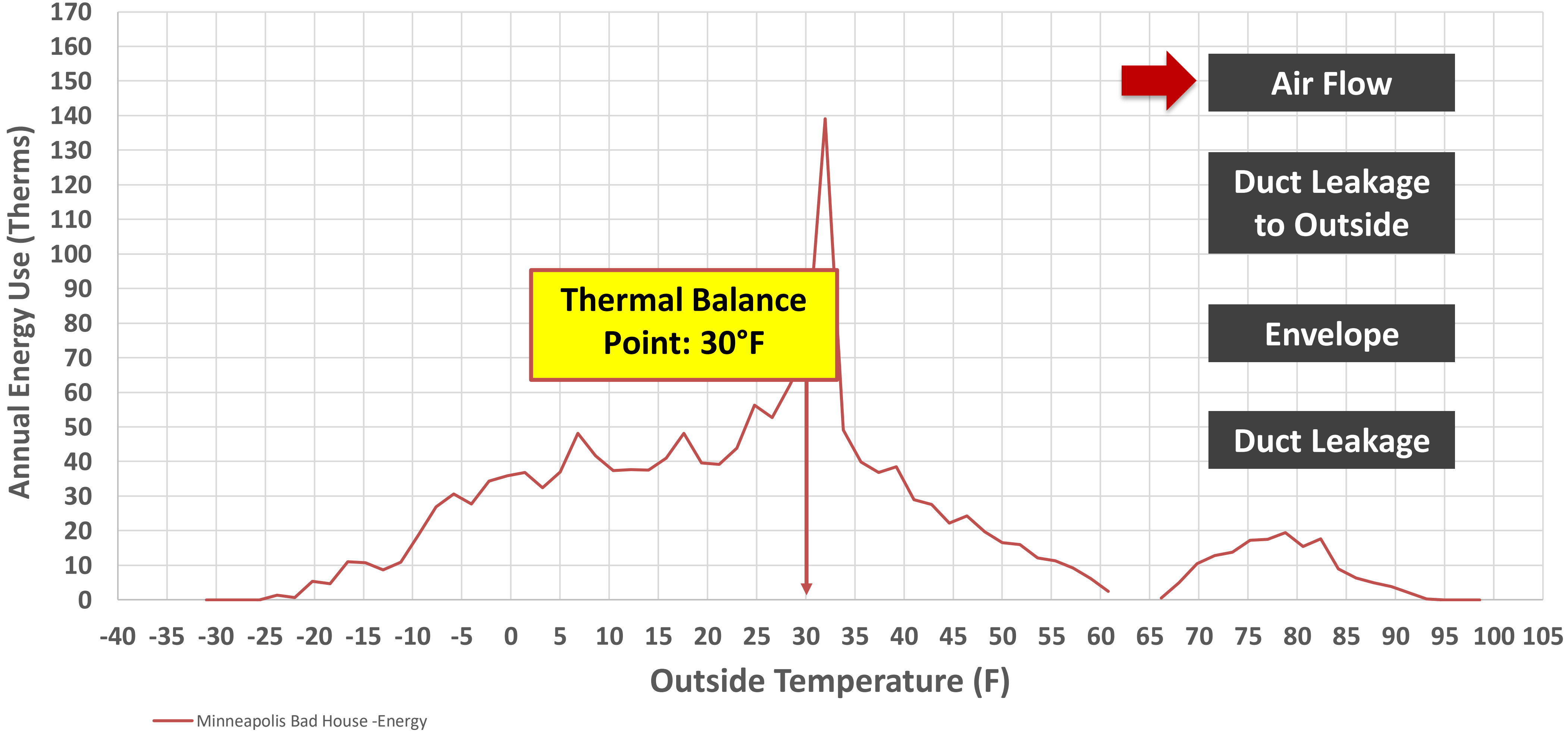


Heating Total	Cooling Total	Grand Total	% Coverage
1491.35	156.00	1647.35	47%

Minneapolis Leaky House

MITSUBISHI ELECTRIC CC 2-Ton

Energy Use vs Temperature



Sizing for Cooling Load

Air Flow

2-ton AC
- **Air flow = 800 cfm**
- **TESP = 0.8 inH2O**

2-ton Heat Pump
- Required air flow = 800 cfm (400 cfm/ton)
- TESP = 0.8 in H2O

2 Ton MITSUBISHI ELECTRIC

Cold Climate 2-Ton
COPs drop at colder temps

2-Ton Goodman

- **Higher Thermal Balance Point**
- **COPs drop at colder temps**

Minneapolis Leaky House Sized for Cooling

Success Factors	Bad Home Size for Cooling
Comparable Initial Cost	Rebate
Comparable Comfort	Heat pump for AC, Leave Furnace for Heat
Comparable Operating Cost	Maybe - depending on COP, Gas & Electricity rates
Reduce Energy CO2 Consumption	Still using Nat Gas for most of the heat load
Comparable Durability	ECM motor may be impacted by high static pressures

MITSUBISHI ELECTRIC Cold Climate 2-Ton

Goodman 2-Ton

Typically, Successful

Example Minneapolis House

Let's Size a Heat Pump for Success!

Retrofit

- 1 Story, ~1500 Sq Ft Home
- 95% Gas Furnace, 2-ton AC

Success Factors
Comparable Initial Cost
Comparable Comfort
Comparable Operating Cost
Reduce Energy CO2 Consumption
Comparable Durability

Air Flow

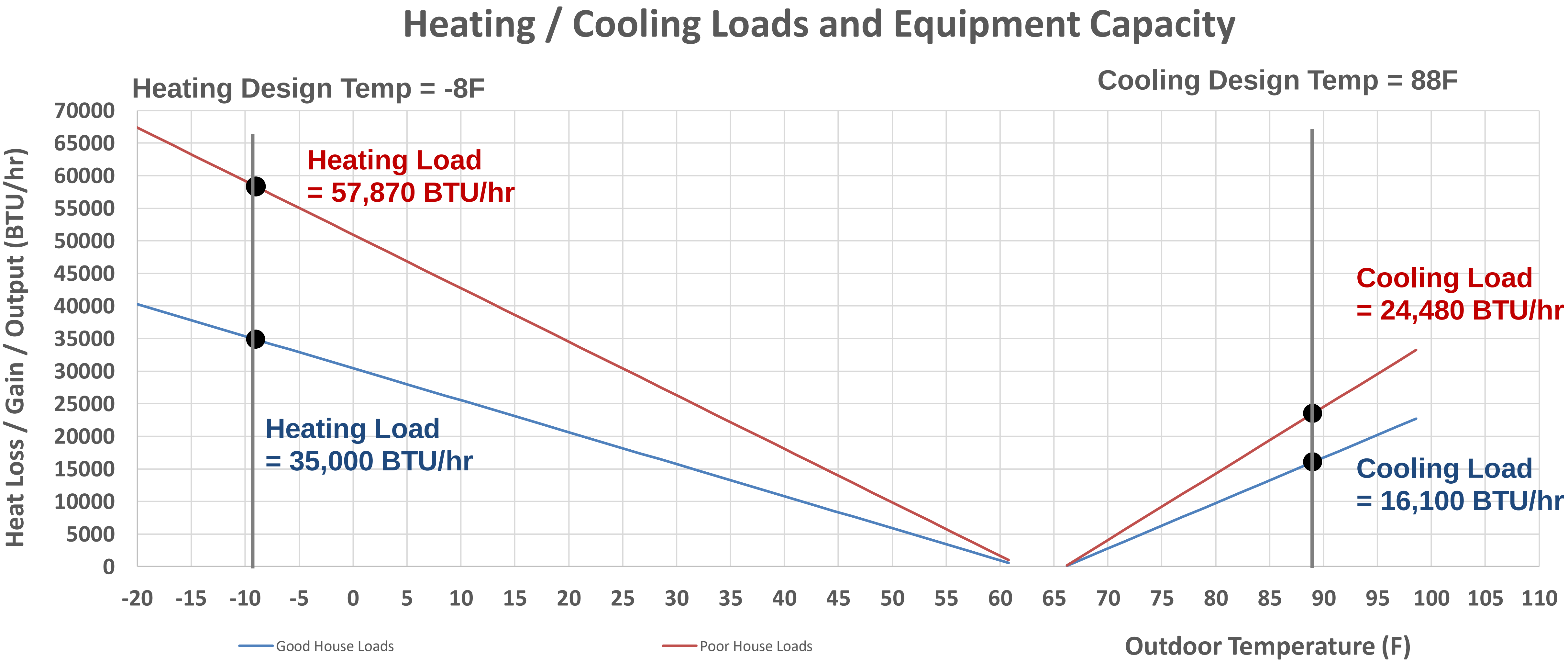
Duct Leakage to Outside

Envelope

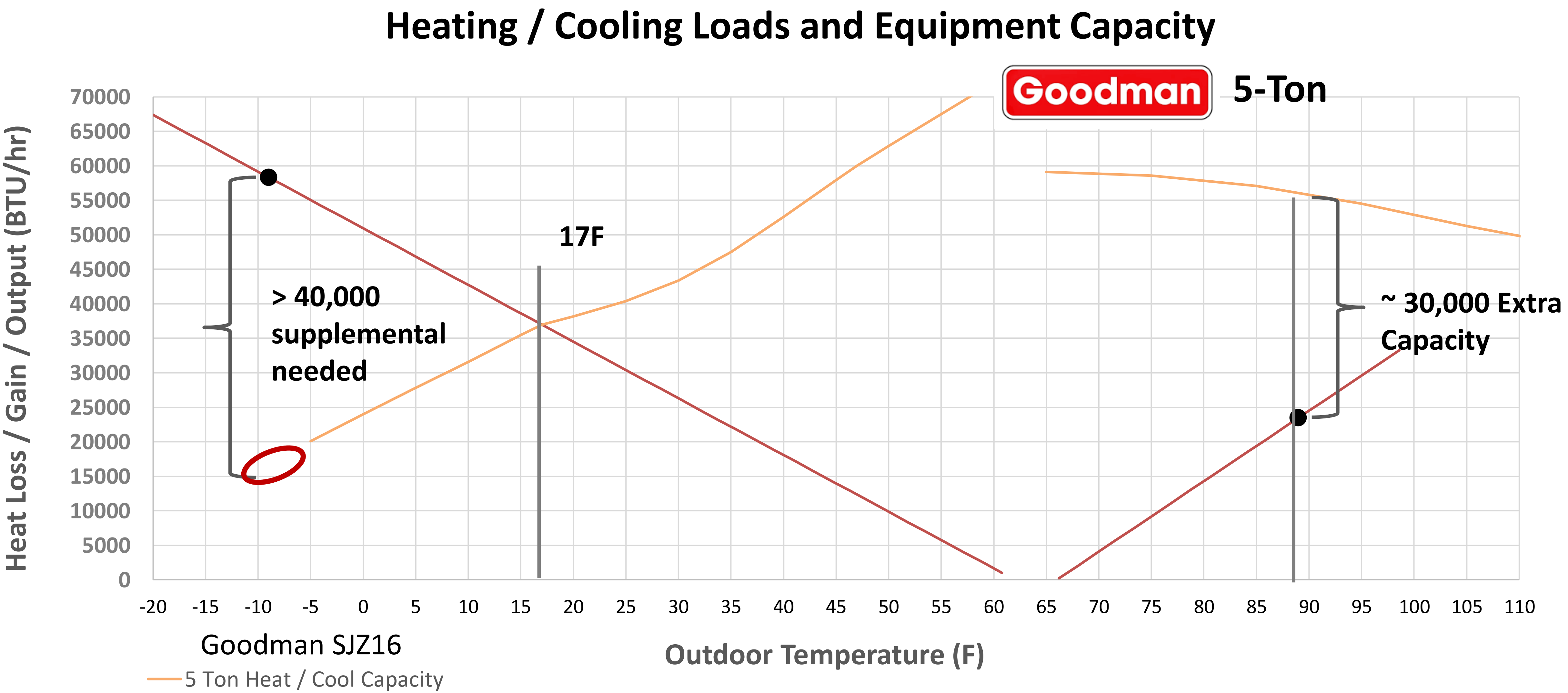
Duct Leakage

Versions	Envelope	HVAC TESP	HVAC Air Flow (heat)	Duct Leakage to Outside
Leaky House	11 ACH50	0.8 inH2O	800 cfm	8%
Tight House	2 ACH50	0.5 inH2O	1000 cfm	0%

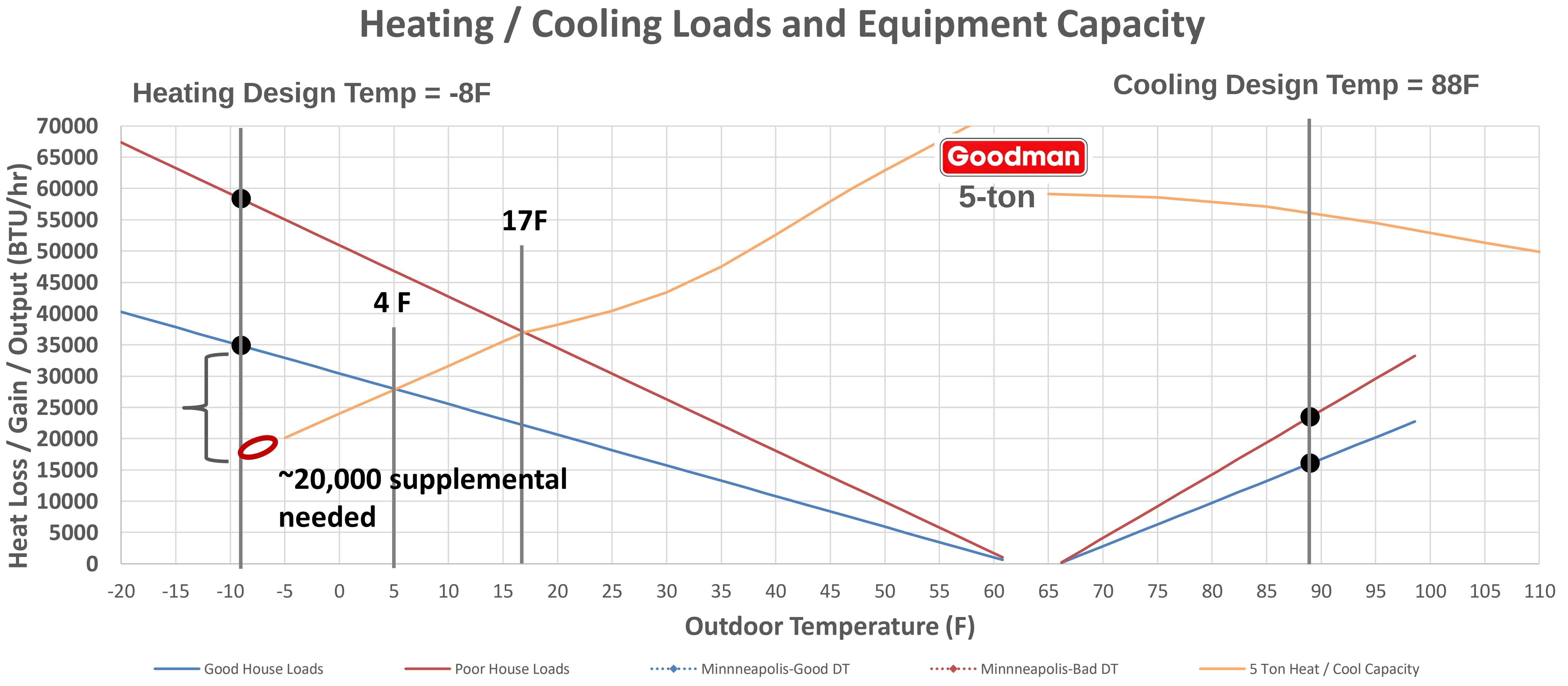
Minneapolis Tight House



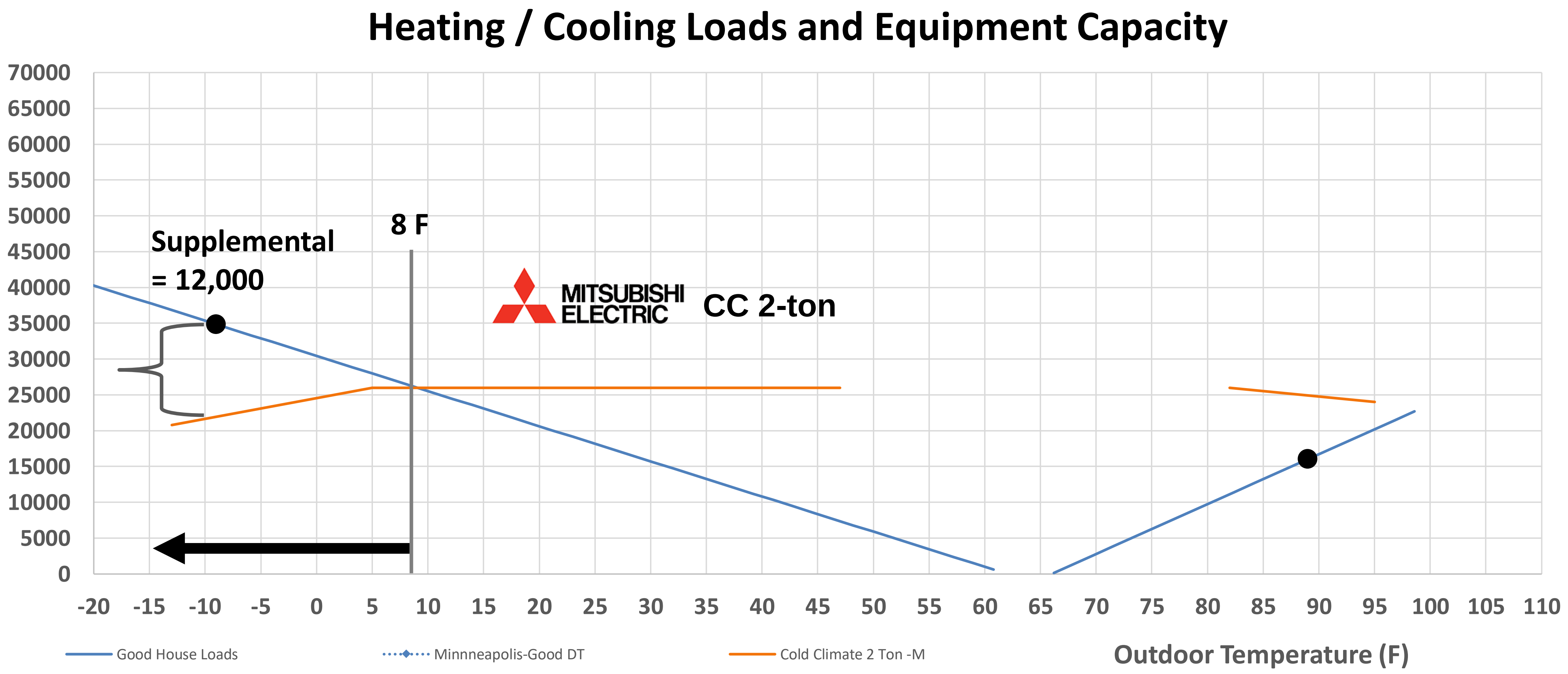
Minneapolis “Leaky House”



Minneapolis Tight House



Minneapolis Tight House

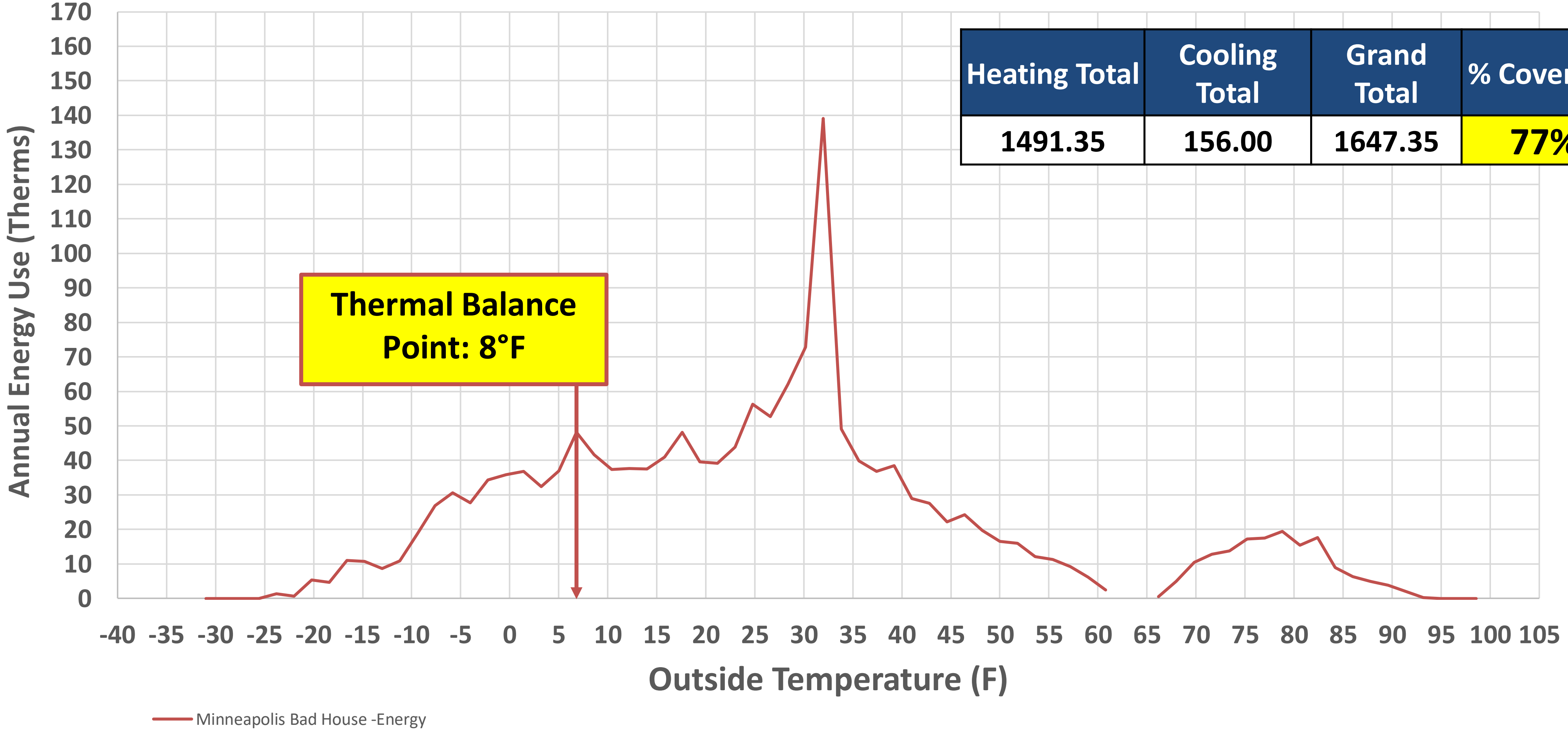


Minneapolis Tight House

MITSUBISHI ELECTRIC

CC 2-ton

Energy Use vs Temperature



Heating Total	Cooling Total	Grand Total	% Coverage
1491.35	156.00	1647.35	77%

Example Minneapolis Home

Success Factors	Good Home Size for Heating
Comparable Initial Cost	Rebate
Comparable Comfort	Probably, depends on ability to support air flow in existing ducts
Comparable Operating Cost	Possible, depends on gas & elec costs and use of electric resistance
Reduce Energy CO2 Consumption	Probably, depends on use excessive electric resistance
Comparable Durability	Reasonable static pressures

MITSUBISHI ELECTRIC

CC 2-ton

Probably Successful

Example Minneapolis House

Let's Size a Heat Pump for Success!

Retrofit

- 1 Story, ~1500 Sq Ft Home
- 95% Gas Furnace, 2-ton AC

Success Factors
Comparable Initial Cost
Comparable Comfort
Comparable Operating Cost
Reduce Energy CO2 Consumption
Comparable Durability

- Air Flow
- Duct Leakage to Outside
- Envelope
- Duct Leakage

Versions	Envelope	HVAC TESP	HVAC Air Flow (heat)	Duct Leakage to Outside
Leaky House	11 ACH50	0.8 inH2O	900 cfm	8%
Tight House	2 ACH50	0.5 inH2O	1000 cfm	0%
Gary's Home	1 ACH50	0.5 inH2O	600 cfm	0%

Minneapolis House

Versions	Envelope	HVAC TESP	HVAC Air Flow (heat)	Duct Leakage to Outside
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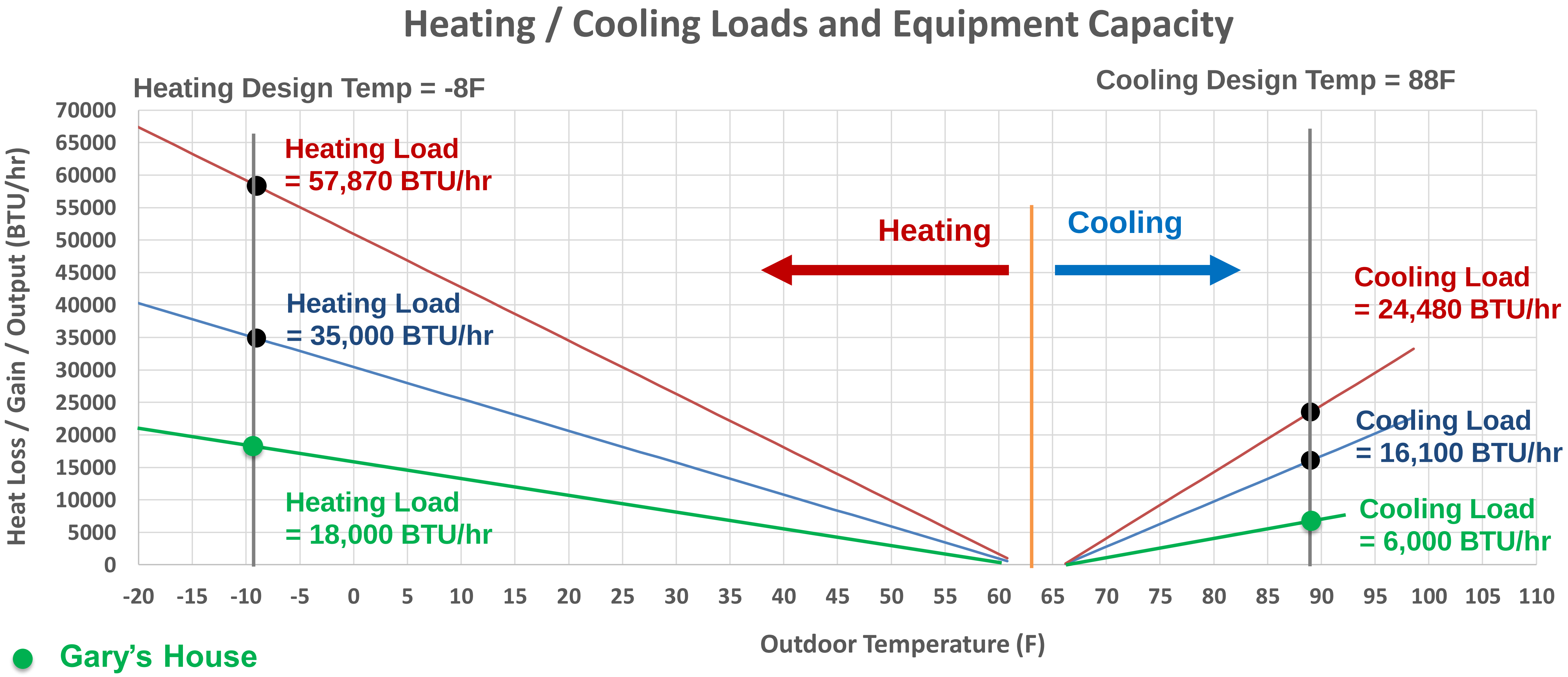

Minneapolis House

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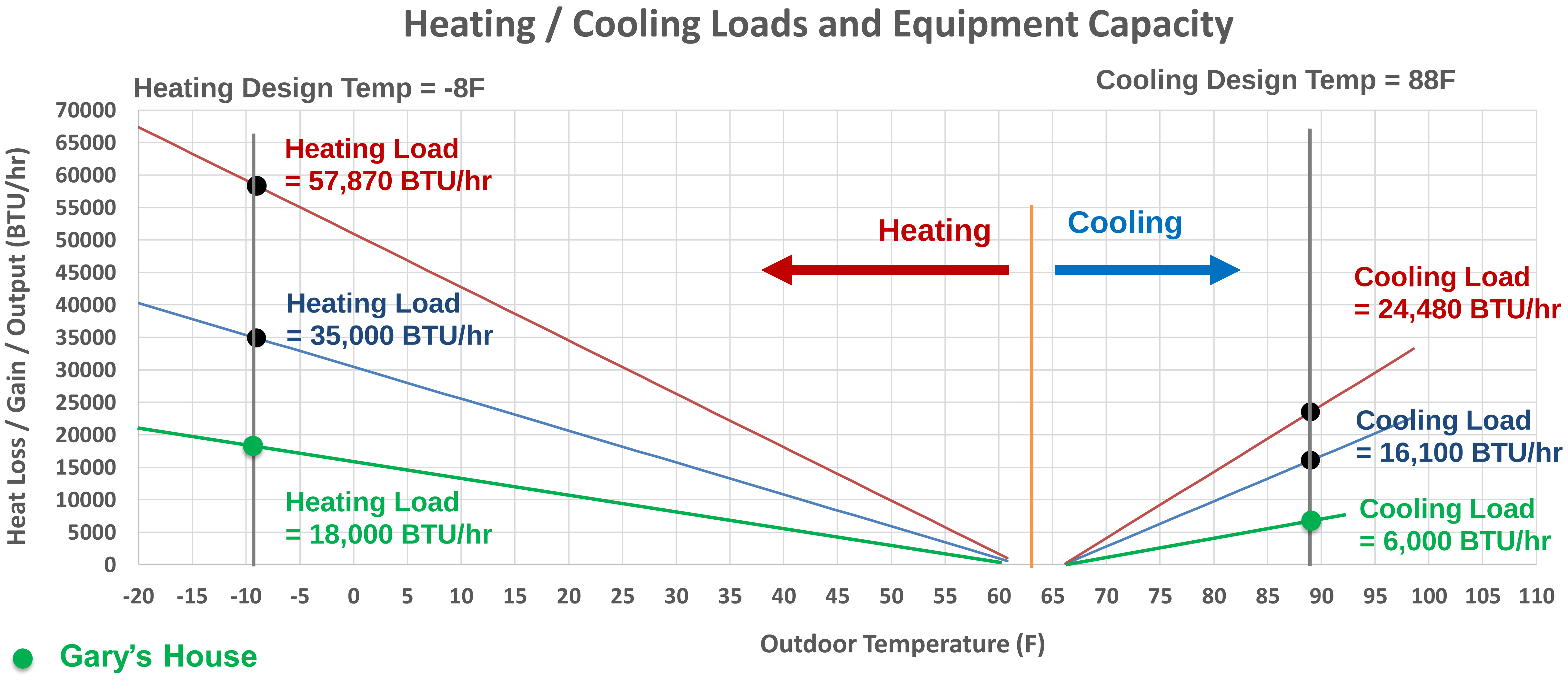
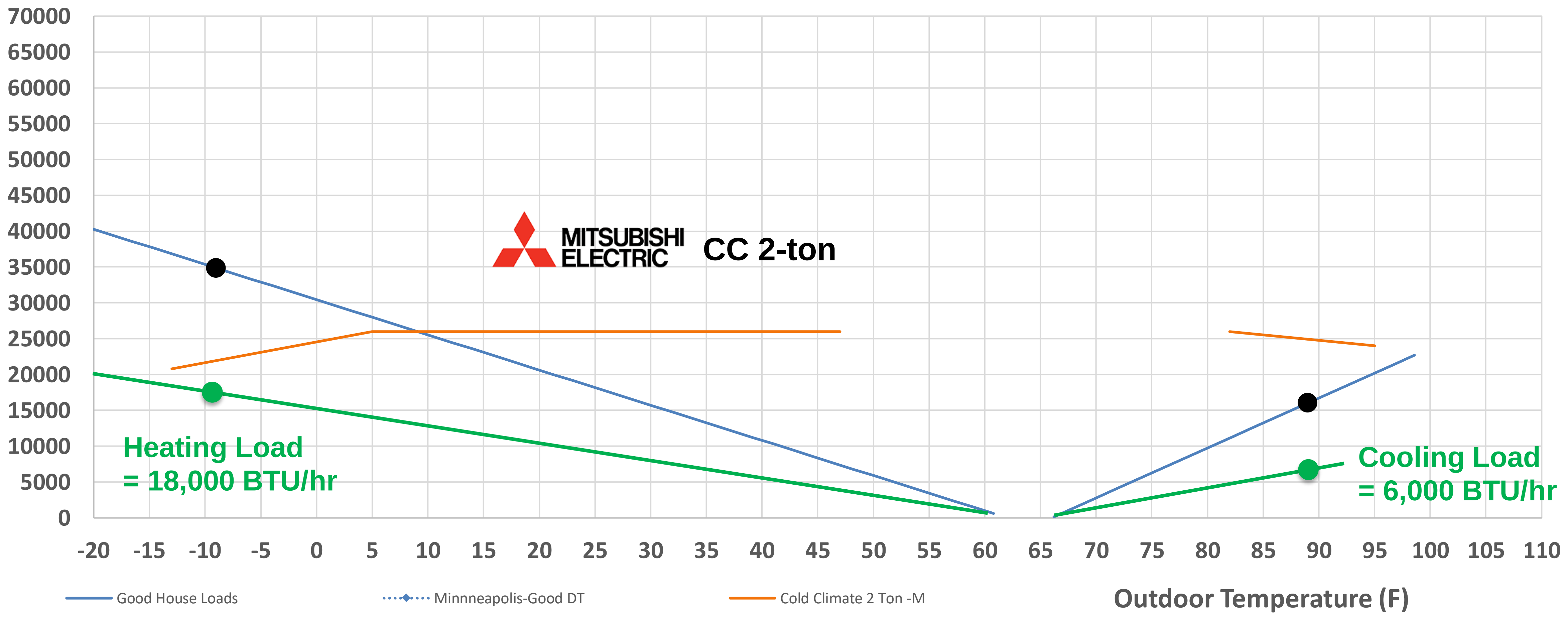


Minneapolis Tight House

Heating / Cooling Loads and Equipment Capacity



Agenda

- Intro: Success with a 1.5-ton heat pump in Minnesota
- Why Cold Weather Heat Pumps?
- Sizing a Heat Pump for Success
    - Minneapolis Example
        - Impact of Air Flow
        - Impact of Building Envelope
        - Impact of Ductwork
- How to Achieve Good Envelope and Ducts
- Final thoughts & Summary

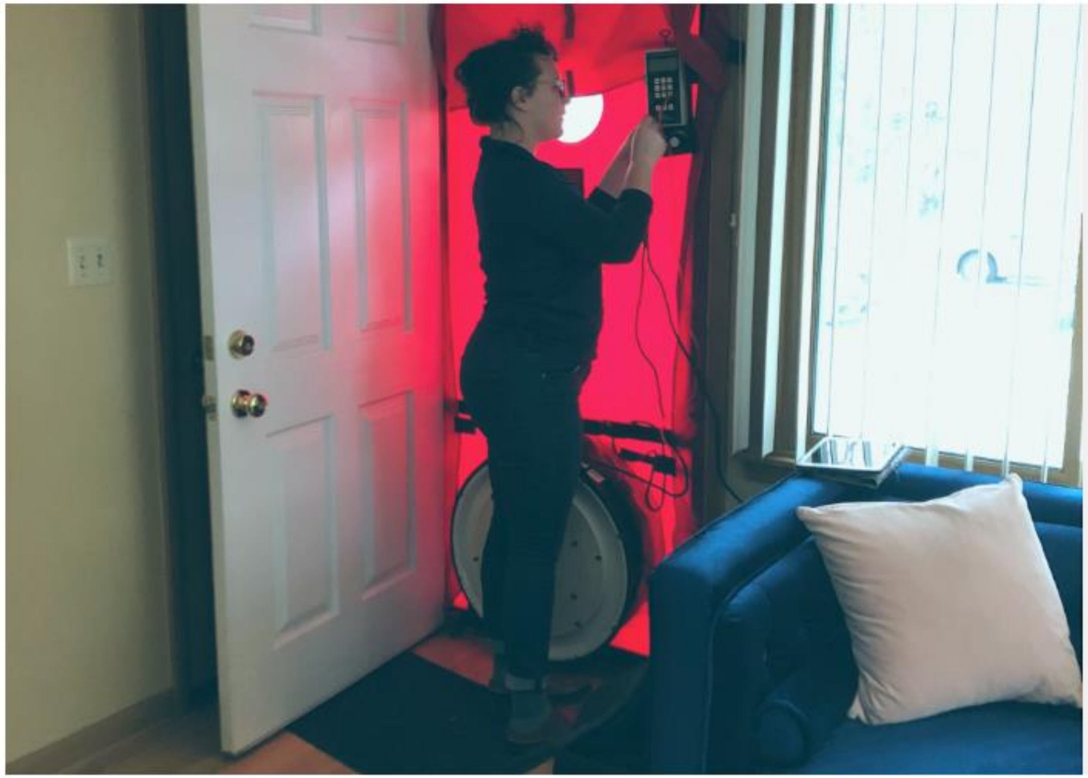
Making a House More Energy Efficient

HOME ENERGY SQUAD

Xcel Energy

CenterPoint Energy

We make saving energy easy.



"The team we had were great! They were quiet, respectful, professional, and very thorough. We couldn't be happier with their service and will recommend the Home Energy Squad to friends and neighbors."

— Bill, Mound Resident

How to Know if it is a "Bad House" or a "Good House"

Process
Diagnose Issues
Create Work Scope
Take Actions
Verify Results/QC

Diagnose Issues – Deciding What Steps are Valuable

Detailed Steps	Scope	Goal for Diagnosis
Investigate / walk property	✓	Should always take the time to walk the property inside & outside to note dimensions and note key observations
Thermography w/o BD	✓	If ΔT = 10F, can help ID potential lack of insulation
Thermography w/BD	✓	If ΔT = 10F, can help ID specific air leakage locations
Blower Door Test	✓	Provides total envelope leakage
Zonal Pressure Diagnostic	✓	Prioritizing where fixing leaks will provide most benefit
ID leaks using a Fog Puffer	✓	ID leaks around weather stripping, windows, doors, recessed lights, baseboards, leaks in ducts (even if insulated)
Investigate zones (Attic)	✓	Confirm suspected leaks prior to scoping work
Assess Ductwork (Leakage, Leakage to Outside)	✓	Biggest concern if Ducts Outside Envelope. If all ductwork inside envelope, occupant complaints should determine if investigation is needed.
HVAC Air Flow, TESP, Filtration	✓	Ensure energy saving opportunities and CAZ safety concerns are identified

Home Performance Upgrade Project

TEC and Seelen Advanced Weatherization






How to Turn a Bad House into a Good House

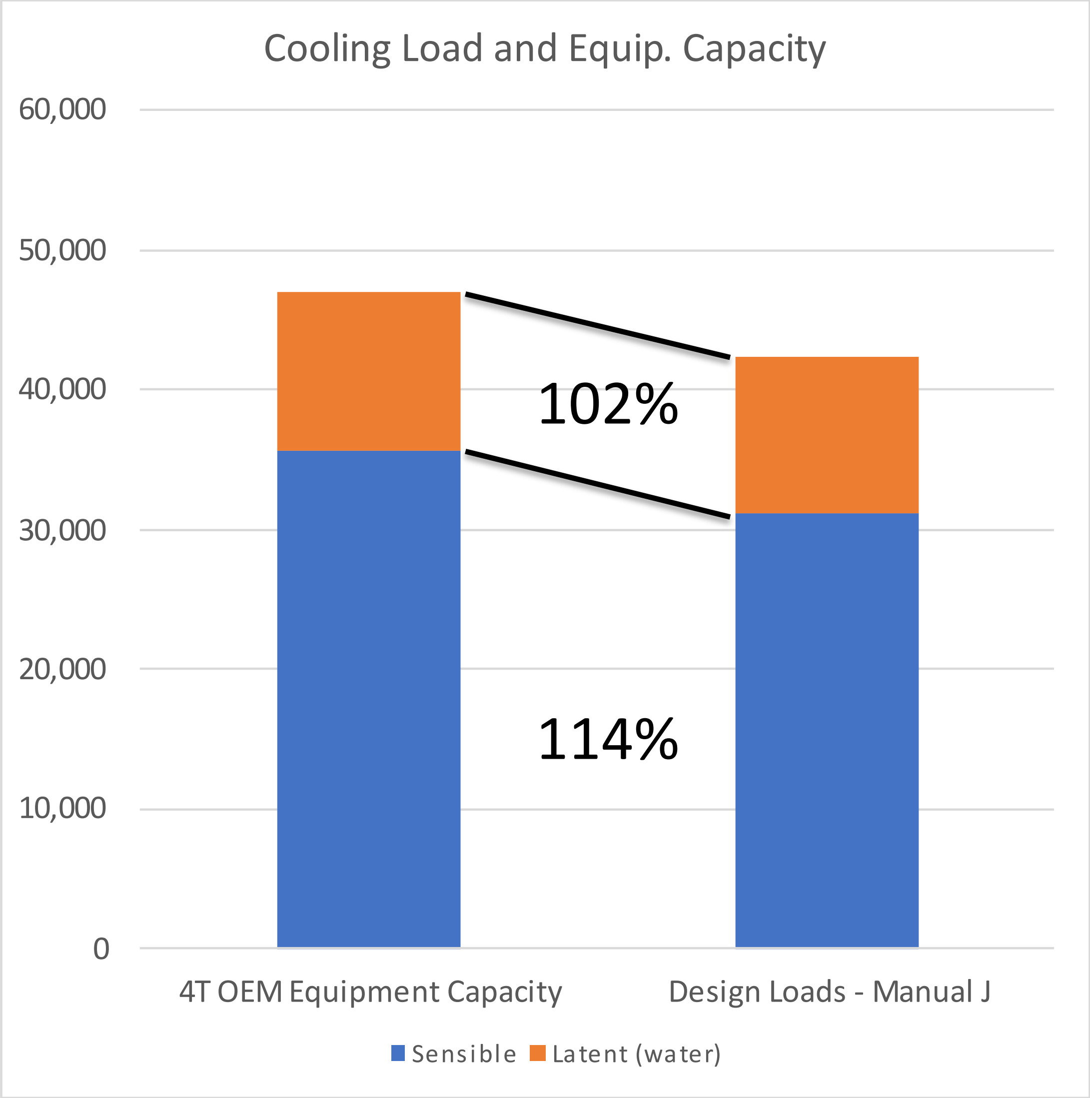
When Does Duct Leakage Matter?

- Our example showed NO duct leakage since they were all inside envelope
- The big concern is when there are ducts outside the envelope
- When they are – this is a BIG Concern…

MIAMI CASE STUDY – UNCOMFORTABLE HOME

Confirm Manual J Calc Results

Existing system is correctly sized – almost exactly

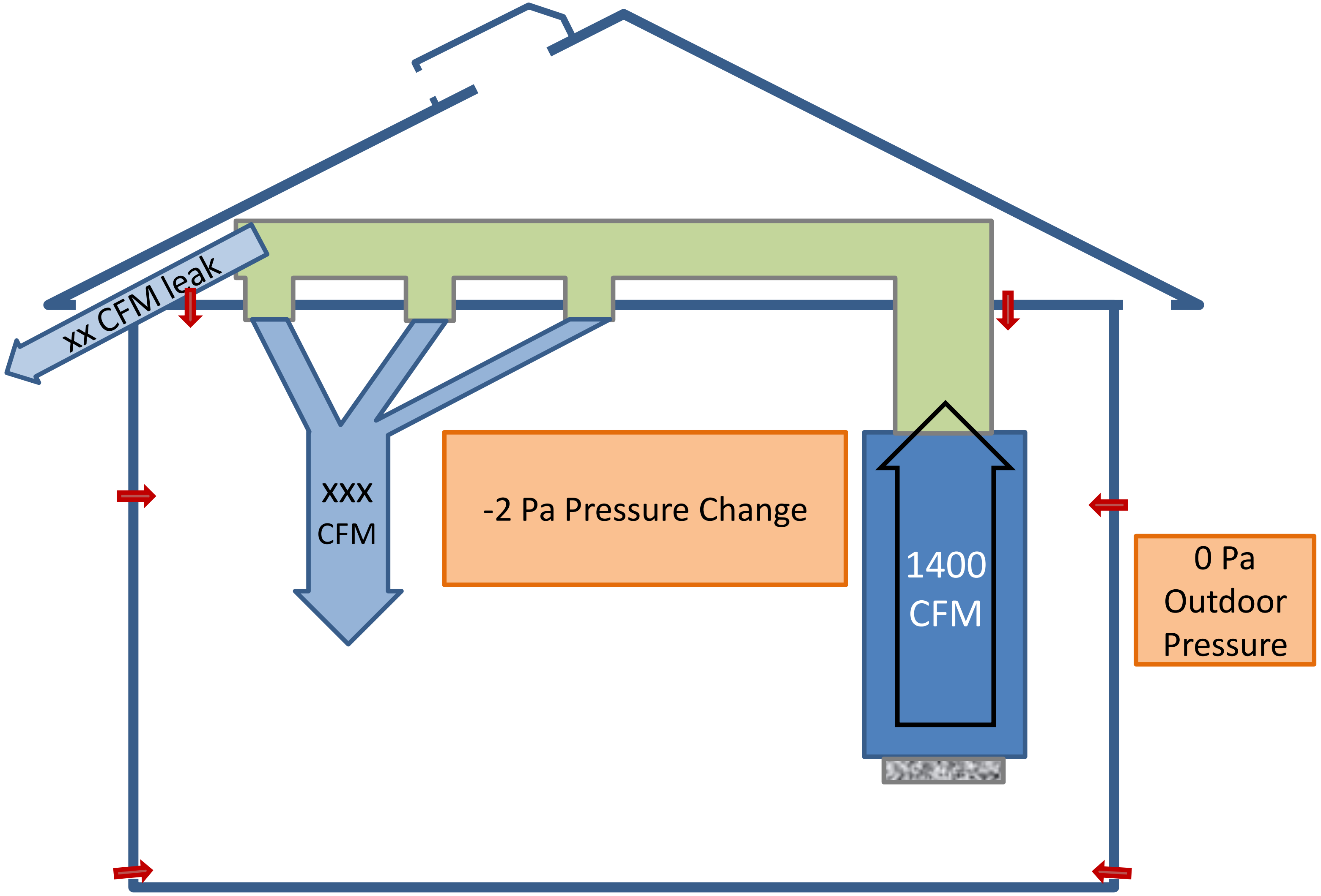


MIAMI CASE STUDY SUMMARY SO FAR

House is depressurizing by 2Pa (0.008 inH2O) when HVAC is turned on

Caused by duct leakage

- Depressurizing means most of leakage is in supply duct



MIAMI CASE STUDY SUMMARY SO FAR

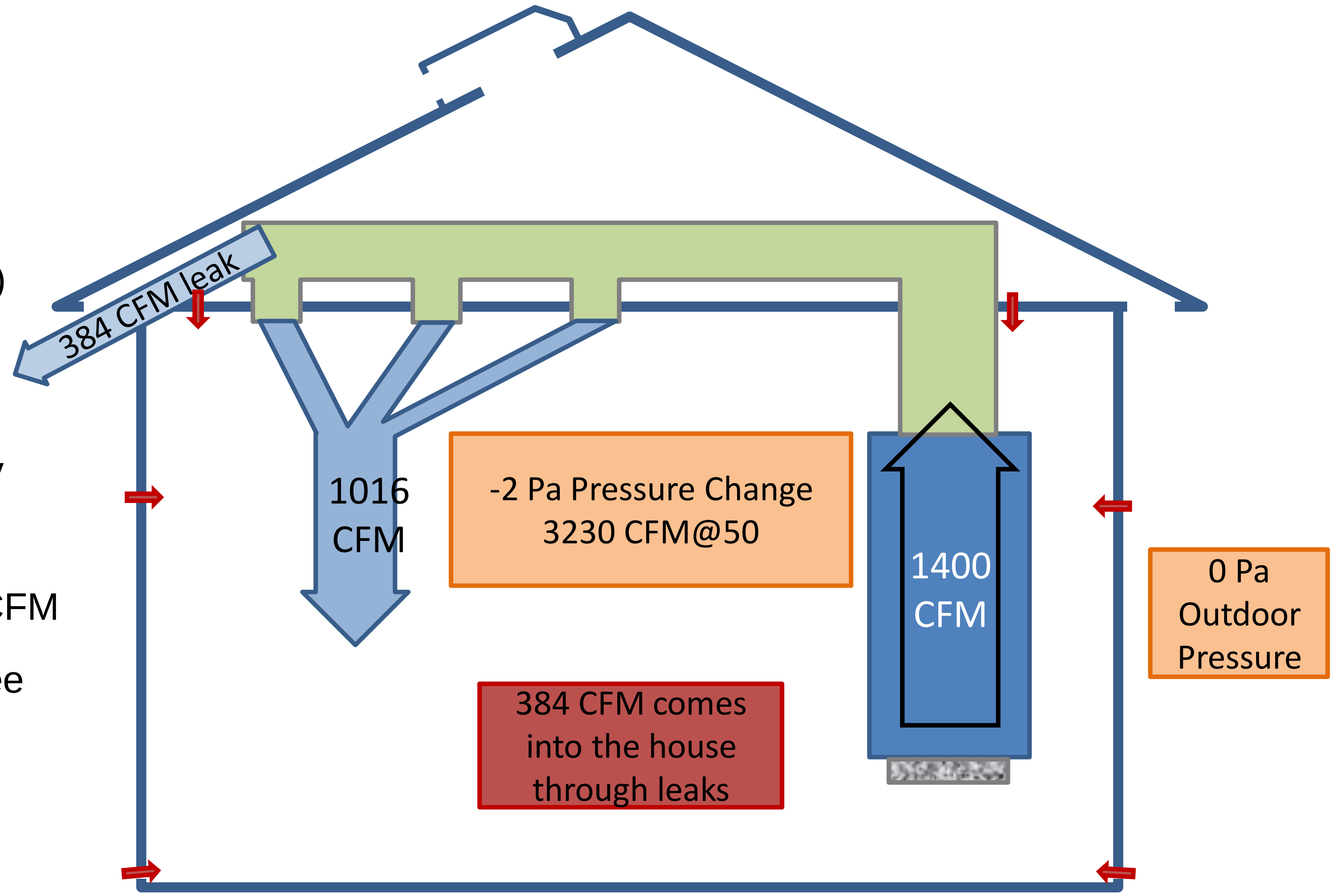
House depressurizing by 2Pa (0.008 inH2O) when HVAC is turned on

This is caused by duct leakage

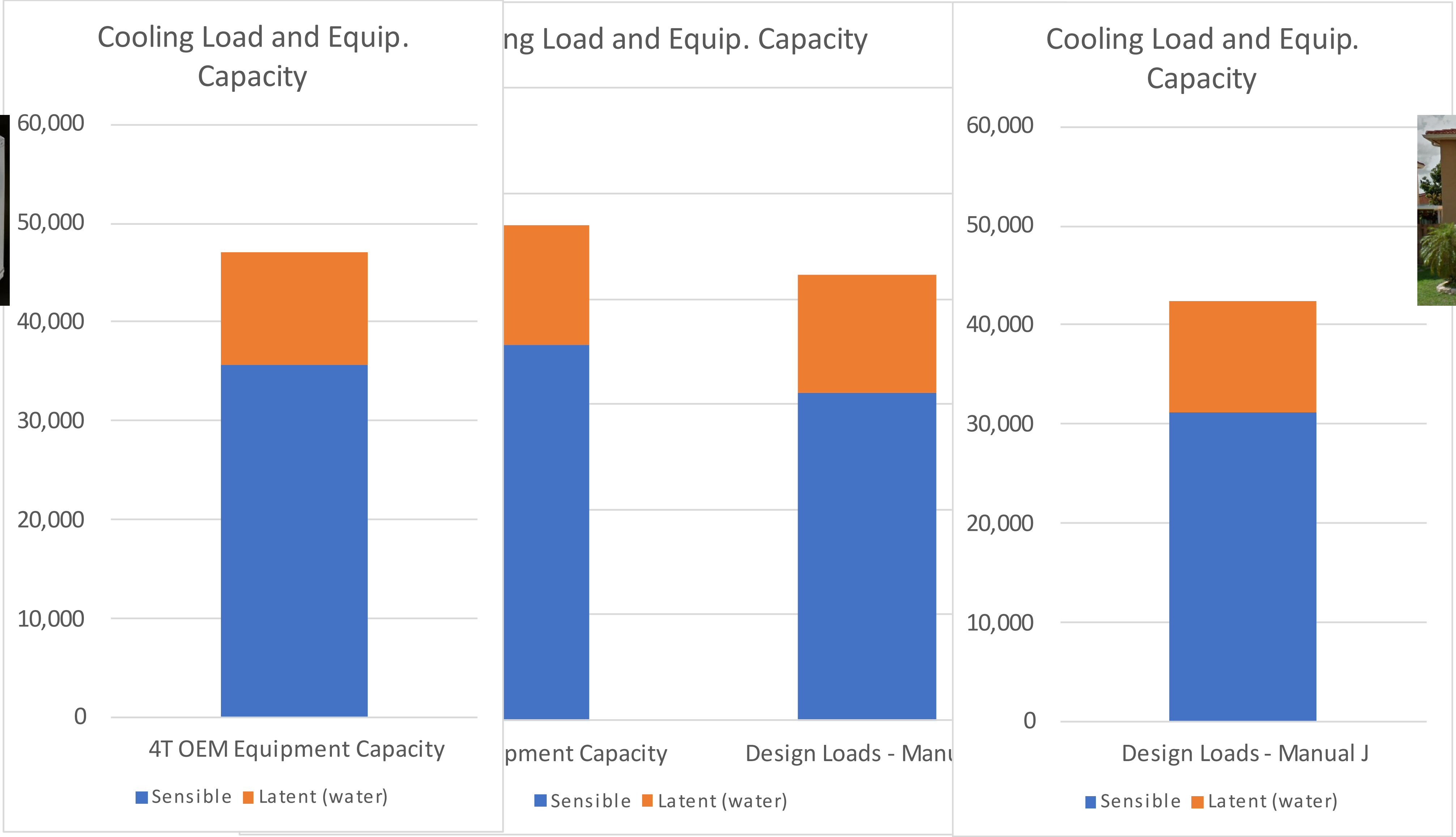
- Depressurizing means from Supply Duct

Resulting in increase in infiltration of ~280 CFM

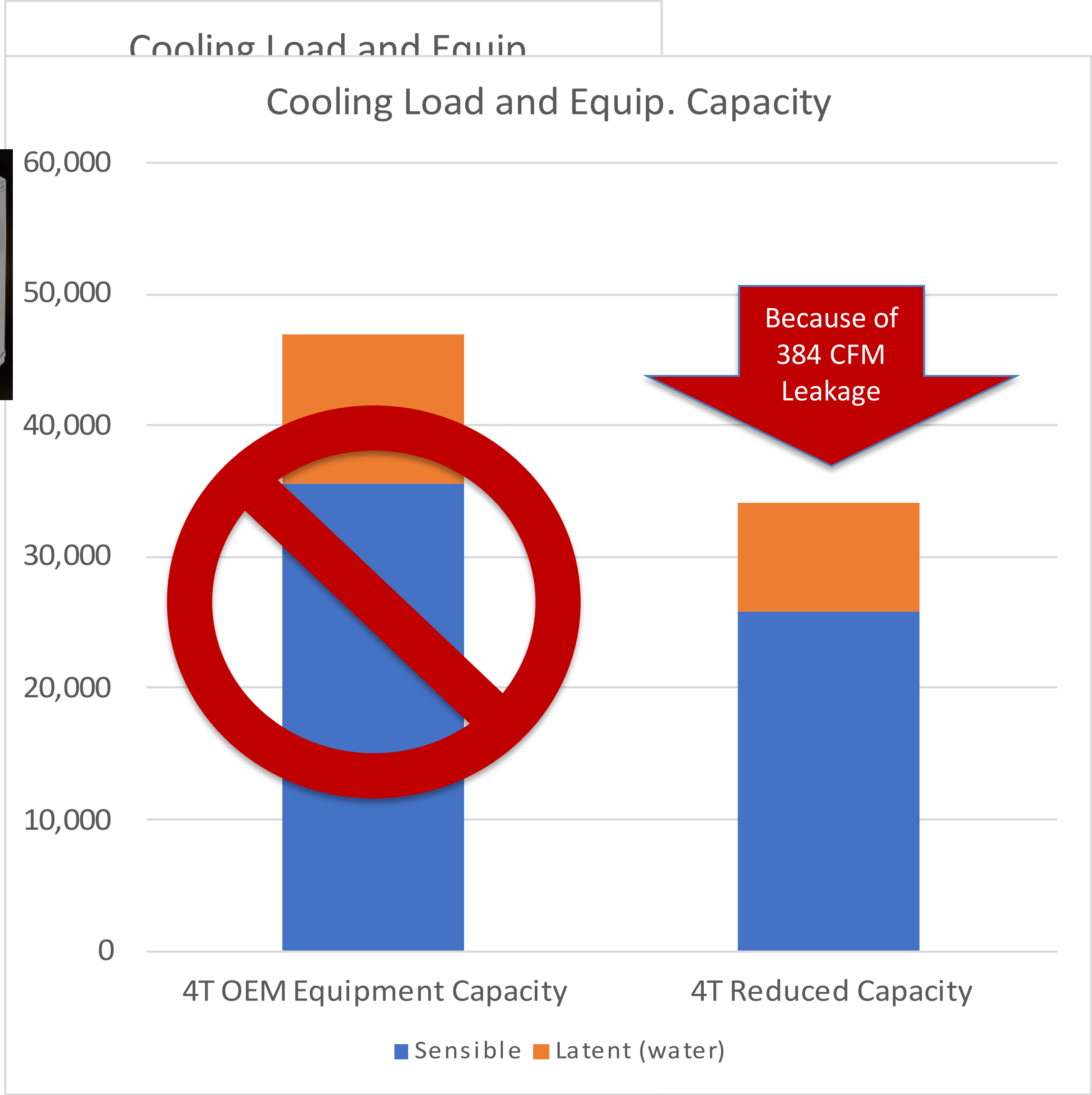
- Based on Blower Door Test and See Stack estimate
- Goes from 102 to 384 CFM.



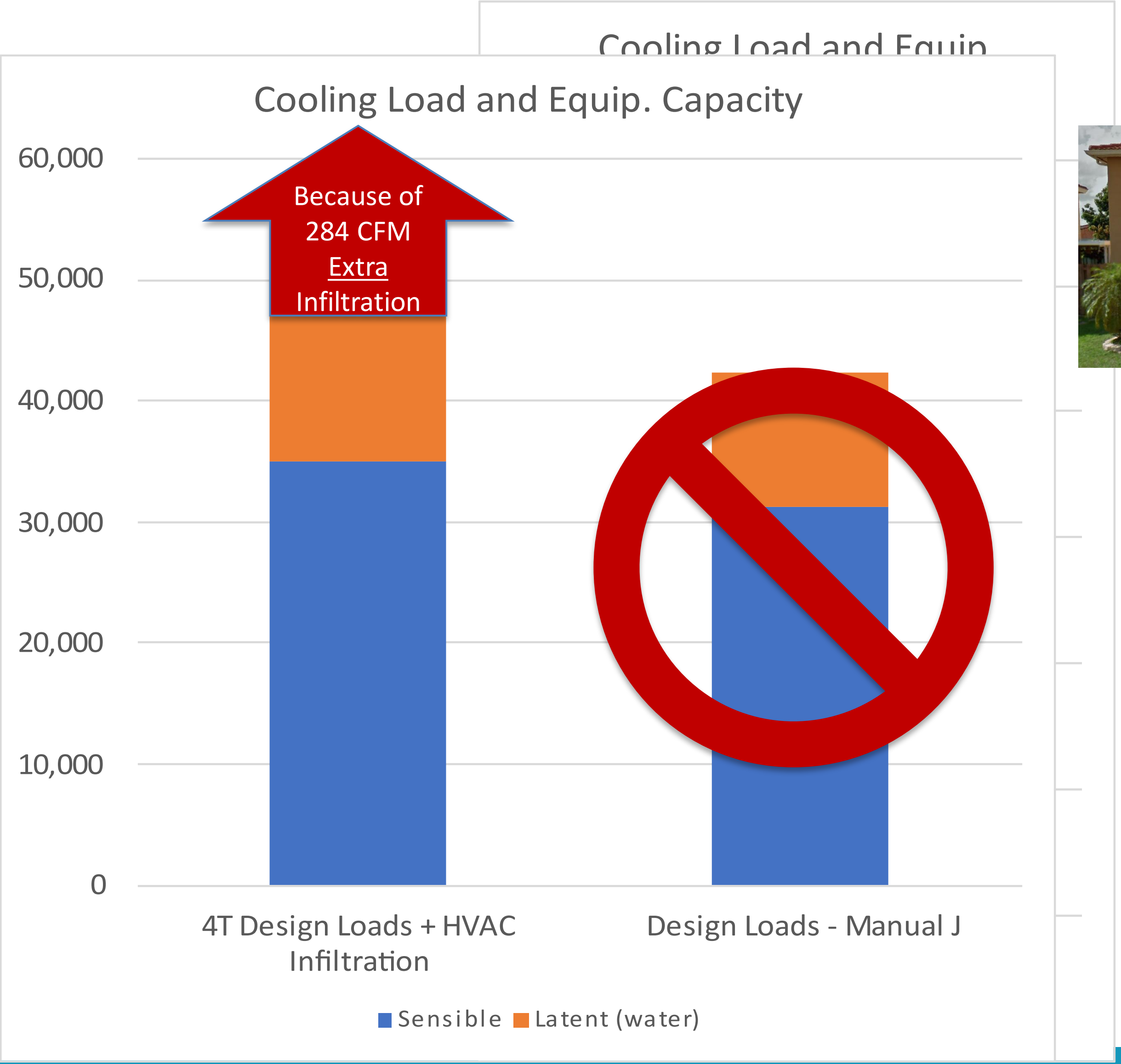
IS LEAKING 380 CFM FROM THE DUCTS A BIG DEAL?



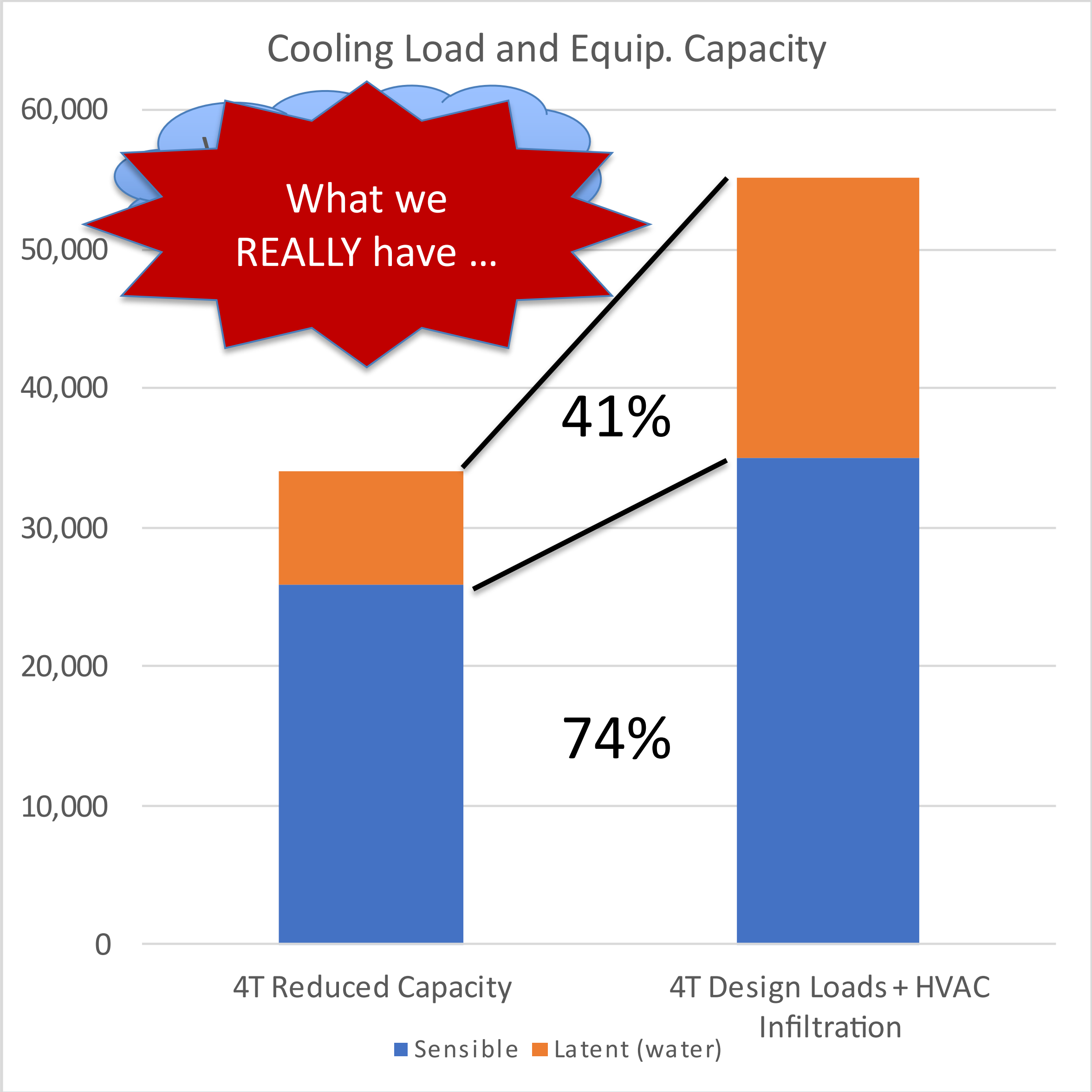
380CFM LEAKAGE – IMPACT ON EQUIPMENT CAPACITY



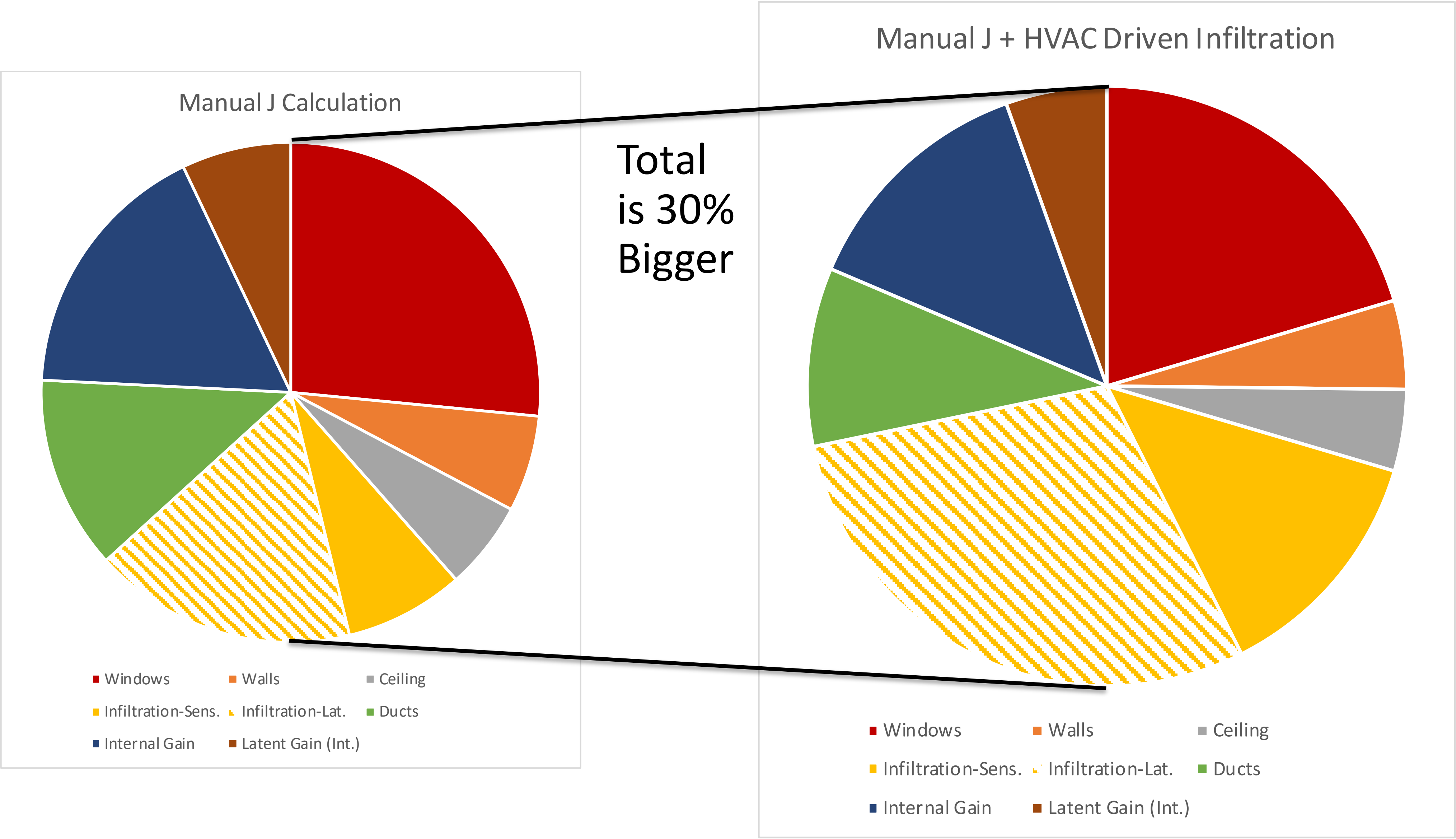
ALSO: THE HOUSE SUCKS… IN HOT HUMID AIR!

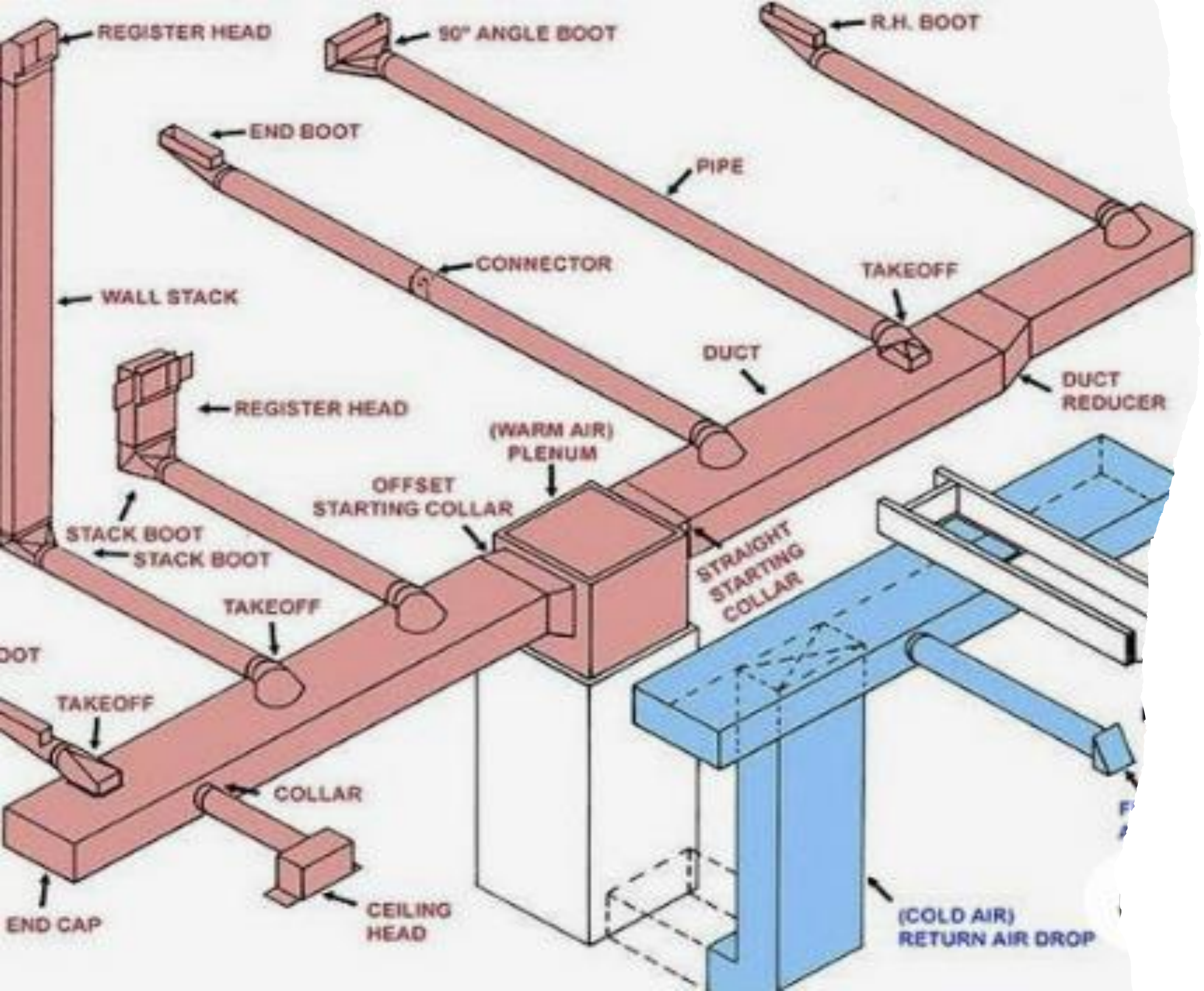


IS LEAKING 380 CFM A BIG DEAL – YES. YES IT IS.

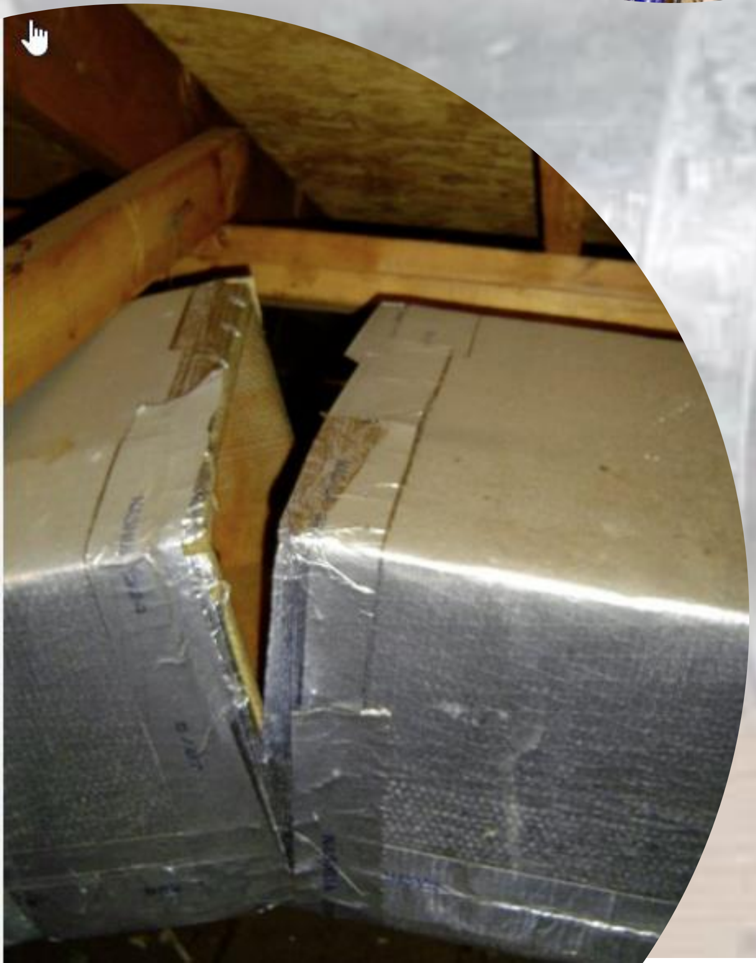


How a Bad Duct Impacts the House Load




REGISTER HEAD
90° ANGLE BOOT
R.H. BOOT
END BOOT
PIPE
CONNECTOR
WALL STACK
TAKEOFF
DUCT
DUCT
REDUCER
REGISTER HEAD
(WARM AIR)
PLENUM
OFFSET
STARTING COLLAR
STACK BOOT
STACK BOOT
STRAIGHT
STARTING
COLLAR
TAKEOFF
TAKEOFF
COLLAR
END CAP
CEILING
HEAD
(COLD AIR)
RETURN AIR DROP

Leaky Ducts



Common Locations of Duct Leakage

How to Know If You Have Leaky Ducts?


MJB


Bud
Budw
Budw

Agenda

- Intro: Success with a 1.5-ton heat pump in Minnesota
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        - Impact of Building Envelope
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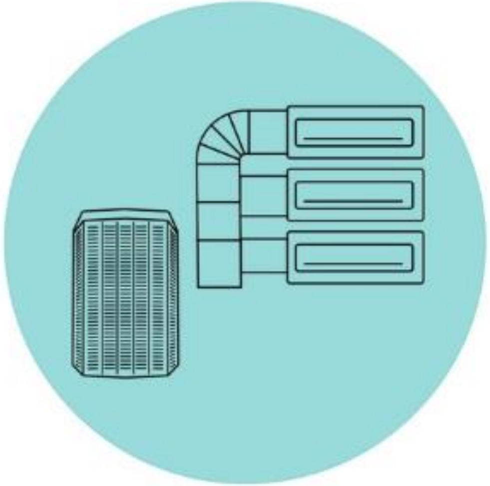
Summary – Final Thoughts



- **Ducted Heat Pumps may be common in Midwest**
  - Retrofits require close attention - **ensure existing ducts can support the required air flow**
- Success should consider achieving reduced energy, while delivering good **comfort, comparable costs and durability**
- Reducing infiltration load **is fundamental to maximizing odds of success**
  - **Likely that energy audit funding will be limited** in IRA programs, but it is a key tool in retrofit situations

Summary – Final Thoughts

Success Factors
Comparable Initial Cost
Comparable Comfort
Comparable Operating Cost
Reduce Energy CO2 Consumption
Comparable Durability

- For retrofits, make sure you **understand the condition of the envelope & ductwork, and the current airflow & TESP.**

- **Reasonable projects to improve the envelope will increase the likelihood that retrofit projects will be successful**

Summary – Final Thoughts

Success Factors
Comparable Initial Cost
Comparable Comfort
Comparable Operating Cost
Reduce Energy CO2 Consumption
Comparable Durability

NEW CONSTUCTION

minnesota power

Air Sealing Incentives: Measured by ACH50 (Air changes per hour at 50 pascals)

Available Rebates	Amount
<1.00 ACH50	$1,700
1.00-1.49 ACH50	$1,200
1.50-1.99 ACH50	$600
2.00-2.49 ACH50	$300

HVAC Bonus Incentives

Available Rebates	Amount
Air Source Heat Pump (ASHP) - Cold Climate	$1,500
Ground Source Heat Pump - MNGHPA Master Installer (per ton)	$1,200
Ground Source Heat Pump (per ton)	$1,000
ASHP - ENERGY STAR®	$500

RETROFIT?

Heat Pump Resources

ASHP
air source heat pump collaborative

cee

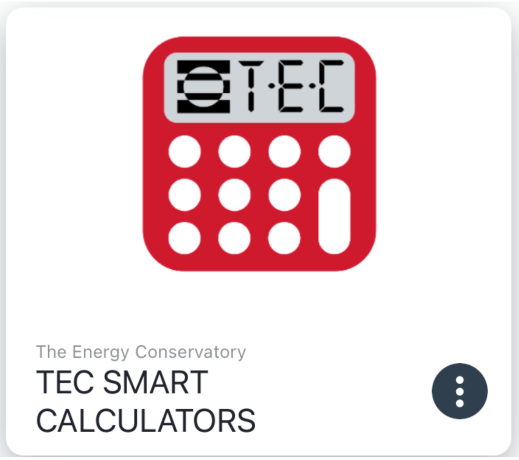
NEEP'S COLD CLIMATE AIR SOURCE
Heat Pump List

slipstream

Heat Pump Resources from The Energy Conservatory

- Home Upgrade Project

- Air Flow & Calculators



Having Success with Cold Weather Heat Pumps

Considerations for duct, envelope, and system performance

Bill Graber and Jake McAlpine
The Energy Conservatory

Energy Design Conference

February 22, 2023

Cold Climate Heat Pumps - Key Messages

- Heat pumps are a **great opportunity.** In many cases in cold climates, these will be **ducted systems**.
- **Look beyond COP** to have a successful heat pump install
- **Goals include comparable comfort, costs and durability**
- Several factors influence a **retrofit project** – including **air flow**, **duct condition**, and **building envelope condition.**
- There are **many great resources** for homeowners and contractors, including **CEE, Slipstream, NEEP**, and others.

We will review two houses ("Good/Tight" & "Bad/Leaky") to show how these factors interact to impact the success in a ducted retrofit application

Standards

Software Process

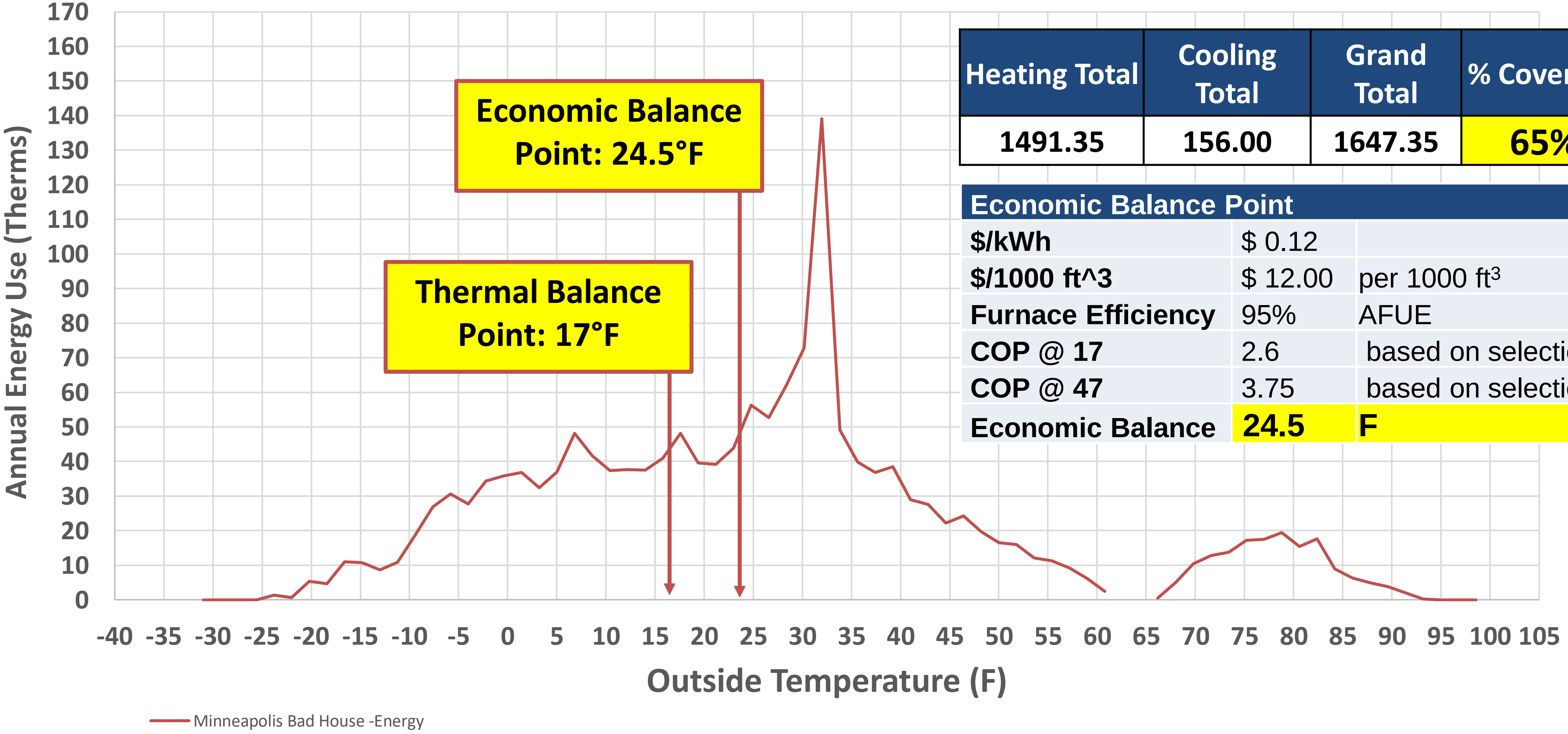
Measurements

Training

Minneapolis Leaky House

Goodman 5-Ton

Energy Use vs Temperature

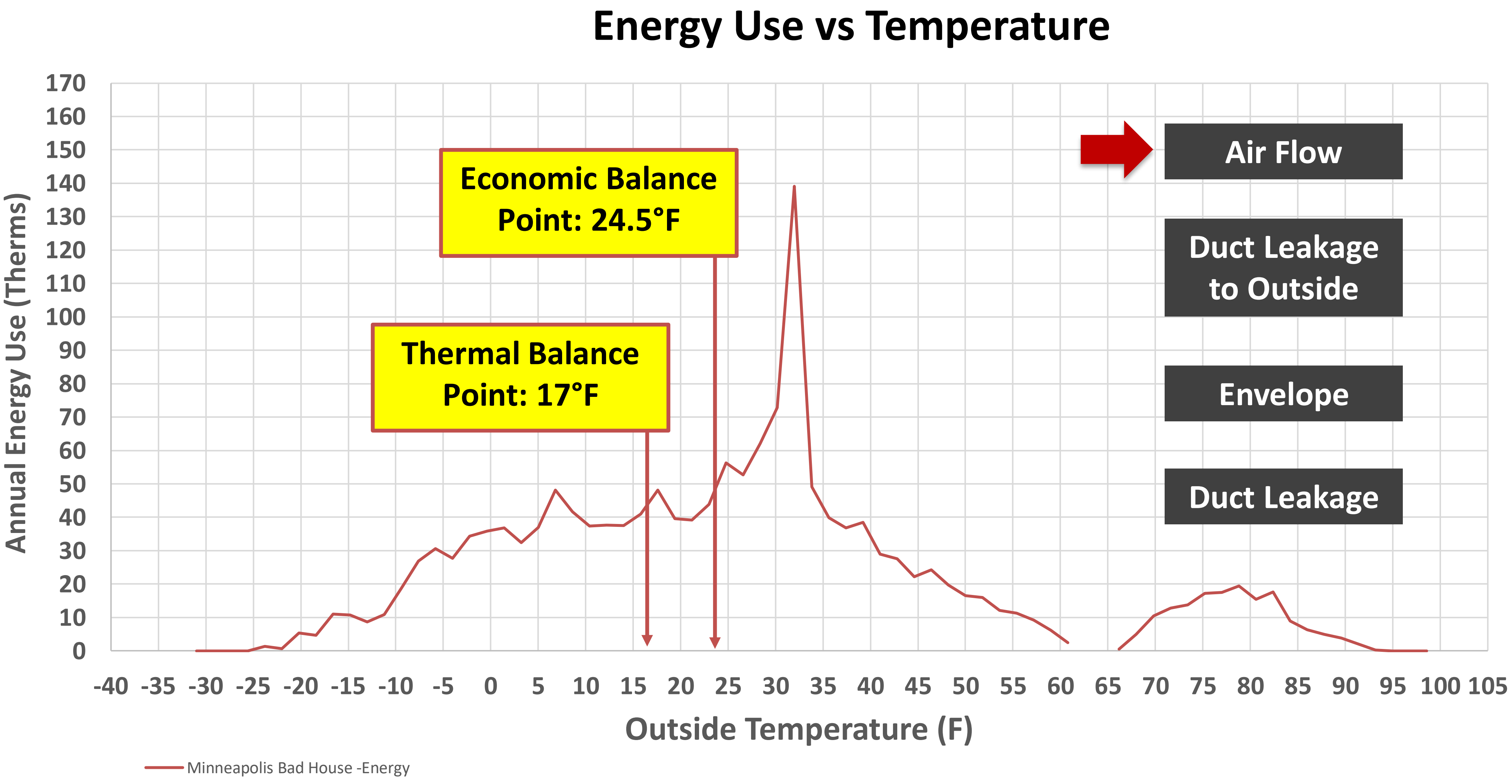


Heating Total	Cooling Total	Grand Total	% Coverage
1491.35	156.00	1647.35	65%

Economic Balance Point		
$/kWh	$ 0.12	
$/1000 ft^3	$ 12.00	per 1000 ft^3
Furnace Efficiency	95%	AFUE
COP @ 17	2.6	based on selection
COP @ 47	3.75	based on selection
Economic Balance	24.5	F

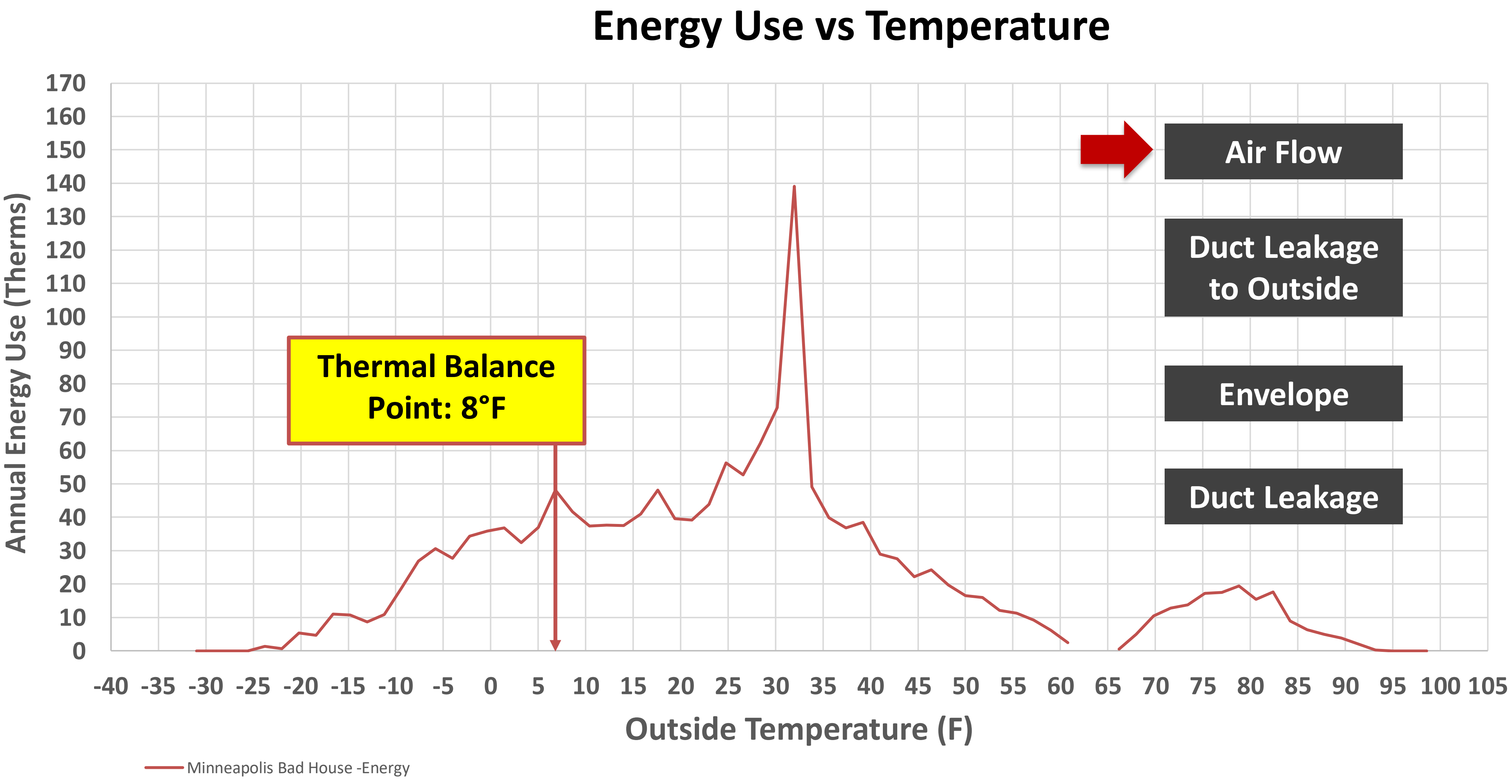
Minneapolis Leaky House

Goodman 5-Ton

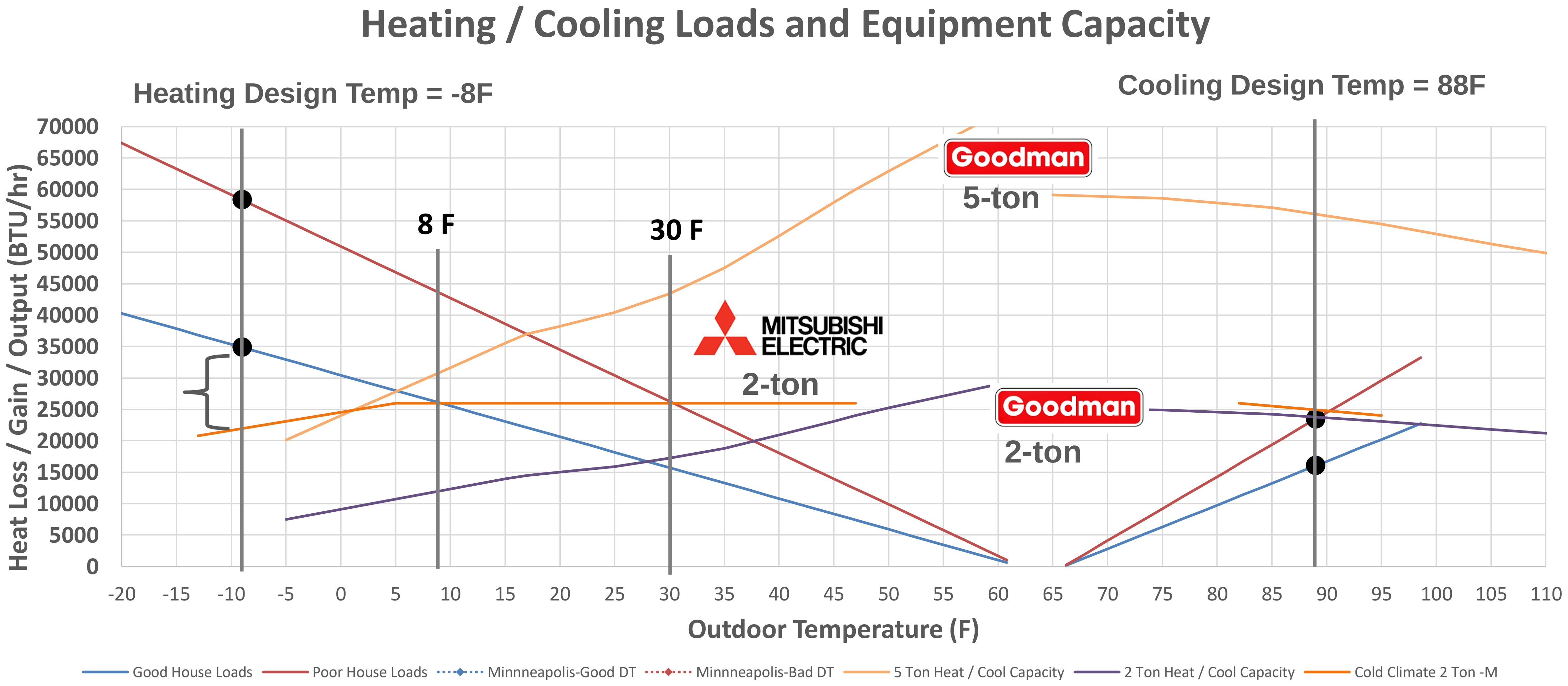


Minneapolis Tight House

MITSUBISHI ELECTRIC
2-ton



Minneapolis Tight House



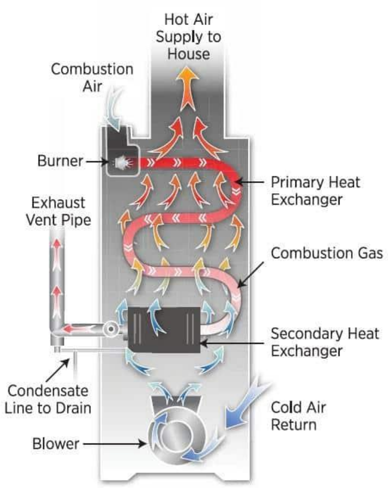
Minneapolis Tight House Sizing for Heat Load

MITSUBISHI ELECTRIC
2-ton

Air Flow

95% Furnace

- 80,000 BTU
- Heat Rise = 35 – 50 F
- **Air flow = 1000 cfm**
- **TESP = 0.5 inH2O**
- ~150 cfm/ton



2-ton Heat Pump

- Design Heat Rise = 20 – 30 F (Typically lower than gas furnace)
- Required air flow = 800 cfm (Typically, requires ~400 cfm/ton)
- ECM motor will try to push 800 cfm at 0.32 inH2O