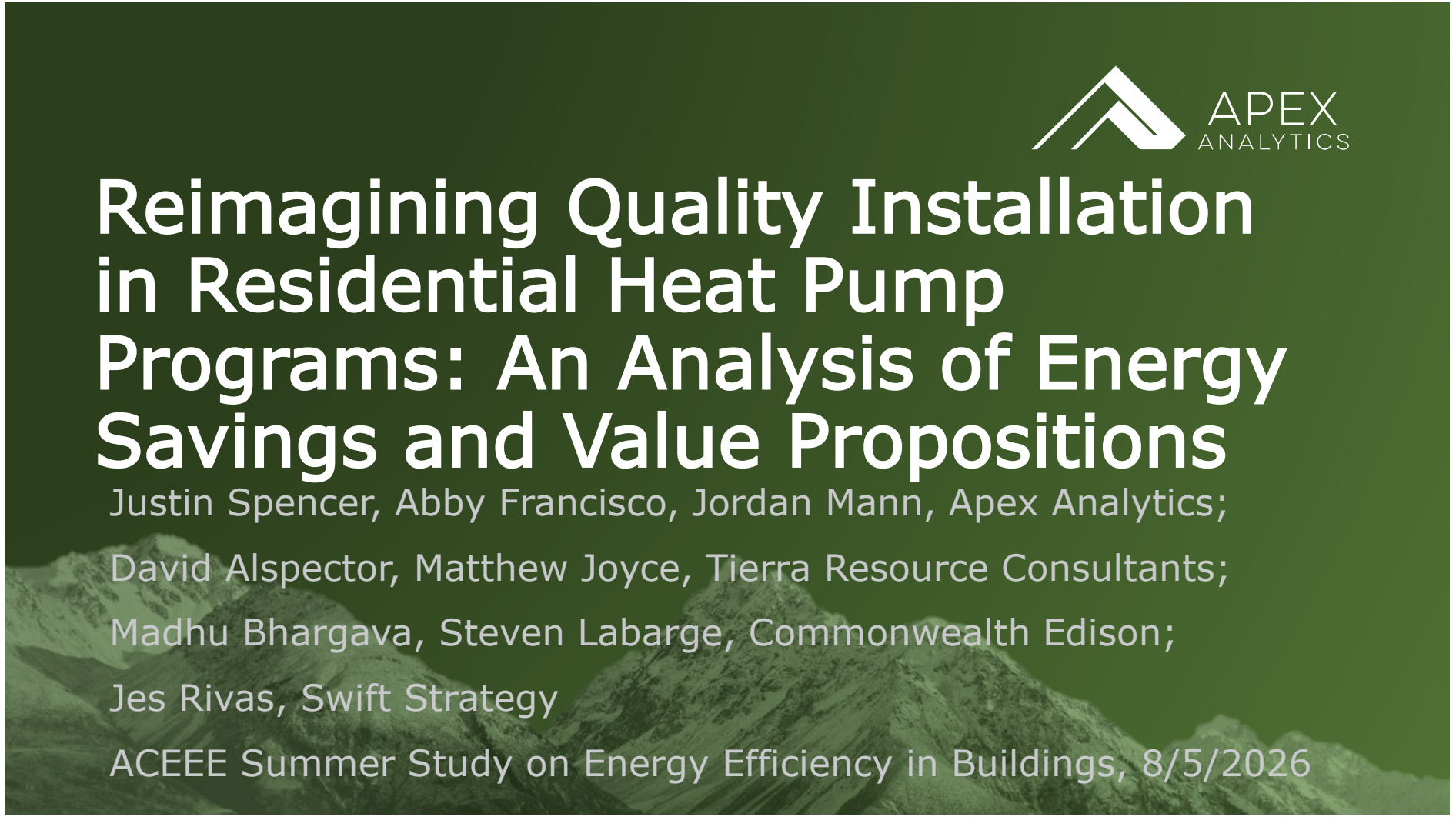

APEX
ANALYTICS
Reimagining Quality Installation in Residential Heat Pump Programs: An Analysis of Energy Savings and Value Propositions
Justin Spencer, Abby Francisco, Jordan Mann, Apex Analytics;
David Alspector, Matthew Joyce, Tierra Resource Consultants;
Madhu Bhargava, Steven Labarge, Commonwealth Edison;
Jes Rivas, Swift Strategy
ACEEE Summer Study on Energy Efficiency in Buildings, 8/5/2026

In the Beginning…

- Quality Installation (QI) of residential HVAC equipment has been a recognized energy saving opportunity since the 1990s.
- Traditionally QI generally has included:
  - Refrigerant Charge
  - Airflow
  - Sizing
- Sometimes it has also included duct sealing and controls.
- Equipment (and programs) have evolved:
  - Early days: Single speed CAC with fixed orifice and cap tube
  - Thermostatic expansion valve (TXV) shows up, making systems more resilient to refrigerant charge errors. Two stage equipment shows up, but not much attention is paid.
  - Comprehensive program offerings for heat pumps with duct sealing and controls (Performance Tested Comfort Systems in the NW)
- **What's the right set of QI practices for Variable Speed Cold Climate Heat Pumps?**

What's different about how a VSHP and conventional CAC run?

- Conventional CAC
  - On or off
  - One airflow
  - One capacity
  - Always runs on high
  - Cycles a lot
  - Does not heat home
- All-electric VSHP
  - Runs at variable airflow and capacity
  - Runs mostly at part load, with lower airflow and capacity
  - Does not cycle much
  - Heats home
  - Also has backup heating at much lower efficiency

What's different about how a VSHP and CAC respond to installation faults?

Type of fault	Traditional CAC + Furnace	VSHP
Refrigerant charge	Low or high charge results in less efficient heat exchange (less phase-change heat exchange area)	Low or high charge results in less efficient heat exchange (less phase-change heat exchange area)
Leaky or underinsulated ducts	Loss of efficiency and capacity, but limited impact on comfort – people don't notice	Loss of efficiency and capacity, which may result in lower supply temps – people might notice
Undersized ducts (leading to low airflow)	High static pressure results in low airflow reduces heat exchanger capacity and efficiency	At high load, same problems. At low load, lower duct static pressure. Should mean little impact on airflow, capacity, and efficiency.
Oversizing	Leads to short-cycling, with efficiency loss	Less short-cycling impact; Oversizing reduces use of electric backup
Controls	Simple controls, hard to mess up.	Control faults are relatively common and can cause large increases in energy consumption from excess electric resistance backup heat running.

What's different about how a VSHP and CAC respond to installation faults?

Type of fault	Traditional CAC + Furnace	VSHP
Refrigerant charge	Low or high charge results in less efficient heat exchange (less phase-change heat exchange area)	Low or high charge results in less efficient heat exchange (less phase-change heat exchange area)
Leaky or underinsulated ducts	Loss of efficiency and capacity, but limited impact on comfort – people don't notice	Loss of efficiency and capacity, which may result in lower supply temps – people might notice
Undersized ducts (leading to low airflow)	High static pressure results in low airflow reduces heat exchanger capacity and efficiency	At high load, same problems. At low load, lower duct static pressure. Should mean little impact on airflow, capacity, and efficiency.
Oversizing	Leads to short-cycling, with efficiency loss	Less short-cycling impact; Oversizing reduces use of electric backup
Controls	Simple controls, hard to mess up.	Control faults are relatively common and can cause large increases in energy consumption from excess electric resistance backup heat running.

What's different about how a VSHP and CAC respond to installation faults?

Type of fault	Traditional CAC + Furnace	VSHP
Refrigerant charge	Low or high charge results in less efficient heat exchange (less phase-change heat exchange area)	Low or high charge results in less efficient heat exchange (less phase-change heat exchange area)
Leaky or underinsulated ducts	Loss of efficiency and capacity, but limited impact on comfort – people don't notice	Loss of efficiency and capacity, which may result in lower supply temps – people might notice
Undersized ducts (leading to low airflow)	High static pressure results in low airflow reduces heat exchanger capacity and efficiency	At high load, same problems. At low load, lower duct static pressure. Should mean little impact on airflow, capacity, and efficiency.
Oversizing	Leads to short-cycling, with efficiency loss	Less short-cycling impact; Oversizing reduces use of electric backup
Controls	Simple controls, hard to mess up.	Control faults are relatively common and can cause large increases in energy consumption from excess electric resistance backup heat running.

Sizing: How big a car or heat pump should you get?

APEX ANALYTICS





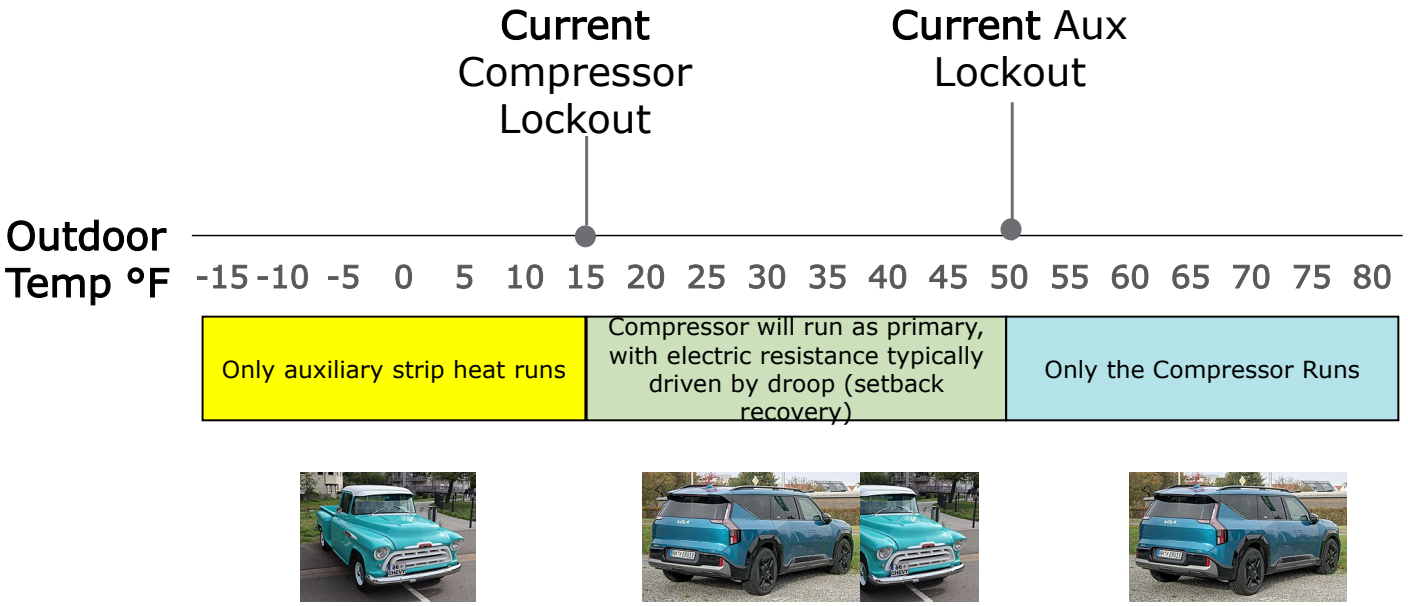


Controls: When should you fire up that old truck?

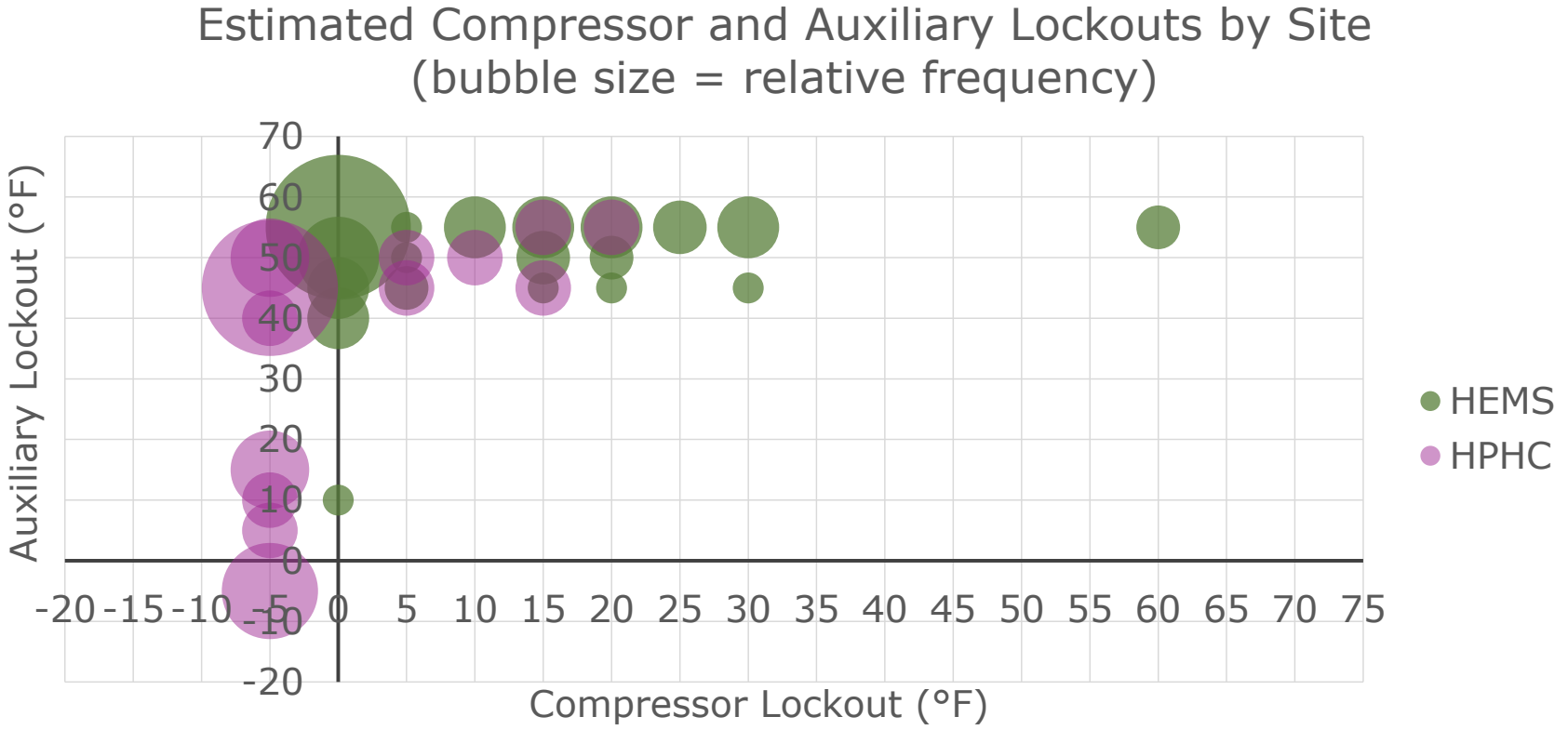




Typical Heat Pump Controls Algorithm



What lockouts are people using? Not very good ones…



Controls savings opportunities in HPs are huge!

- Based on our modeling of baseline and improved controls, we calculated 17% savings for VSHPs and 26% savings for conventional HPs in IL.
- These savings are comparable in size to what you get from installing a VSHP compared to a conventional HP in IL.
- Getting controls right doesn’t cost much time on site for contractors.

Sizing of VSHPs

- Bigger isn't always better, except maybe in some cases it is.
- **Larger systems:**
  - **Shortcycle more often under low heating and cooling loads** – uses more energy (but not as much in VSHP as conventional HP, we think)
  - **Use less aux electric resistance heat when compressor and aux run together during cold temperatures** – uses less energy (but how often is this really happening in most climates?)
  - **Don't dehumidify as much** (but may be offset for VSHPs with a drying-focused mode)


TRITON

Sizing of VSHPs: Potential Savings impacts in Chicago

Conventional Heat Pump		Cold-Climate Heat Pump	
Compressor | Aux Lockouts (°F)	Sizing Savings (%)	Compressor | Aux Lockouts (°F)	Sizing Savings (%)
None | 20	5%	None | 20	11%
None | 25	7%	None | 30	12%
None | 30	8%	None | 40	12%
None | 35	9%	None | 50	12%
25 | 25	0%	15 | 20	5%
25 | 30	1%	15 | 30	6%
25 | 35	1%	15 | 40	6%

- Conventional sizing advice should be revisited for VSHPs operating in cold climates.
- Larger systems can save a lot of electric resistance heating in these climates.

Methods

- Interview distributors and contractors to ask about typical installation practices
- Extract 15 minute heating loads from ResStock for building simulations with Midway Airport as weather station (Thanks NLR!)
- Use conventional HP and VSHP equipment models based on Carrier equipment
- Size equipment to meet load in low 20s F (partially based on contractor conversation)
- Interpolate expected runtime and power based on loads and equipment models
- Assume any unmet loads are met with additional HP or electric resistance
- Run large number of different HP control settings and two different equipment sizes
- Compare runs to estimate potential savings

Recommendations

- Controls should be foundational to QI of HPs. Adding controls QI can vastly improve savings and cost-effectiveness of VSHPs.
- Sizing of VSHPs really needs more research:
  - Understand efficiency impacts from short-cycling of larger systems.
  - Compare these to efficiency impacts from reduced aux heat runtime.
  - Test hypothesis that in cold climates, larger systems save energy instead of cost more energy.

Questions?

Justin Spencer

Justins@apexanalyticsllc.com