Better Buildings Residential Network Peer Exchange Call Series:

How Quality Installation Impacts Equipment

March 26, 2020

Agenda and Ground Rules

- Agenda Review and Ground Rules
- Opening Poll
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers:
  - **Dean Gamble**, U.S. Environmental Protection Agency (EPA)
  - **David Lis**, Northeast Energy Efficiency Partnerships (NEEP)
  - **Christopher Boyce**, Emerson Climate Technologies
- Open Discussion
- Closing Poll and Announcements

Ground Rules:

1. **Sales of services and commercial messages are not appropriate** during Peer Exchange Calls.
2. Calls are a safe place for discussion; **please do not attribute information to individuals** on the call.

The views expressed by speakers are their own, and do not reflect those of the Dept. of Energy.

Better Buildings Residential Network

Join the Network

Member Benefits:

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- One-on-One brainstorming conversations

Commitment:

- Members only need to provide *one number*: their organization's number of residential energy upgrades per year, or equivalent.

Upcoming Calls (2nd & 4th Thursdays):

- Apr 09: How Hot Is It? – Preparing for Summer Cooling Season
- May 14: How is the Coronavirus Impacting Energy Efficiency Businesses?
- May 28: Is the Smart Home Delivering on Its Promises?

Peer Exchange Call summaries are posted on the Better Buildings website a few weeks after the call

For more information or to join, for no cost, email bbresidentialnetwork@ee.doe.gov, or go to energy.gov/eere/bbrn & click Join

Dean Gamble

U.S. Environmental Protection Agency

U.S. DEPARTMENT OF ENERGY

How Bad Installation Can Negate Good Equipment

Better Buildings Residential Network Peer Exchange Call

Dean Gamble

March 26, 2020

Introduction

HVAC installation defects are common

HVAC installation defects are common

- Improper airflow:
  - Average airflow ~20% below target. Blasnik et al. (1995)
  - Average airflow 14% below design. Proctor (1997)
  - Measured airflow ranging from 130 - 510 CFM / ton. Parker (1997)
  - 70% of units had airflow < 350 CFM / ton. Neme et al. (1999)
  - Improper airflow in 44% of systems. Mowris et al. (2004)

HVAC installation defects are common

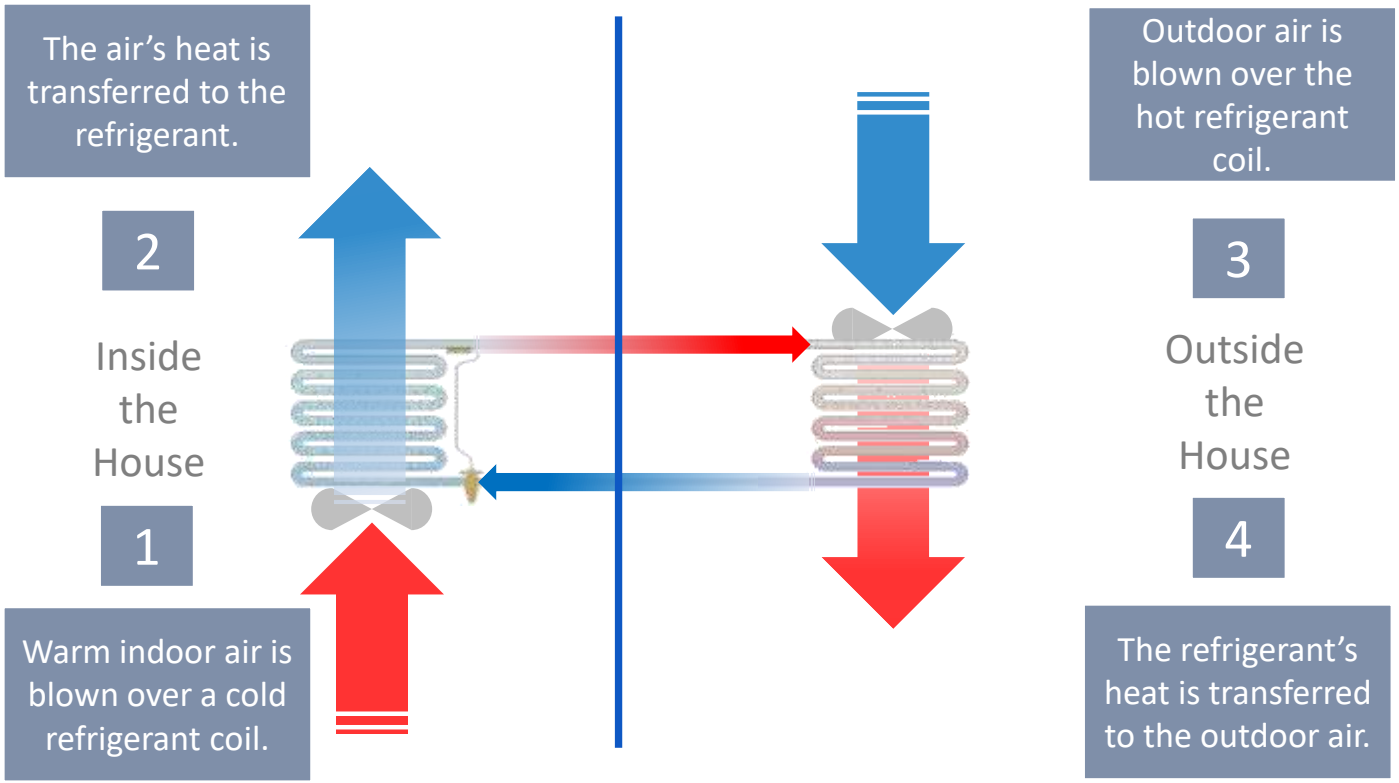
- Incorrect refrigerant charge:
  - In 57% of systems. Downey/Proctor (2002)
  - In 62% of systems. Proctor (2004)
  - In 72% of systems. Mowris et al. (2004)
  - In 82% of systems. Proctor (1997)

HVAC installation defects are common

Study Author	State	Existing or New Home?	Sample Size	Average Airflow	Airflow <350 cfm	Airflow w/in 10% of 400/ton	Energy Savings Potential	Notes
Blasnik et al. 1995a	NV	New	30	345	50%		8%	Est @ 33% combined charge/air flow correction benefits
Blasnik et al. 1995b	CA	New	10	319	90%			
Blasnik et al. 1996	AZ	New	22	344	64%	29%	10%	Est @ 33% combined charge/air flow correction benefits
Hammarlund et al. 1992	CA	New	12			30%	10%	Single family results
Hammarlund et al. 1992	CA	New	66		76%	14%	12%	Multi-family results
Neme et al. 1997	MD	New	25	340				Average for non-participant homes
Palani et al. 1992	n.a.	n.a.	n.a.				4%	Lab test of EER degradation at 25% reduction in air flow
Parker et al. 1997	FL	Both	27	270	89%	7%	10%	Field measurements of flow; lab test of effic loss
Proctor & Pernick 1992	CA	Existing	175		44%			Random sample from PG&E Model Energy Communities Prog
Proctor 1991	CA	Existing	15			33%		Two-thirds h
Proctor et al. 1995a	CA	Existing	30	300	80%	11%		SCE Coach
Rodriguez et al. 1995	n.a.	n.a.	n.a.				2%	Lab test of T
Rodriguez et al. 1995	n.a.	n.a.	n.a.				10%	Lab test of (
VEIC/PEG 1997	NJ	New	52	372		30%	7%	Est @ 33%
Average				327	70%	22%	8%	

Study Author	State	Existing or New Homes?	Sample Size	Charge correct to mfg spec	% over charge	% under charge	Energy Savings Potential	Notes
Blasnik et al. 1995a	NV	New	30	36%	5%	59%	17%	Est @ 67% combined charge/air flow correction benefits
Blasnik et al. 1995b	CA	New	10				8%	Est @ 67% combined charge/air flow correction benefits
Blasnik et al. 1996	AZ	New	22	18%	4%	78%	21%	Est @ 67% combined charge/air flow correction benefits
Farzad & O'Neal 1993	n.a.	n.a.	n.a.				5%	Lab test of TXV; 8% loss @20% overchg; 2% loss @20% underchg
Farzad & O'Neal 1993	n.a.	n.a.	n.a.				17%	Lab test of Orifice; 13% loss @20% overchg; 21% loss @ 20% underchg
Hammarlund et al. 1992	CA	New	12				12%	Single family results
Hammarlund et al. 1992	CA	New	66	31%	61%	8%	12%	Multi-family results
Katz 1997	NC/SC	New	22	14%	64%	23%		Charge measured in 22 systems in 13 homes
Proctor & Pernick 1992	CA	Existing	175	44%	33%	23%		Results from PG&E Model Energy Communities Program
Proctor 1991	CA	Existing	15	44%				Fresno homes
Proctor et al. 1995a	CA	Existing	30	11%	33%	56%		
Proctor et al. 1997a	NJ	New	52				13%	Est @ 67% combined charge/air flow correction benefits
Rodriguez et al. 1995	n.a.	n.a.	n.a.				6%	Lab test of TXV EER; 5% loss at both 20% overchg & 20% underchg
Rodriguez et al. 1995	n.a.	n.a.	n.a.				15%	Lab test of Orifice EER; 7% loss @20% overchg, 22% loss @ 20% underchg
Average				28%	33%	41%	12%	

HVAC installation defects are common



Overview of Std 310: Grading the Installation of HVAC Systems

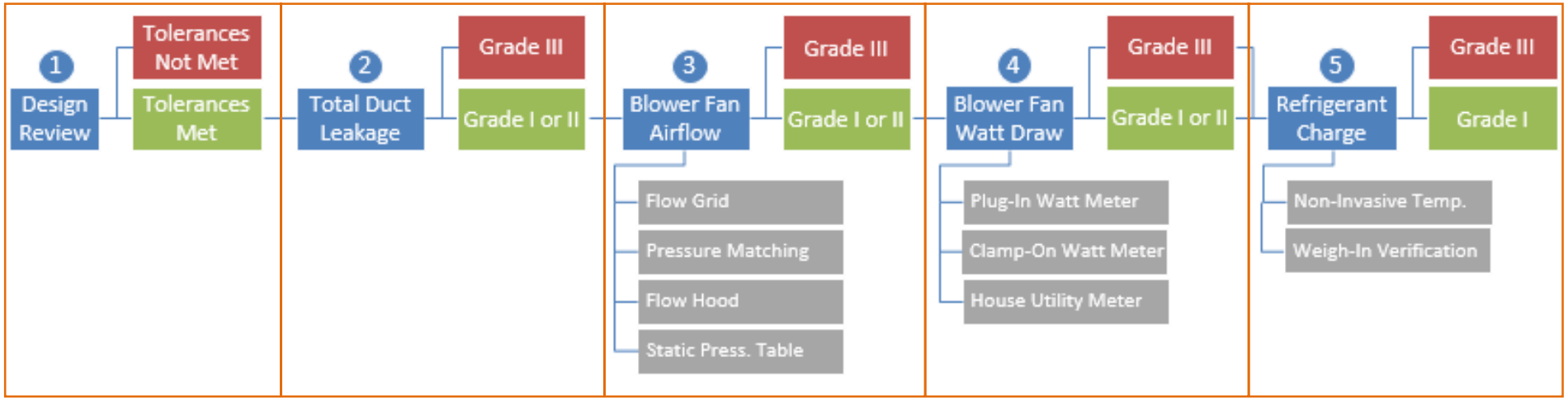
RESNET/ACCA Std. 310: Grading Concept

- Integrate into a standard HERS/ERI rating process.
  - Completed by home energy raters.
  - Primarily, but not exclusively, applicable to new construction industry
- Follow RESNET's insulation quality-installation model:
  - Grade III: The default. No assessment. No penalty and no credit.
  - Grade II: Assessment completed and the system is ok. Partial credit.
  - Grade I: Assessment completed and the system is very good. Full credit.
- Use tasks that California's code requires as a starting point.

RESNET/ACCA Std. 310: Guiding Principles

- Take a ‘carrot’ rather than a ‘stick’ approach.
- Reward incremental improvement.
- Include procedures applicable to both Rater and HVAC professionals.
- Ensure the procedures provide value in and of themselves.

RESNET/ACCA Std. 310:
Standard for Grading the Installation of HVAC Systems



Task 1: Design Review

Task 1: Evaluate the design

1. Rater collects design documentation for the dwelling with the HVAC system being tested.
2. Rater reviews design documentation for completeness and compares it to the dwelling. Key features must fall within defined tolerances. For example:

Floor Area	Indoor Design Temps	Insulation Levels
Window Area	Outdoor Design Temps	Infiltration Rate
# Occupants	Window SHGC	Ventilation Rate

3. If tolerances are met, proceed to next task. Otherwise stop here.

Task 2: Total Duct Leakage

Task 2: Evaluate total duct leakage

1. Rater measures total duct leakage according to Std. 380, evaluates the results, and assigns a grade:

Grade	Test Stage	# Returns	Total Leakage Limit (CFM per 100 ft² or Total CFM)
I	Rough-In	< 3	4 or 40 total
		≥ 3	6 or 60 total
	Final	< 3	8 or 80 total
		≥ 3	12 or 120 total
II	Rough-In	< 3	6 or 60 total
		≥ 3	8 or 80 total
	Final	< 3	10 or 100 total
		≥ 3	14 or 140 total
III	N/A	N/A	No Limit

2. If Grade I or II is achieved, proceed to next task. Otherwise stop here.

Task 3: Blower Fan Airflow

Task 3: Evaluate Blower Fan Airflow

- Raters measure the total volumetric airflow going through the blower fan using one of four test methods:
  A. Flow Hood
  B. Flow Grid
  C. Pressure Matching
  D. OEM Static Pressure Table

- This is just one or two measurements for most systems. It is not measuring the airflow from each register and summing those.

- The result is compared to the design airflow. The closer the better. This difference is used to assign Grade I, II, or III.

- If Grade I or II is achieved, proceed to next task. Otherwise stop here.

Task 4: Blower Fan Watt Draw

Task 4: Evaluate Blower Fan Watt Draw

- Raters evaluate the watt draw of the blower fan using one of three test methods:
  A. Plug-In Watt Meter
  B. Clamp-On Watt Meter
  C. Utility Meter

- The airflow and watt draw is used to calculate fan efficiency. The more efficient, the better. This is used to assign Grade I, II, or III.

- Regardless of grade, you can proceed to next task.

Task 5: Refrigerant Charge

Task 5: Evaluate Refrigerant Charge

- Raters evaluates the refrigerant charge of the system using one of two test methods:
  A. Non-Invasive Method
  B. Weigh-In Verification Method

Task 5: Evaluate Refrigerant Charge

A. Non-Invasive Method

- 'Non-invasive' means no gauges connected to refrigerant system.
- Instead, the temperature of the air and refrigerant lines are used.
- Triage systems into two bins:
  - Grade I – Charge is okay
  - Grade III – Charge is not okay

Refrigerant Gauges Not Connected

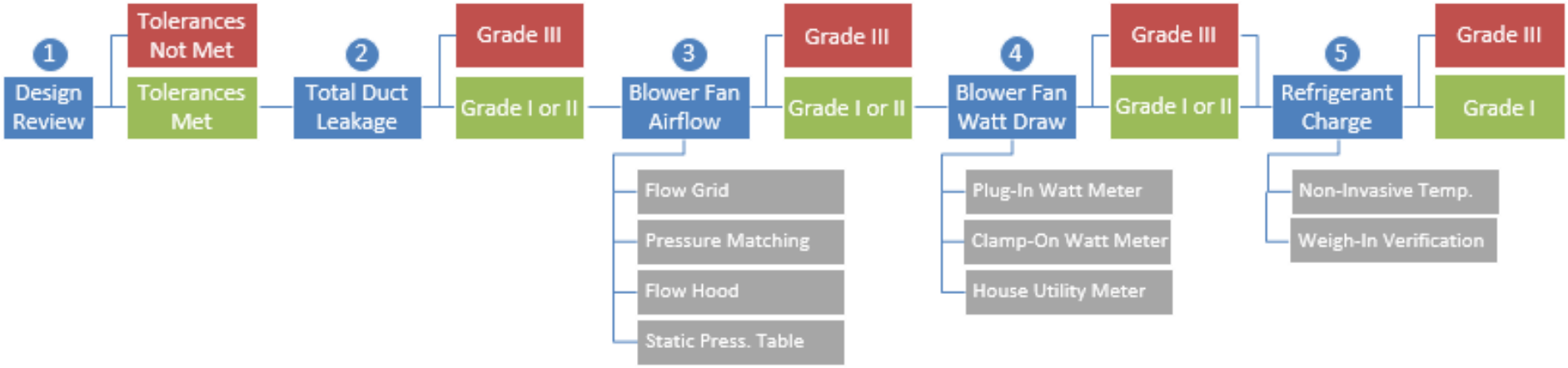
Temperature Sensors Used Instead

Task 5: Evaluate Refrigerant Charge

B. Weigh-In Verification Method

- The weigh-in verification method can be used year-round and it must be used for:
  - Extreme outdoor conditions.
  - Mini/multi-split systems.
- This method is primarily a document review rather than a performance test.

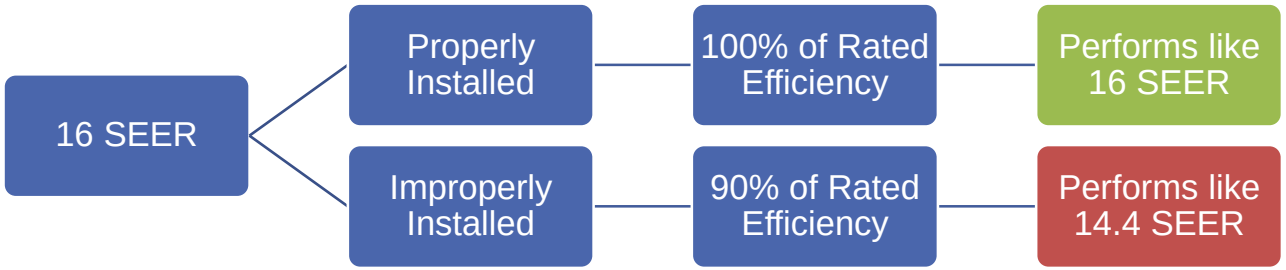
Std. 310: Standard for Grading the Installation of HVAC Systems



Benefits

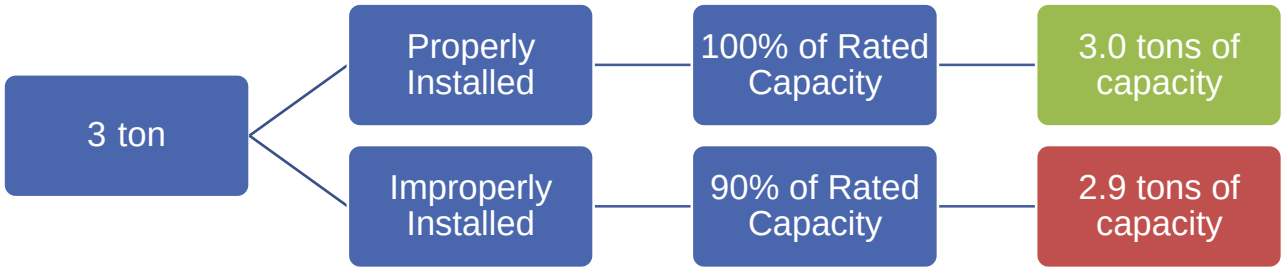
Properly-installed HVAC maintains efficiency

- Rewarded with better efficiency and a better HERS / ERI rating.



Properly-installed HVAC maintains capacity

- Rewarded with better comfort and durability.



HVAC grading benefits for..

- Builders – Energy ratings, tax credit, comfort, durability.
- Utility Programs – Energy and demand benefits.
- HVAC Manufacturers – Rewarded for features that ease installation.
- Raters – Valuable new service for any energy rated home.
- ENERGY STAR Certified Homes – Extra credit for program requirements, lower compliance cost.

Alternative Compliance Paths

Alternative Compliance Paths

- Primary goal of Std. 310 is to define a method for Raters to assess HVAC design and installation.
- However, the standard also includes a framework for two alternative compliance paths:
  - On-board diagnostics that directly provide data to Raters.
  - Third-party verifiers that collect and provide data in lieu of Raters, with oversight outside of RESNET.

Summary

Summary

- Installation defects impact the efficiency & capacity of HVAC systems.
- Standard 310 will be a new standard for evaluating the design and installation quality of HVAC systems.
- The standard is primarily designed for home energy raters, but includes a framework for two alternative compliance paths.
- This will allow homes to earn HERS/ERI points for properly installed HVAC systems.
- To read the second public draft of Standard 310, visit: www.resnet.us/about/standards/resnet-ansi/draft-pds-02-bsr-resnet-acca-310-20xx/
- The standard should be finalized and available for use by the end of this year.

ENERGY STAR Residential New Construction

Web & Email:

Single Family: www.energystar.gov/newhomesrequirements
Multifamily: www.energystar.gov/mfnc
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David Lis

Northeast Energy Efficiency Partnerships

U.S. DEPARTMENT OF ENERGY

Getting Residential Air-Source Heat Pumps Right in Cold Climates

- Dave Lis, Director, Technology and Market Solutions
- March 26, 2020
- BBRN Webinar- How Bad Installation Can Negate Good Equipment

Northeast Energy Efficiency Partnerships

Mission

We seek to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities.

Approach

Drive market transformation regionally by fostering collaboration and innovation, developing tools, and disseminating knowledge

"Assist the Northeast and Mid-Atlantic region to reduce building sector energy consumption 3% per year and carbon emissions 40% by 2030 (relative to 2001)"

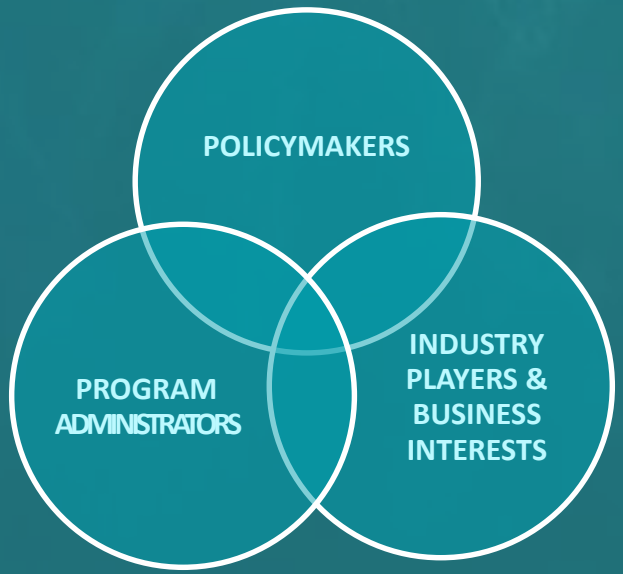
About NEEP

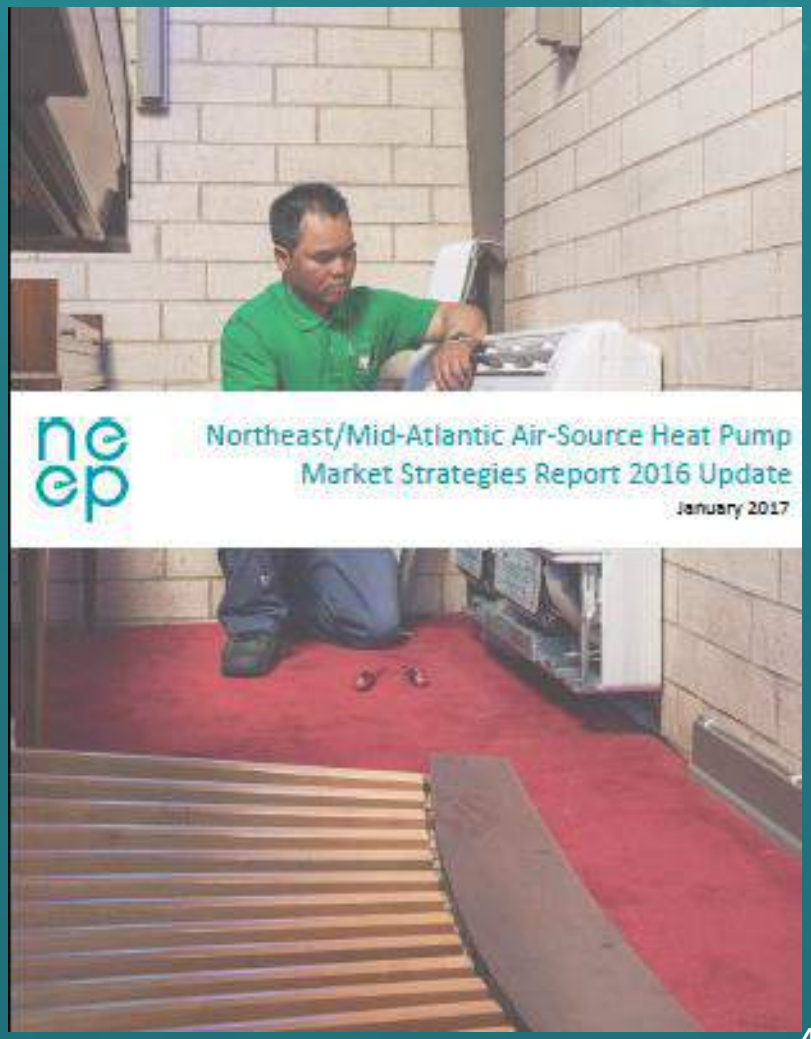
A Regional Energy Efficiency Organization

Here's what I'll be covering today

- Quick background on NEEP's regional Air-Source Heat Pump Initiative
- Why we care about design and installation practices
- Overview of NEEP's ASHP Installer Resources
  - Sizing & Selecting
  - Installation

Regional ASHP Market Transformation Strategy





ASHP adoption plays a significant role in our region achieving carbon reduction goals

- Assumed Market shares in 2035 according to NEEP's "Plausibly Optimistic" scenario reflects;
  - Residential Heat Pumps-
    - 89% for delivered fuel systems
    - 68% sales share of today's natural gas systems sales

Market Transformation Strategies

1. Increase Consumer Education and Awareness
2. Increase Installer/Builder Awareness of, and Confidence in, ASHP through expanded training and education
3. Reduce Upfront Costs of installed systems through robust and aligned promotional programs and the support of alternative business models
4. Mobilize State and Local Policymakers to expand support for ASHPs
5. Promote Advanced Control technologies to allow automated coordination among multiple heating systems
6. Enable the promotion of climate-appropriate ASHPs through Improved Performance Metrics
7. Develop more accurate tools to predict energy, cost and GHG savings associated with ASHP installation through collection and analysis of Real World Performance Data

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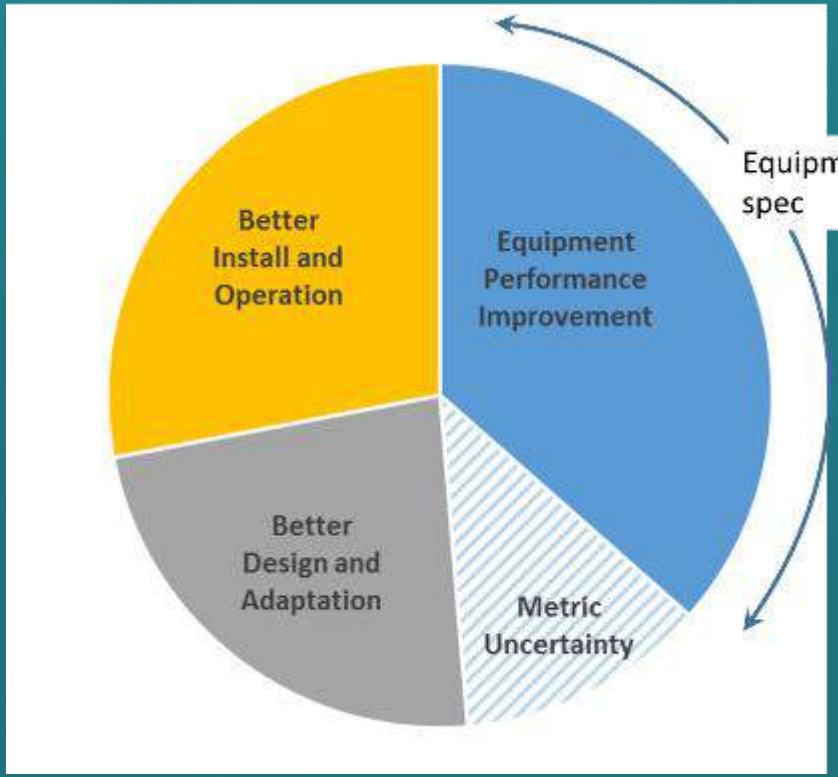
In field performance relies on the design, equipment, and install

- We often focus too heavily on equipment ratings
- Working regionally and with partners outside the region on driving improvements in all areas



Sizing/selecting/installing in cold climates

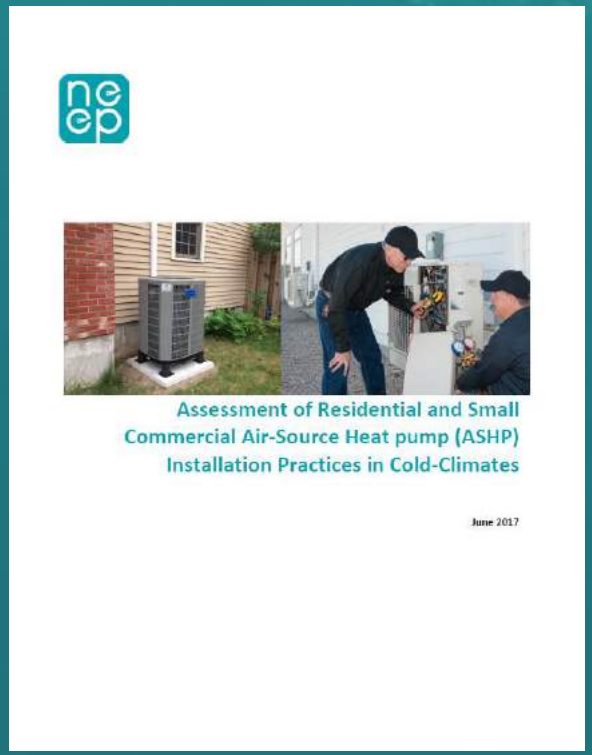
- Sizing/selection/Installation crucial to system performance
- New systems, new applications challenge longstanding metrics, tools and practices.

Quantifying the opportunity

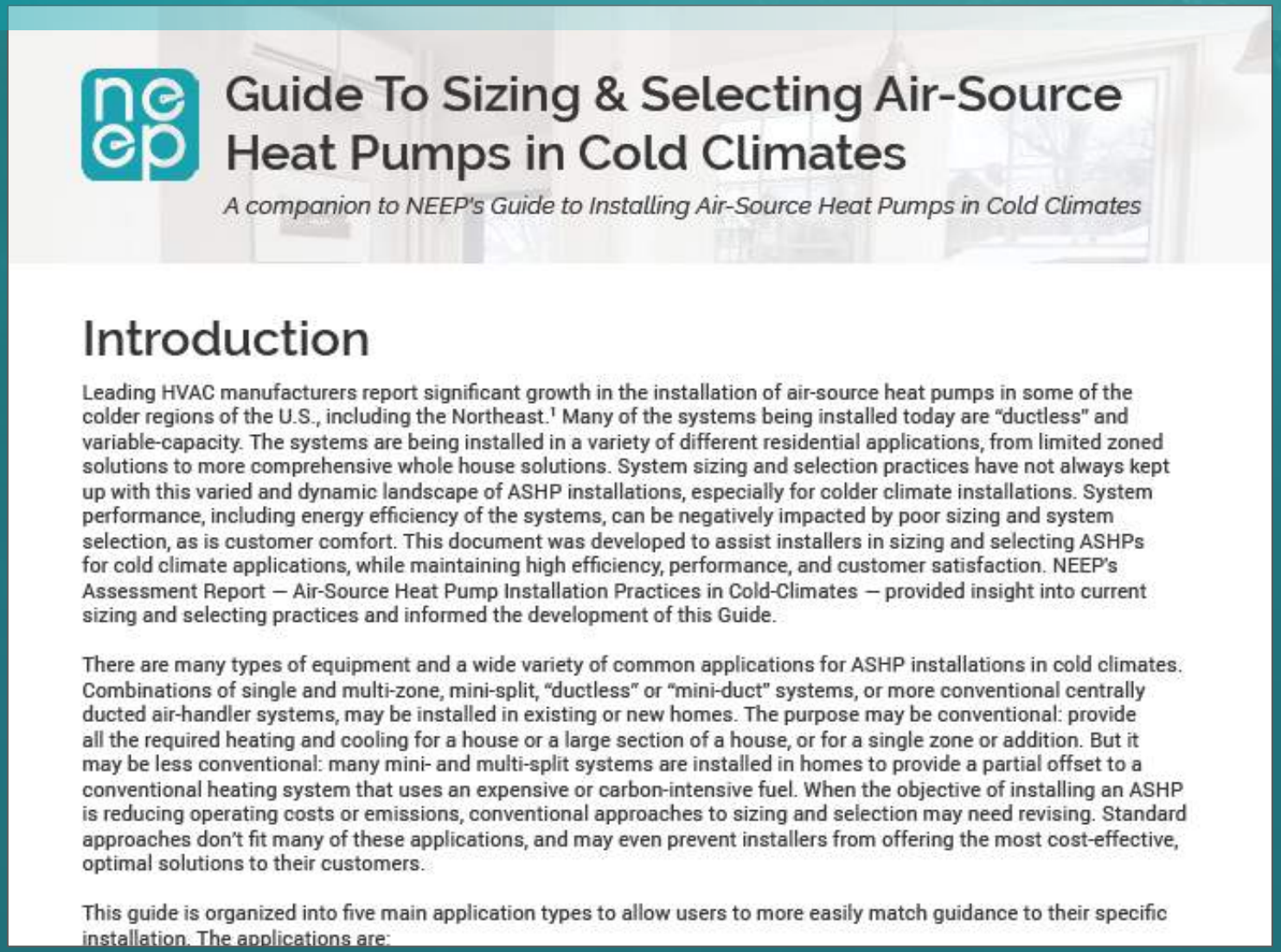
- Numerous studies have found significant energy penalties resulting from installation faults
- 2014 NIST Study- “Increases of energy use by 30% due to improper installation practices seem to be plausible.”
- Anecdotal example- difference between MA/RI and VT field performance results

Resource Development process

- With DOE support
- Assessment of Residential and Small Commercial Air-Source Heat pump (ASHP) Installation Practices in Cold-Climates
- Convened Regional Sub-committee



Sizing and Selecting Guide



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

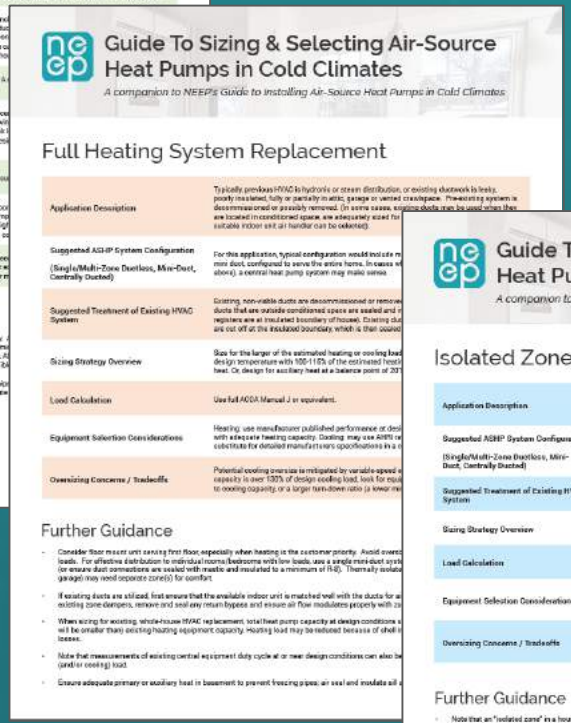
Introduction

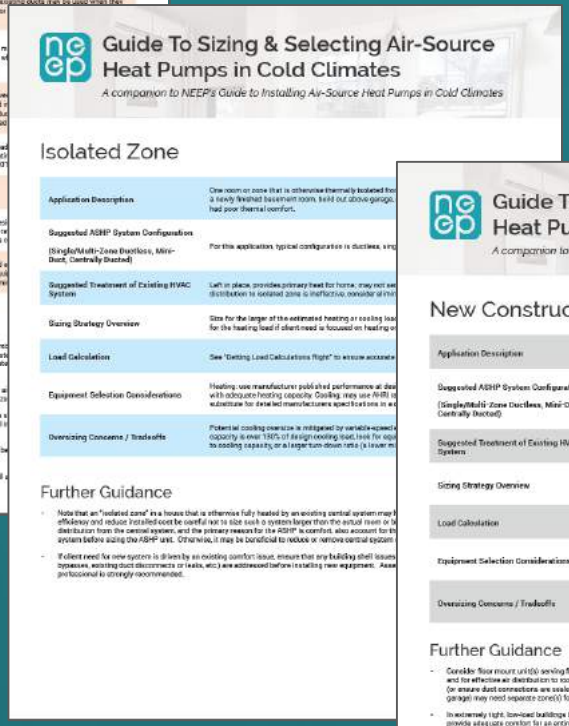
Leading HVAC manufacturers report significant growth in the installation of air-source heat pumps in some of the colder regions of the U.S., including the Northeast.[1] Many of the systems being installed today are "ductless" and variable-capacity. The systems are being installed in a variety of different residential applications, from limited zoned solutions to more comprehensive whole house solutions. System sizing and selection practices have not always kept up with this varied and dynamic landscape of ASHP installations, especially for colder climate installations. System performance, including energy efficiency of the systems, can be negatively impacted by poor sizing and system selection, as is customer comfort. This document was developed to assist installers in sizing and selecting ASHPs for cold climate applications, while maintaining high efficiency, performance, and customer satisfaction. NEEP's Assessment Report — Air-Source Heat Pump Installation Practices in Cold-Climates — provided insight into current sizing and selecting practices and informed the development of this Guide.

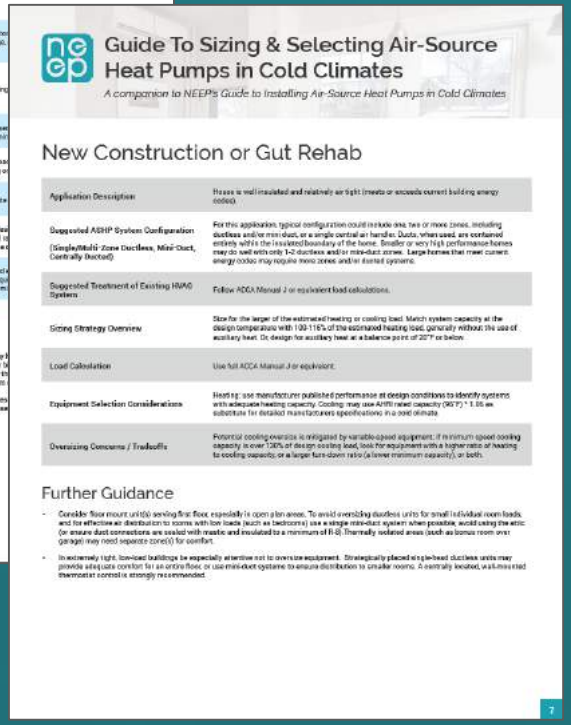
There are many types of equipment and a wide variety of common applications for ASHP installations in cold climates. Combinations of single and multi-zone, mini-split, "ductless" or "mini-duct" systems, or more conventional centrally ducted air-handler systems, may be installed in existing or new homes. The purpose may be conventional: provide all the required heating and cooling for a house or a large section of a house, or for a single zone or addition. But it may be less conventional: many mini- and multi-split systems are installed in homes to provide a partial offset to a conventional heating system that uses an expensive or carbon-intensive fuel. When the objective of installing an ASHP is reducing operating costs or emissions, conventional approaches to sizing and selection may need revising. Standard approaches don't fit many of these applications, and may even prevent installers from offering the most cost-effective, optimal solutions to their customers.

This guide is organized into five main application types to allow users to more easily match guidance to their specific installation. The applications are:

Application Sheets







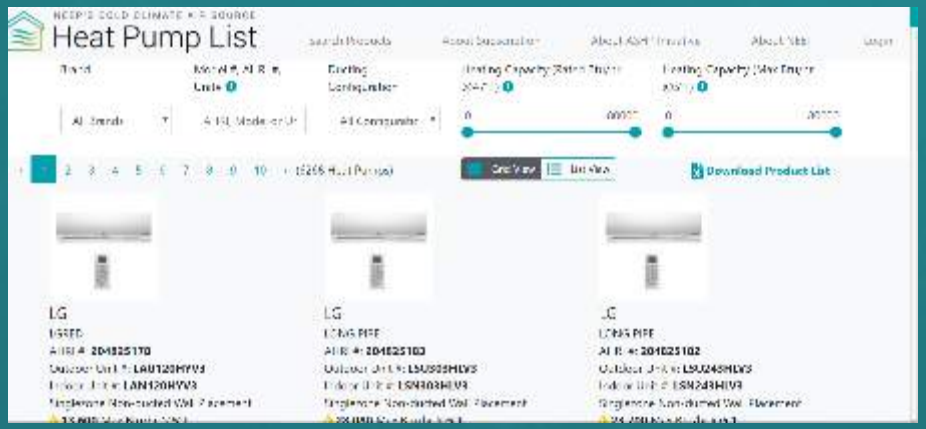
Important concepts

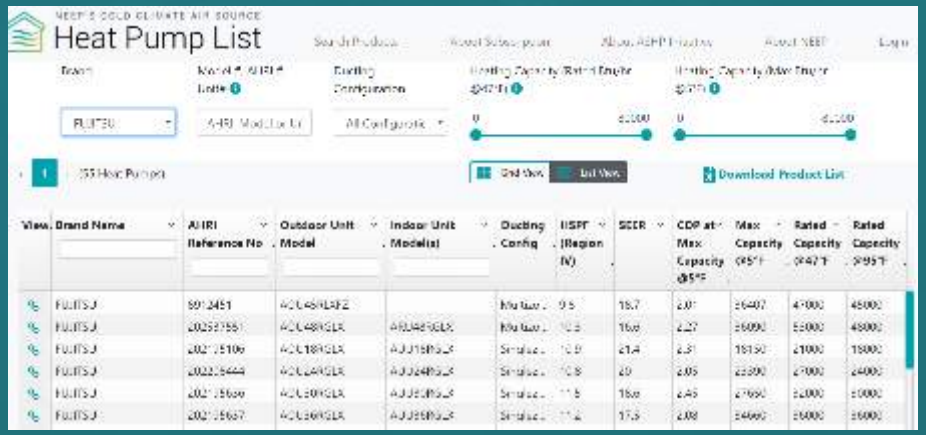
- Address building enclosure issues before sizing/selecting ASHP
  - Reduces heating/cooling costs
  - Reduces needed capacity, cost of system
  - Improved comfort, satisfaction
- Need to go beyond “rule of thumb” Load calculations

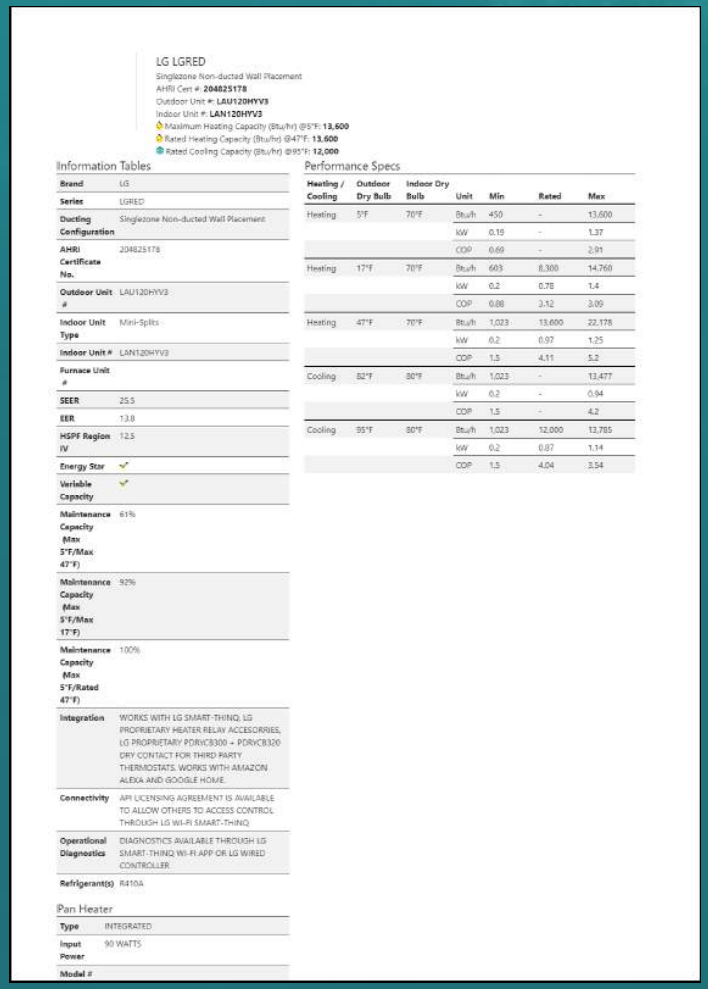
Important concepts

- Oversizing is an efficiency killer
  - Increased importance on load calcs
- Size for heating and cooling, rather than “larger of the two”
- Ensure adequate “turn-down”
- Pay special attention to multi-zones
  - turn-down, oversizing
- Generally encourage more, smaller outdoor units

NEEP Cold-Climate Specification/ Product List







https://neep-ashp-prod.herokuapp.com

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

Installation Best Practices: Categories

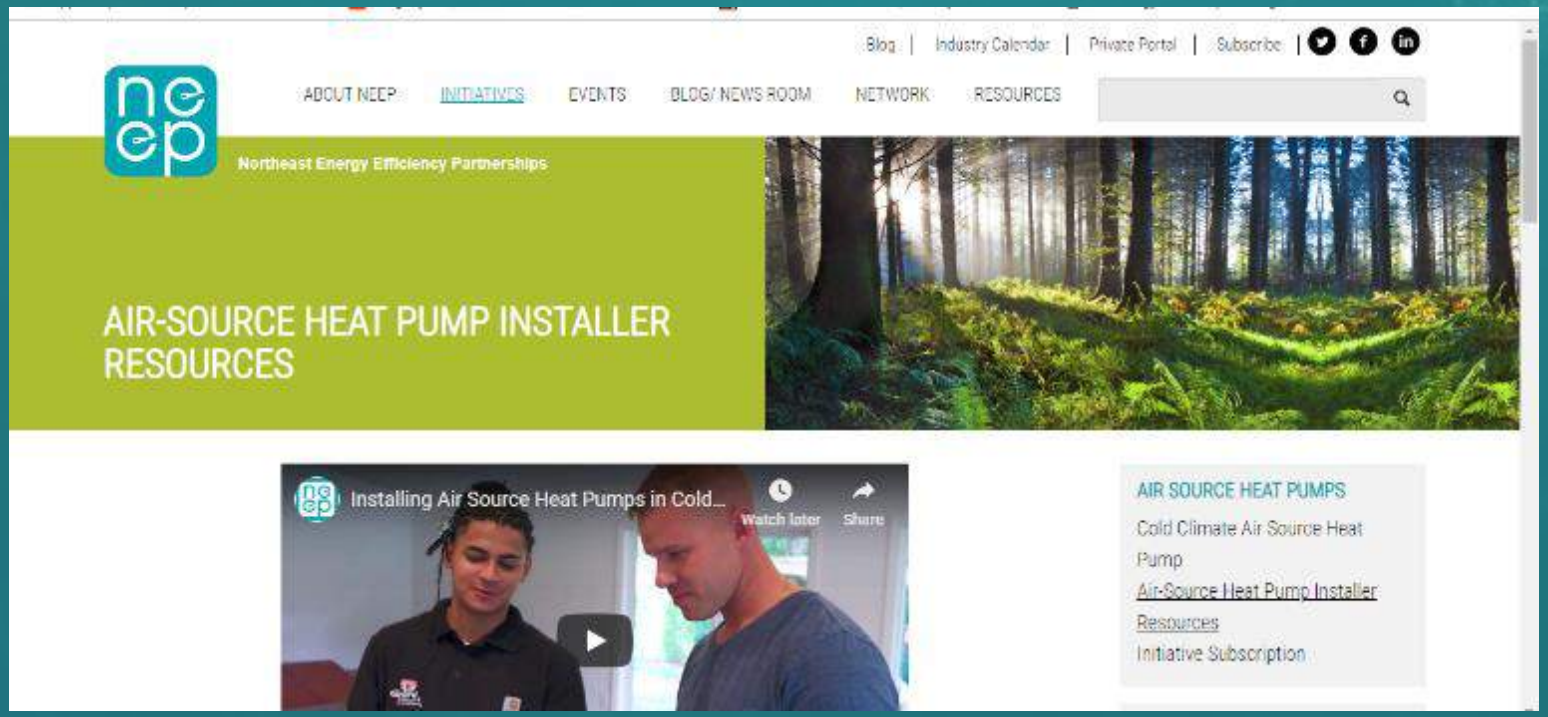
- Line Set
- Recommended Tools
- Refrigerant Tubing
- Refrigerant Charge
- Condensate Drain
- Outdoor Unit Installation
- Indoor Unit Installation
- Placement of Indoor Unit
- Ducting Considerations

Notable for Cold Climates

- Ensure adequate clearance of outdoor unit above historical average maximum snow depth
- Focus on protecting outdoor unit from eaves/drip/snow
  - De-emphasis on pan heaters
- Ensure adequate clearance of indoor wall unit from the ceiling
- Recommendation of floor-mount / console units
  - For heating-focused applications, lower floors
- Avoid field fabricated flare fittings if possible
  - Gasketed press/crimp designed for the refrigerant and tubing type (e.g., Sporlan Zoom Lock®, Vulkan LokRing®).
- Wall-mounted control shall be installed in a location that will be representative of the space the unit is serving

Video versions now available

Installer Resources



Go to; www.neep.org/ASHPInstallerResources
Spread the word!

Opportunity going forward…

- Improved ASHP Design practices
- Onboard/3rd party diagnostic functionality
  - QI verification, real time performance monitoring
  - Support for ENERGY STAR's QI requirements
- Expanding virtual platforms for training installers

Take-aways

- QI is important across all HVAC, but particularly critical for ASHP adoption in cold climates
- HVAC Industry/stakeholders need to prioritize this
- Help us get the word out.. please share the Resources, contact us if you have suggestions for updates
  - www.neep.org/ASHPInstallerResources

THANK YOU!

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March 26, 2020

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Christopher Boyce
Emerson Climate Technologies

U.S. DEPARTMENT OF
ENERGY

Sensi Predict Overview

Manage the surprises

Confirm Quality Work

- Reduce Callback

Optimize Workforce

- Expand Technician Efficiency & Coverage
- Eliminate Nuisance Calls
- Balance High Volume Call Periods

Create Meaningful Connections with Homeowners

- Expand Maintenance Relationships
- Increase Close Rate

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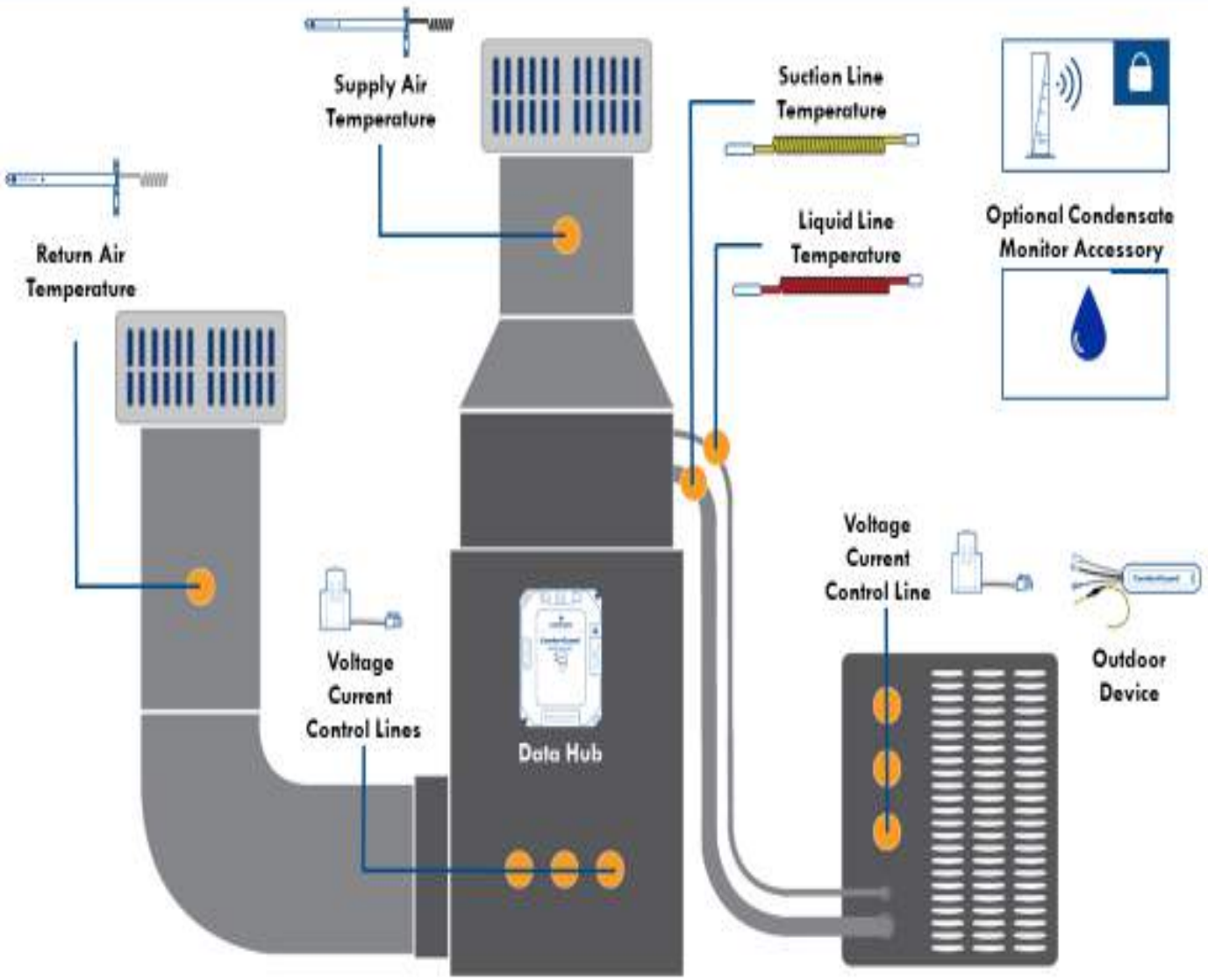
The Product behind the Solution



Live Data Sensors

Supply Air
Return Air
Liquid Temp
Suction Temp
Indoor Control Lines
Outdoor Control Lines
Indoor Current
Indoor Voltage
Outdoor Current
Outdoor Voltage

Automotive Type Predictive Diagnostics comes to HVAC

Predictive Diagnostics – Data leads to Action

32 Key Technical Functions of Sensi Predict

Creating the Bond between Contractor & Homeowner

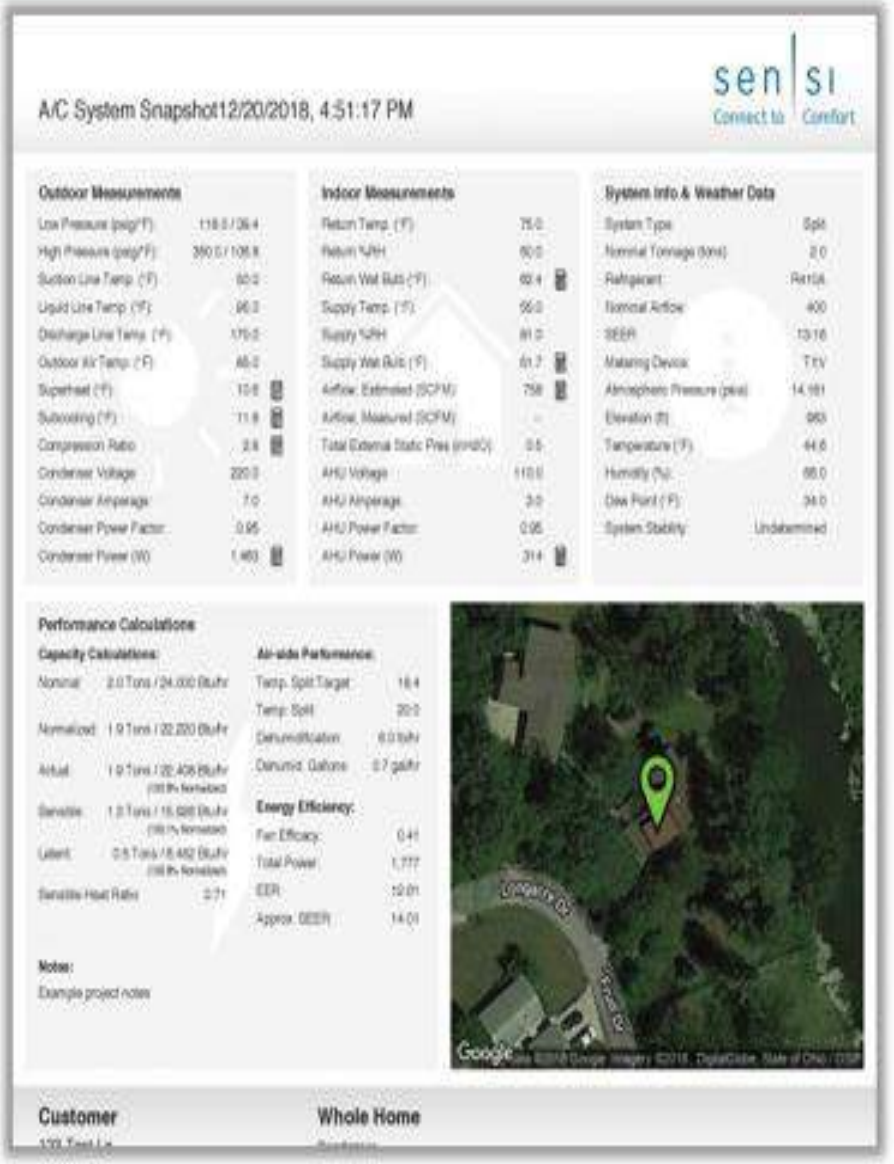
- Ability to Upgrade or Offer Smart Technology
- 24/7 Monitoring
- Real-time Performance Alerts
- Monthly Reports of System Performance/Cost of Operation
- Filter Reminders
- Peace of Mind

Confirm Quality Install with measureQuick

- Reduce Callback
- Tools for technician while on-site for performance confirmation
- Provide Customers an installation report
- Monthly Reports of System Performance

Confirm Quality Install with measureQuick

- Utilizes Bluetooth Tools
- Most comprehensive diagnostic tool
- Verify SEER & Capacity
- Works with Sensi Predict
  - Sensor Data Live Streams into MQ



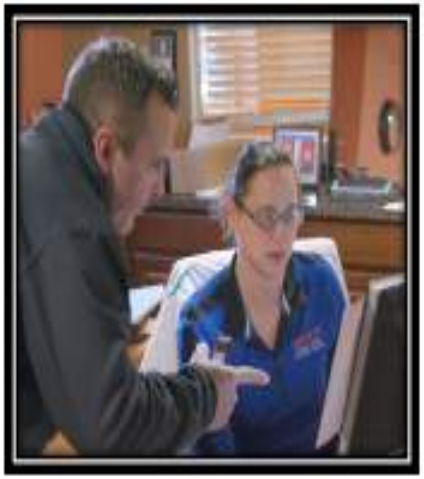
Grow Efficiency and Profitability of the Contractor

- Increase Revenue per Truck Roll
- Manage Workflow / Labor
- Verify Repairs & Quality of Installations

Know Before You GO

Eliminate Nuisance Calls

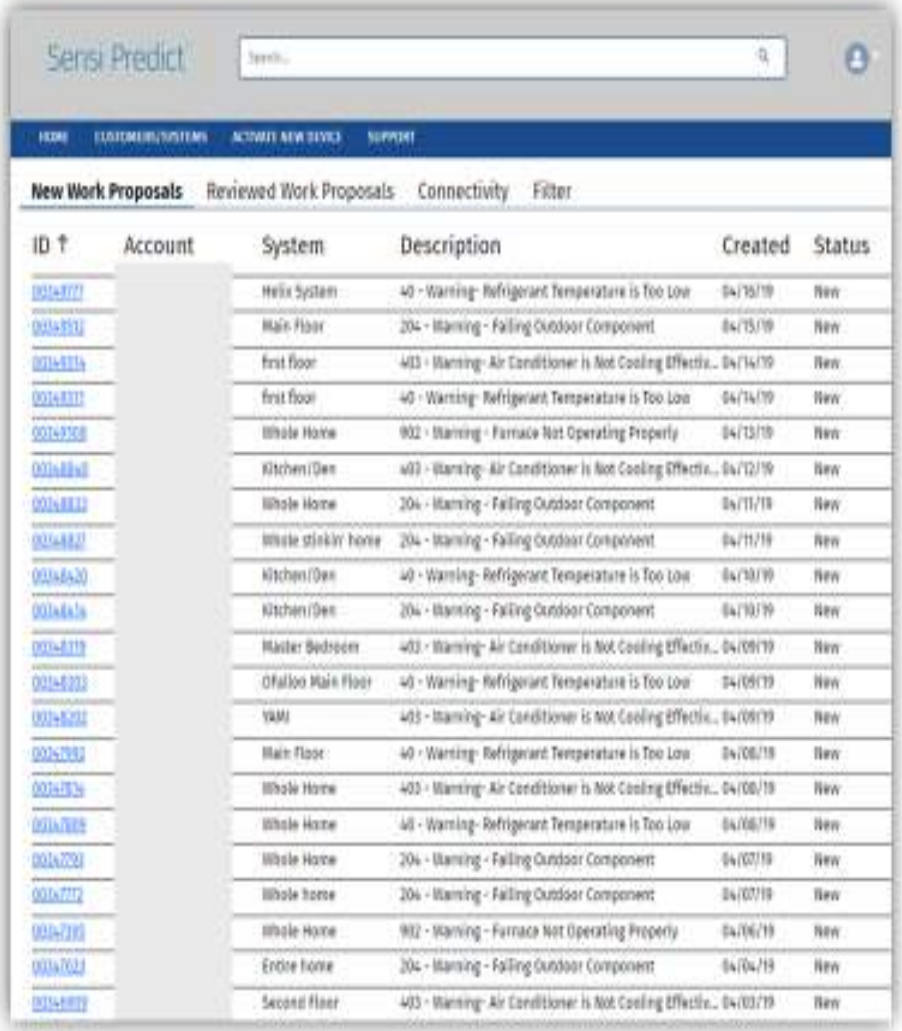
Assign the Right Tech



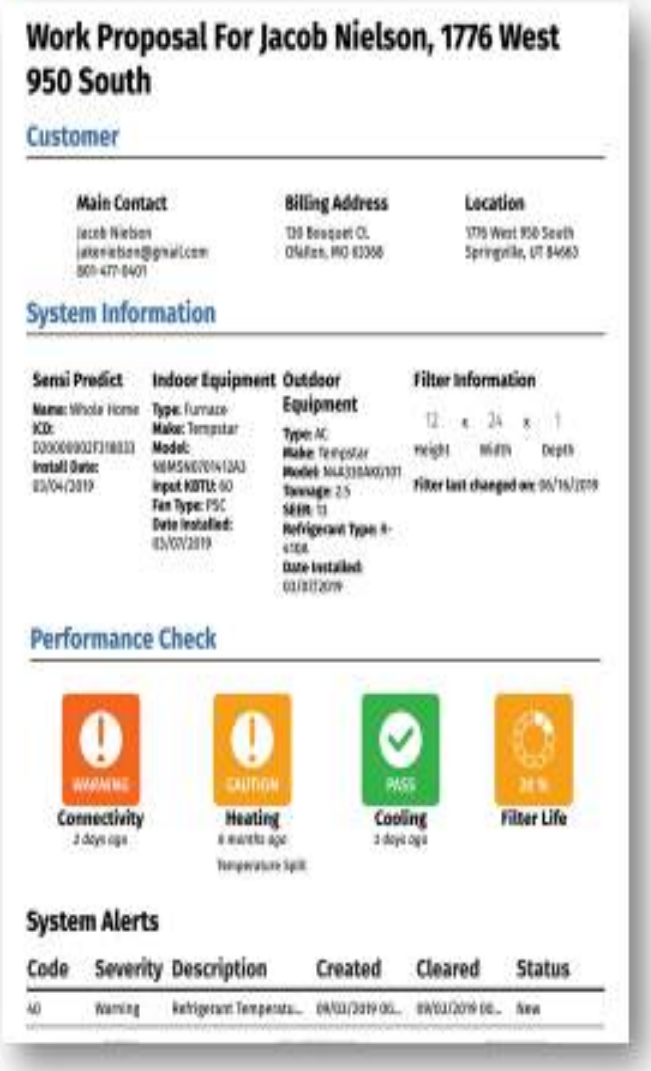
Remote Diagnostic / Work Verification

How information is delivered to Contractor

Work Management Portal



Work Proposal Summary



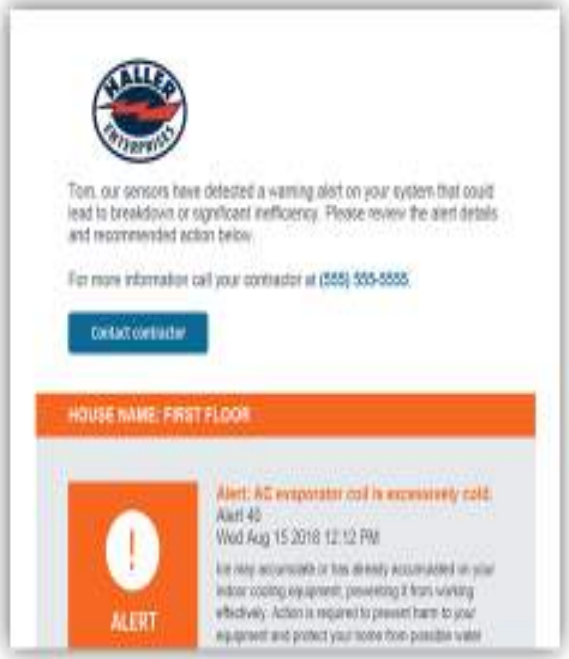
How information is delivered to the Homeowner

Contractor Branding

– Replaces the some traditional awareness marketing Branded communication
  - Performance reports, Account Portal, Monthly Reports, Alerts
  - Links provide direct access to the contractors

Monthly Report

Real-Time Alert



Homeowner Portal

Sensi Predict™

Questions
And Thank You

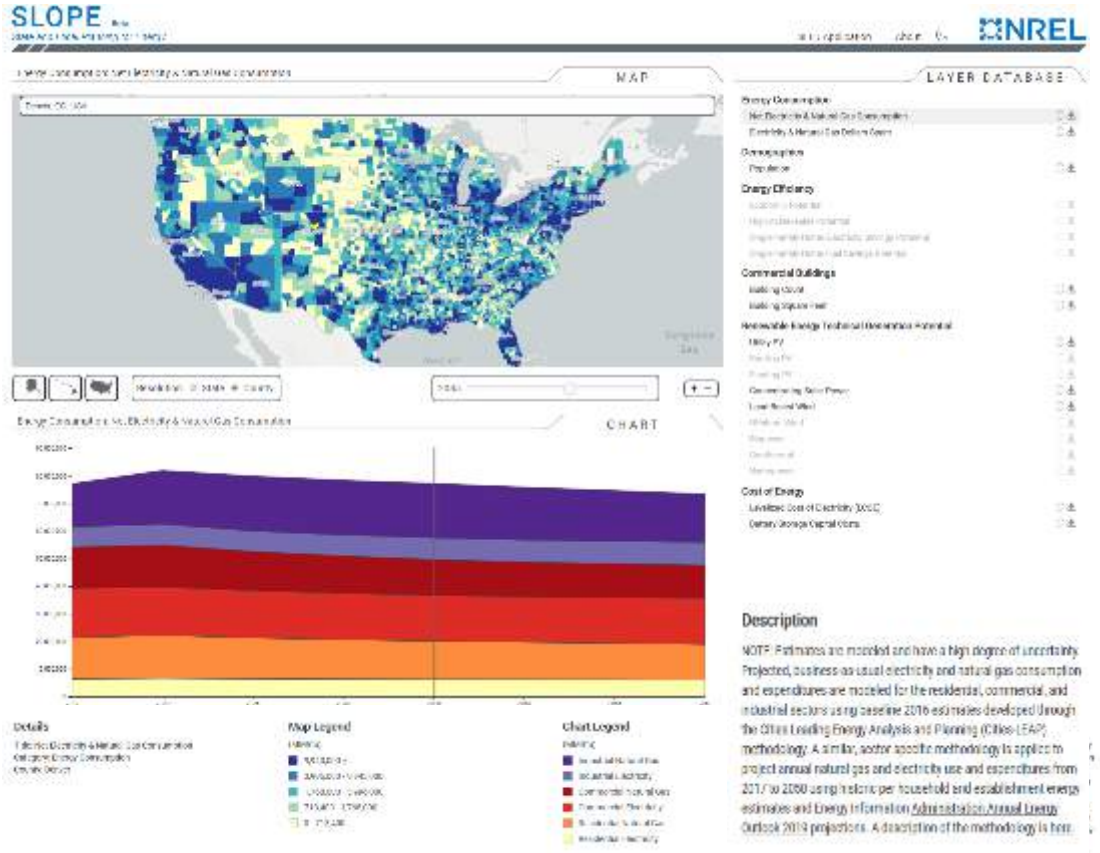
SLOPE Platform

A DOE-led collaboration between NREL and 8 EERE technology offices to create a *dynamic, comprehensive energy planning platform* of integrated, localized data for state and local decision makers

- **Phase I:** Beta version launched (Jan. 2020)
- **Phase II:** Adding transportation and generation mix data; enabling user-saved settings (under development in 2020)

Access the Platform:
https://gds.nrel.gov/slope

Comments or Questions?
slope@nrel.gov



Explore the Residential Program Solution Center

Resources to help improve your program and reach energy efficiency targets:

- Handbooks - explain *why* and *how* to implement specific stages of a program.
- Quick Answers - provide answers and resources for common questions.
- Proven Practices posts - include lessons learned, examples, and helpful tips from successful programs.
- Technology Solutions NEW! - present resources on advanced technologies, **HVAC** & **Heat Pump Water Heaters**, including installation guidance, marketing strategies, & potential savings.

https://rpsc.energy.gov

Thank You!

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Please send any follow-up questions or future call topic ideas to:
bbresidentialnetwork@ee.doe.gov