Earning HERS Points for Quality HVAC Design & Installation

Tuesday, February 26, 2019

Introduction

Installation defects in HVAC systems are commonplace

- Improper airflow.
- Incorrect refrigerant charge.

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							
Blasnik et al. 1995b	CA							
Blasnik et al. 1996	AZ							
Hammarlund et al. 1992	CA							
Hammarlund et al. 1992	CA							
Neme et al. 1997	MD							
Palani et al. 1992	n.a.							
Parker et al. 1997	FL							
Proctor & Pernick 1992	CA							
Proctor 1991	CA							
Proctor et al. 1995a	CA							
Rodriguez et al. 1995	n.a.							
Rodriguez et al. 1995	n.a.							
VEIC/PEG 1997	NJ							
Average								

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%	

Typical operation of an HVAC system

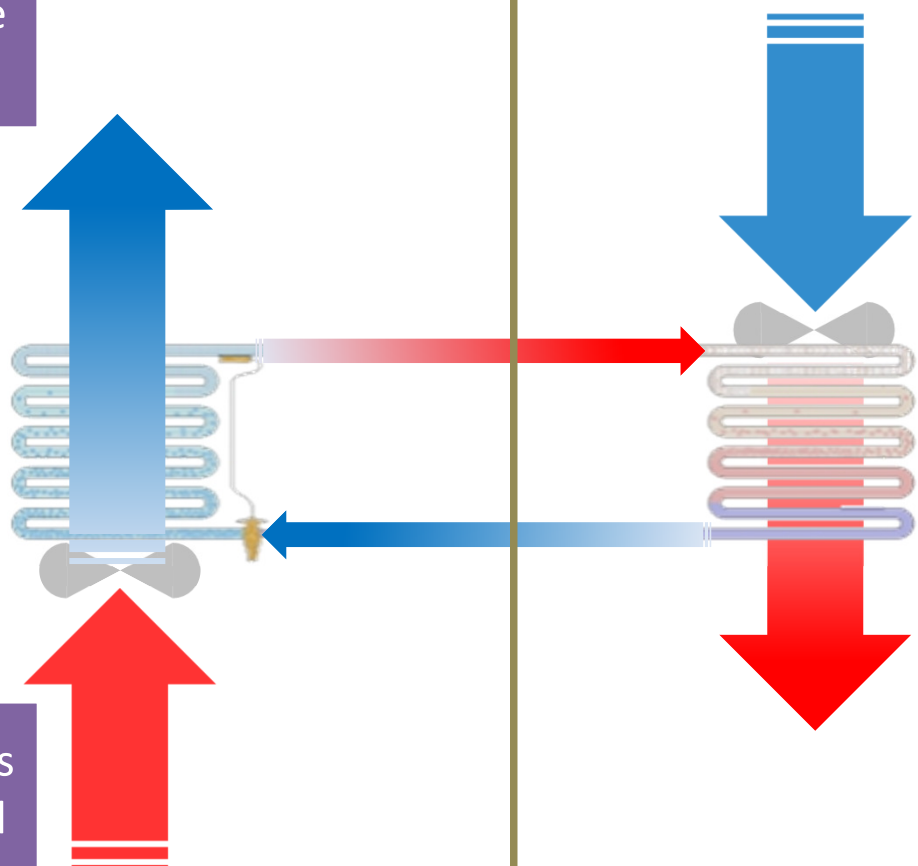
The air's heat is transferred to the refrigerant.

2

Inside the House

1

Warm indoor air is blown over a cold refrigerant coil.



Outdoor air is blown over the hot refrigerant coil.

3

Outside the House

4

The refrigerant's heat is transferred to the outdoor air.

The installation process impacts airflow and refrigerant charge

- Airflow is impacted by the installation:
  - Fan-speed setting
  - Components attached to the system (like the filter)
  - Duct system installed
- Refrigerant charge is impacted by the installation:
  - Length of refrigerant line

Why is this relevant to HERS / ERI ratings?

- Today, installation faults have zero impact on a HERS or ERI rating.
- Not only do these faults impact efficiency, they impact performance.
- ENERGY STAR has promoted quality installation since 2011.
- However, uniform and practical procedures for Raters to assess systems will be a more effective approach.
- And, HERS / ERI points can be granted in exchange.

A standard is born

- ACCA initiated a proposal that RESNET include an evaluation of HVAC design and installation in the HERS index.
- In Summer 2016, EPA started leading a working group.
- The working group encompasses a diverse set of stakeholders interested in solving this problem:

Jim Bergman, Measure Quick	Laurel Elam, RESNET	Brian Mount, Tempo Air
Tommy Blair, AE	Philip Fairey, FSEC	Dave Roberts, NREL
Michael Brown, ICF	Dean Gamble, EPA	Dennis Stroer, CalcsPlus
Greg Cobb, EI	Dan Granback, EI	Iain Walker, LBNL
Wes Davis, ACCA	James Jackson, Emerson	Dan Wildenhaus, TRC
Brett Dillon, IBS Advisors	Rob Minnick, Minnick's Inc.	Jon Winkler, NREL

Guiding principles of the standard

- Take a ‘carrot’ rather than a ‘stick’ approach.
- Reward incremental improvement by HVAC professionals and Raters.
- Rely upon procedures that deliver value in and of themselves.

Conceptual overview of standard

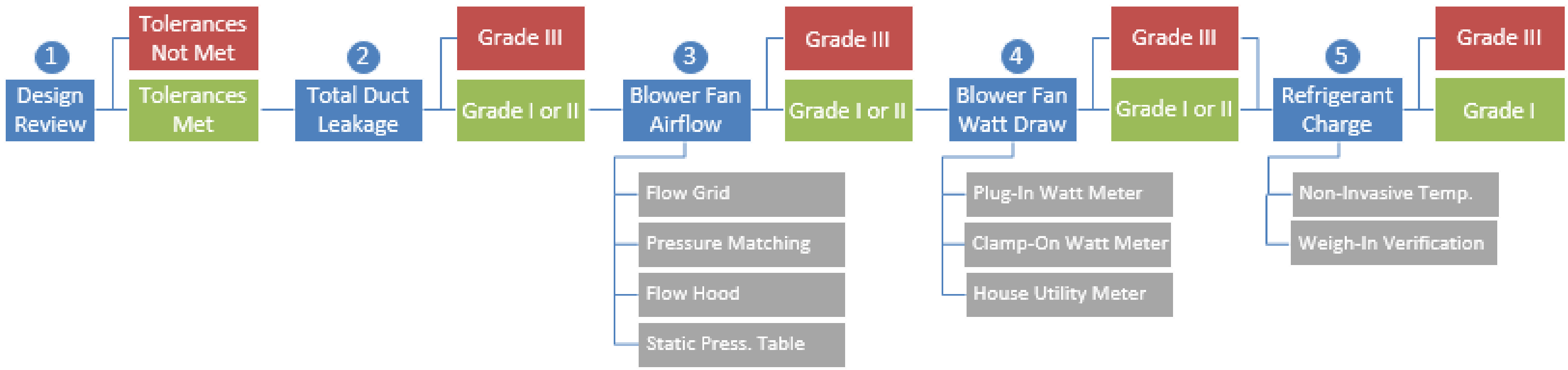
- Follow the insulation quality-installation model:
  - Grade III:
    - The default.
    - HVAC system installation quality is not assessed.
    - No HERS points earned (but no penalty either).
  - Grade II:
    - Rater assesses HVAC system.
    - HVAC system installation quality is so-so.
    - Some HERS points are earned.
  - Grade I:
    - Rater assesses HVAC system.
    - HVAC system installation quality is pretty good.
    - Full HERS points are earned.

A standard will be born..

- RESNET and ACCA have reviewed a nearly final draft.
- Currently working to address their comments and create a final draft.
- Then we proceed to public comment.
- Once the standard is final:
  - An implementation date will be set.
  - Raters will be trained.
  - Software will be updated.

Overview of Standard 310: Standard for Grading the Installation of HVAC Systems

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



Task 1: Design Review

Task 1: Evaluating the design of the forced-air system

1. Rater collects design documentation for the dwelling with the HVAC system under test.
2. Rater reviews design documentation for completeness and compares it to the dwelling to be rated. Key features must fall within tolerances defined in the standard. For example:

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

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

ENERGY STAR Partners are already doing this!

Task 2: Total Duct Leakage

Task 2: Evaluating the 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
I	Rough-In	< 3	4 CFM/100 sqft or 40 CFM
	Rough-In	≥ 3	6 CFM/100 sqft or 60 CFM
	Final	< 3	8 CFM/100 sqft or 80 CFM
	Final	≥ 3	12 CFM/100 sqft or 120 CFM
II	Rough-In	< 3	6 CFM/100 sqft or 60 CFM
	Rough-In	≥ 3	8 CFM/100 sqft or 80 CFM
	Final	< 3	10 CFM/100 sqft or 100 CFM
	Final	≥ 3	14 CFM/100 sqft or 140 CFM
III	N/A	N/A	No Limit

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

ENERGY STAR Partners are already doing this!

Task 3: Blower Fan Airflow

Task 3: Evaluating the Blower Fan Volumetric Airflow

- Raters measure the total volumetric airflow going through the blower fan using one of four test methods:
  A. Pressure Matching
  B. Flow Grid
  C. Flow Hood
  D. OEM Static Pressure Table
- This is just a single measurement. It is not measuring the airflow from each register and summing those.

Task 3: Evaluating the Blower Fan Volumetric Airflow

A. Pressure Matching

1. Measure static pressure created in supply plenum during operation of HVAC system.
2. Turn off HVAC system, connect a fan-flowmeter at the return or at the blower fan compartment.
3. Turn on the HVAC system and the flowmeter fan and adjust to achieve same static pressure in supply plenum.
4. Determine HVAC airflow by recording airflow of flowmeter fan.

Task 3: Evaluating the Blower Fan Volumetric Airflow

A. Pressure Matching

Pros	Cons
Uses equipment many Raters already own	Can’t reach high flows for big systems: needs extrapolation
Accurate: +/- 3%	Need at least one large return duct or must connect at equipment
	Requires hole in supply plenum

Task 3: Evaluating the Blower Fan Volumetric Airflow

B. Flow Grid

1. Measure static pressure created in supply plenum during operation of HVAC system.
2. Install flow grid in filter slot.
3. Measure pressure difference at flow grid and convert to airflow.
4. Re-measure static pressure in same location as Step 1, and correct airflow.

Task 3: Evaluating the Blower Fan Volumetric Airflow

B. Flow Grid

Pros	Cons
Easy/simple for many systems	Multiple filter slots in a single system require multiple flow grids
Can work at higher flows	Need to make sure a good seal is achieved around the plate perimeter
	Slightly less accurate +/- 7%
	Requires hole in supply plenum

Task 3: Evaluating the Blower Fan Volumetric Airflow

C. Flow Hood

1. Turn on HVAC system.
2. Connect flow hood to return grille.
3. Turn on flow hood and allow reading to stabilize. This may require an additional step to account for back-pressure.
4. Resulting airflow of flow hood determines HVAC airflow.

Task 3: Evaluating the Blower Fan Volumetric Airflow

C. Flow Hood

Pros	Cons
Accurate: +/- 3%	Can be heavy/unwieldy
Easy to use	Can be sensitive to placement
Does not require hole in supply plenum	Can be expensive
	Will not always fit around air inlet

Task 3: Evaluating the Blower Fan Volumetric Airflow

D. OEM Static Pressure Table

1. Turn on HVAC system.
2. Measure external static pressure of system's supply side and return side.
3. Determine fan-speed setting through visual inspection.
4. Using blower table information, look up total external static pressure and fan-speed setting to determine airflow.

Motor Speed	Tons AC[1]	External Static Pressure, (Inches Water Column)												
		0.1		0.2		0.3		0.4		0.5		0.6	0.7	0.8
		CFM	Rise	CFM	Rise	CFM	Rise	CFM	Rise	CFM	Rise	CFM	CFM	CFM
High	3	1,498	N/A	1,446	N/A	1,368	N/A	1,302	N/A	1,227	N/A	1,145	1,059	954
Med	2.5	1,223	N/A	1,182	N/A	1,153	30	1,099	31	1,051	32	982	901	813
Med-Lo	2	983	35	971	35	945	36	919	37	878	39	813	746	659
Low	1.5	816	42	794	43	758	45	734	46	678	50	637	597	523

Task 3: Evaluating the Blower Fan Volumetric Airflow

D. OEM Static Pressure Table

Pros	Cons
Inexpensive equipment	Rater required to get OEM Blower Table for installed equipment
Works for systems of all sizes and airflows	Needs carefully-placed hole in supply-side and return-side, sometimes in equipment housing


Task 4: Blower Fan Watt Draw

Task 4: Evaluating the 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

Task 4: Evaluating the Blower Fan Watt Draw

A. Plug-In Watt Meter

1. Plug in the watt meter and blower fan equipment into standard electrical receptacle.
2. Turn on equipment in required mode.
3. Record reading from portable watt meter.

Task 4: Evaluating the Blower Fan Watt Draw

A. Plug-In Watt Meter

Pros	Cons
Simple	Not usable with hard-wired equipment
Direct measurement of equipment	

Task 4: Evaluating the Blower Fan Watt Draw

B. Clamp-On Watt Meter

1. Turn on equipment in required mode.
2. Connect clamp-on watt meter to measure voltage and current at either the service disconnect or through a service panel (not at breaker panel).
3. Record reading from clamp-on watt meter.

Task 4: Evaluating the Blower Fan Watt Draw

B. Clamp-On Watt Meter

Pros	Cons
Useable with hardwired equipment that has service panel or service disconnect	Requires proper training and safety equipment
Direct measurement of equipment	

Task 4: Evaluating the Blower Fan Watt Draw

C. Utility Meter

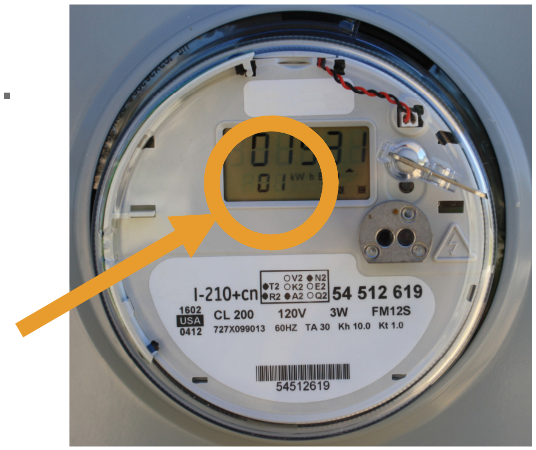
1. Turn off all circuits except air handler's.
2. Turn on equipment in required mode.

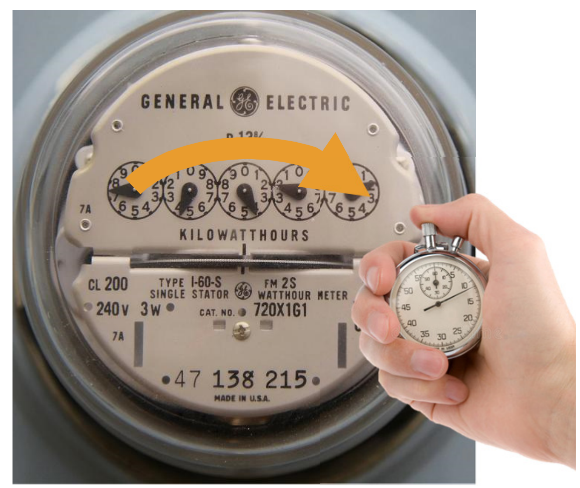
<u>For a digital utility meter:</u>

3. Record watt draw from utility meter.

<u>For an analog utility meter:</u>

3. For 90+ seconds, record the number of meter revolutions and time.
4. Calculate watt draw.





Task 4: Evaluating the Blower Fan Watt Draw

C. Utility Meter

Pros	Cons
Works with all equipment	Indirect measurement, and some meters are less sensitive to low watt draw.
No new equipment needed	Turning off all other circuits can be disruptive

Task 5:
Evaluating Refrigerant Charge

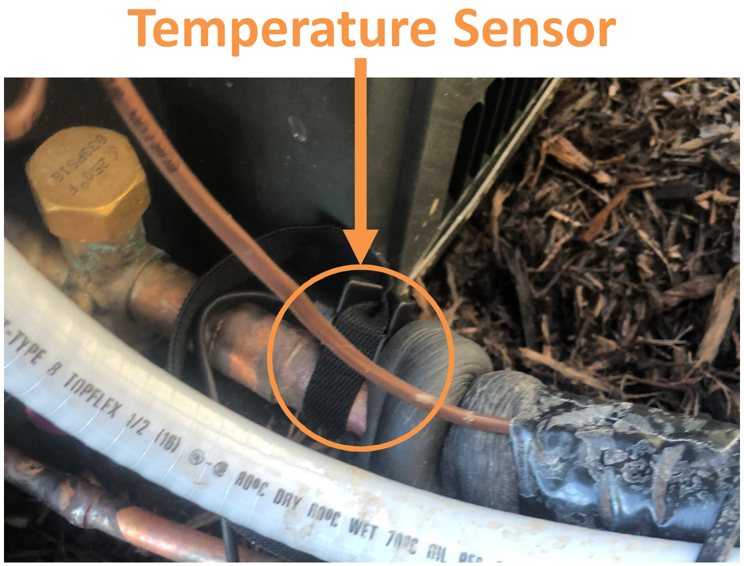
Task 5: Evaluating the Refrigerant Charge

- Raters evaluates the refrigerant charge of the system using one of two test methods:
  A. Non-Invasive Test
  B. Weigh-In Verification - Only for select equipment and conditions

Task 5: Evaluating the Refrigerant Charge

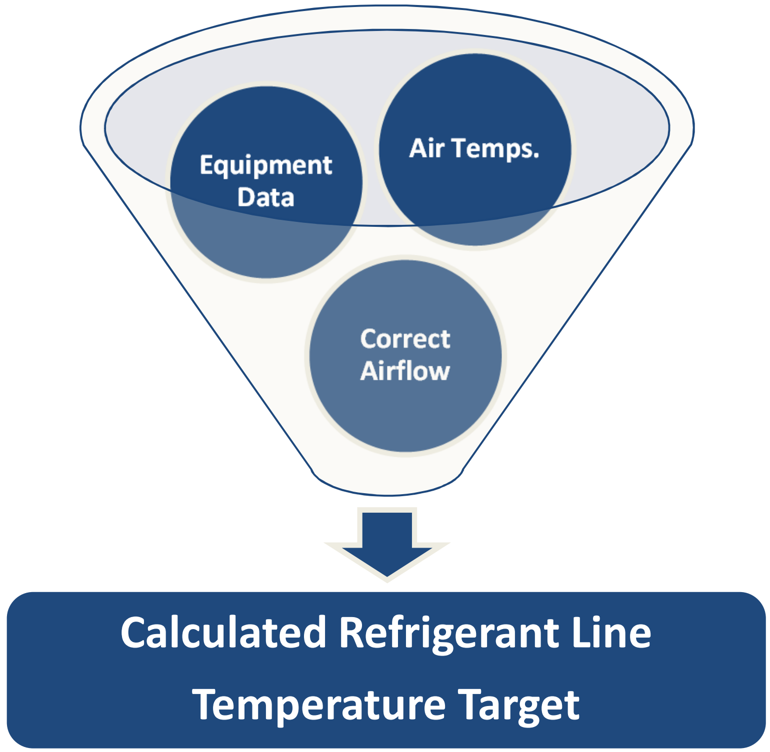
A. Non-Invasive Test

- Non-invasive = No refrigerant gauges
- Triage systems into two bins
  - Grade I – Probably OK
  - Grade III – Not good
- Only flags really bad systems



Task 5: Evaluating the Refrigerant Charge

A. Non-Invasive Test



- How close is the actual refrigerant line temperature to the calculated target?

Task 5: Evaluating the Refrigerant Charge

A. Non-Invasive Test

Step 1	**Determine Equipment Characteristics:** Need SEER, and manufacturer specified superheat / subcooling.
Step 2	**Measure Air Temperatures:** Need outdoor air and return air temperatures.
Step 3	**Calculate Target Refrigerant Line Temperatures:** Calculated for suction line and liquid line.
Step 4	**Measure Actual Refrigerant Line Temperatures:** Measuring both suction line and liquid line with a temperature probe.
Step 5	**Compare & Evaluate:** Compare the target line temperatures to the measured temperatures, if they are too far apart, then the system is not properly charged.

Task 5: Evaluating the Refrigerant Charge

A. Non-Invasive Test

Pros	Cons
No refrigerant handling certification needed	New procedure to learn
No risk of refrigerant contamination and leaks	Minimum outdoor air temperature required
Less Rater liability	

Task 5: Evaluating the Refrigerant Charge

B. Weigh-In Verification

1. Contractor provides:
    1. Weight of refrigerant added / removed
    2. Line length and diameter
    3. Default line length from factory charge (usually 15 feet)
    4. Factory supplied charge
    5. Geotagged photo of scale with weight added / removed

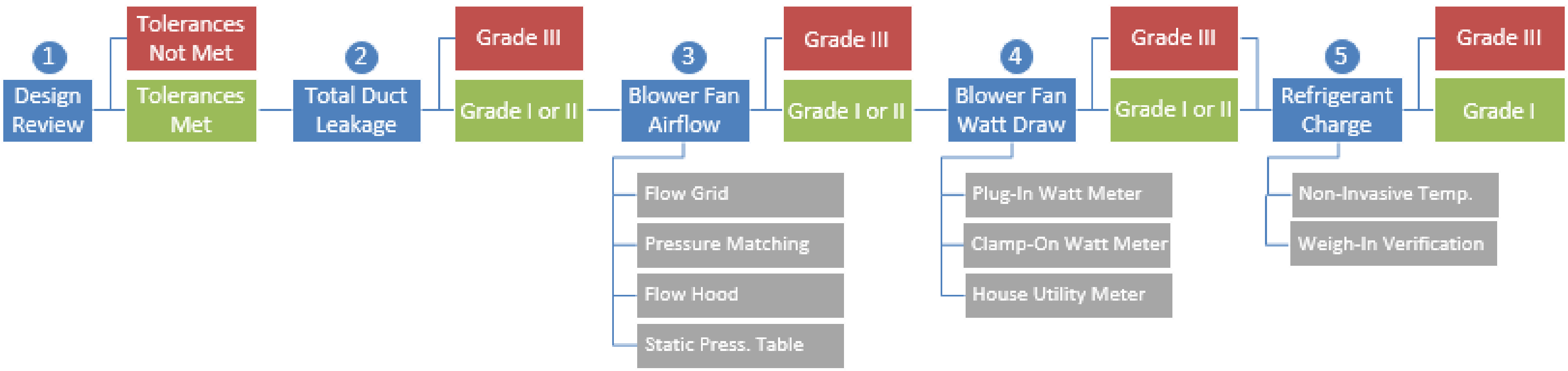
2. Rater then:
    1. Measures line length and diameter
    2. Uses lookup table to determine how much refrigerant should have been added / removed
3. Rater verifies the following:
    1. Deviation between lookup and contractor value within tolerance
    2. Location of geotagged photo matches "in the judgment of the party conducting the evaluation" the location of the equipment

Task 5: Evaluating the Refrigerant Charge

B. Weigh-In Verification

Pros	Cons
No refrigerant handling certification needed	Requires information from contractor
Works at any outdoor temperature	Not a true performance test

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



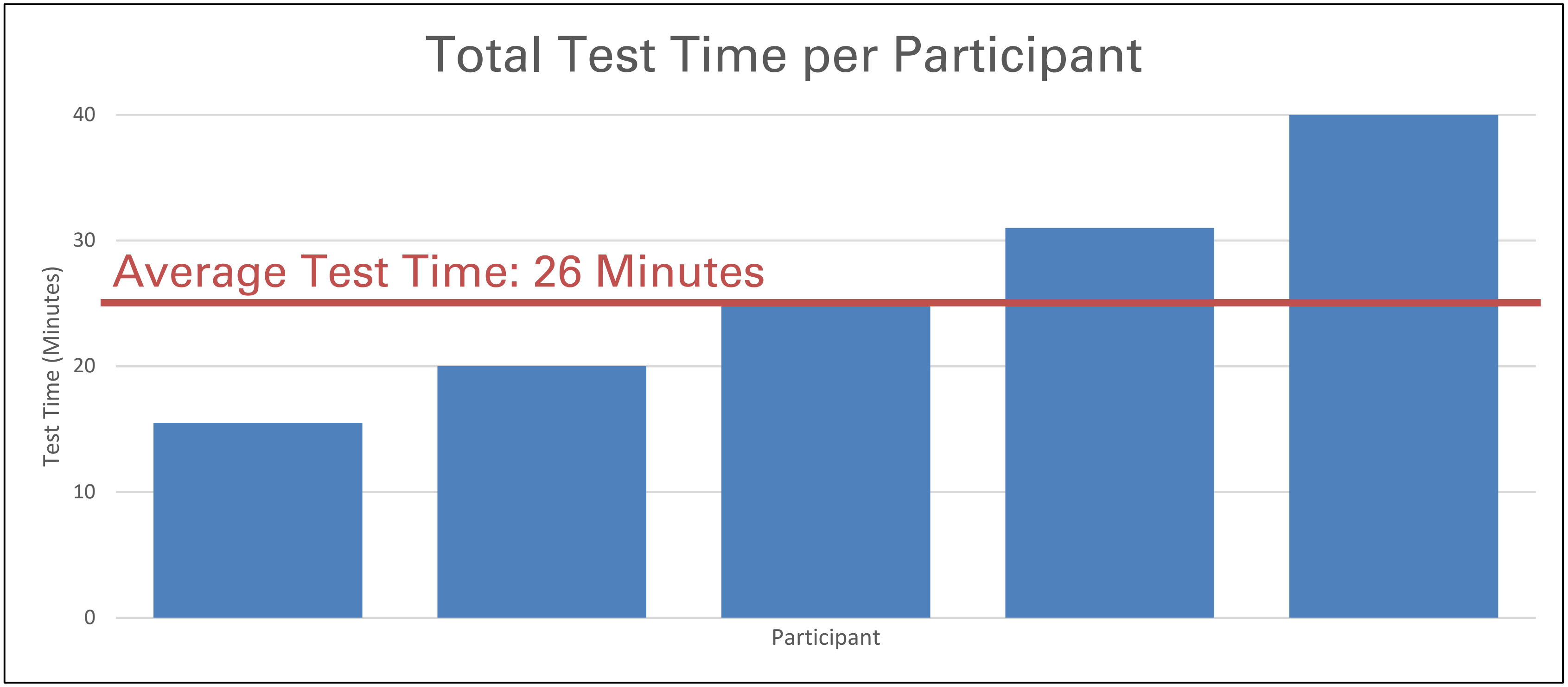
Field Test Results

Field Test: Overview

- Select six providers to give field procedures a quick spin:
  - **18 systems** evaluated
  - **63 individual tests** performed
- Goals:
  - Were there any obstacles or anything unclear in the procedures?
  - Did they have any major concerns with the procedures?
  - How long did it take to conduct each test?
  - Did different test procedures for the same parameter get similar results?
  - Did the systems they tested receive Grade I, II, or III?

Field Test: Required time to test

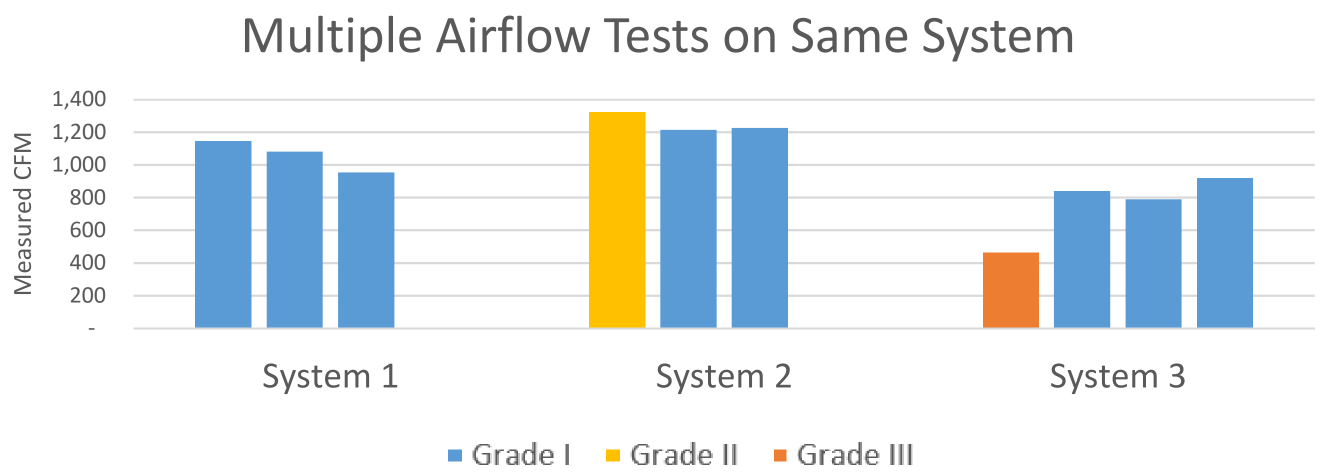
- Required HVAC warm-up time is 15 minutes, but Raters can do other tasks during this time. Then they can proceed with testing.
- Average time for all tests among participants was 26 minutes.



Field Test: Required time to test

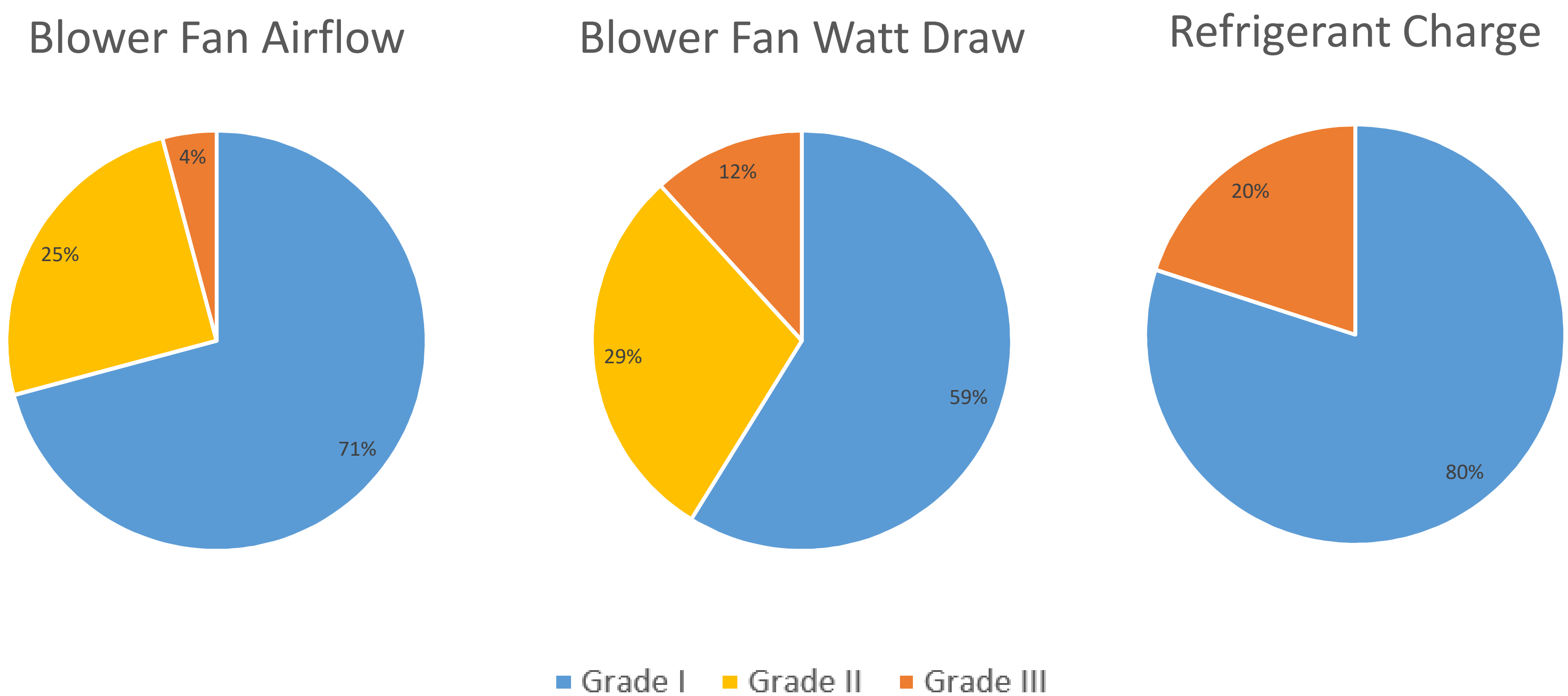
Test Type	Average Time (minutes)	# Tests
Blower Fan Airflow	9	28
Blower Fan Watt Draw	6	18
Refrigerant Charge	11	17

Field Test: Consistency between tests



- These were the first tests done, without training, so this could improve.
- For consistency with a contractor, Raters may need to coordinate on test procedures and equipment.
- However, Grade bins were made to be relatively large to accommodate some variability.

Field Test: What grades were achieved?



Field Test: Qualitative feedback

- No major hurdles were identified.
- Several refinements were suggested (e.g., equipment calibration frequency).
- Some participants found parts of the procedures confusing at first, or time-consuming to follow, but these tests were conducted without training.
- Overall, feedback was positive:
  - "Draft procedures were clear, and [represent] common test protocols in the HERS industry"
  - "The 310 standard offers a lot of benefits to the homebuilding industry and its homeowners, it gives a quantifiable way to confirm that a healthy HVAC system was installed and should minimize warranty issues in this category."

Summary

Summary

- Standard 310 will be a new standard for evaluating the design and installation quality of HVAC systems.
- The standard should be final before we get together at next year's RESNET conference.
- If you're doing ENERGY STAR today, this new standard will look very familiar to you. The key difference will be the field tests.
- This should allow ENERGY STAR builders to get more HERS points for things that they're already doing today.
- This will be a major step towards unifying the ENERGY STAR program and HERS ratings.


Potential HERS Points

Estimating the ERI Point Potential of Quality Installation

David Roberts
Jon Winkler

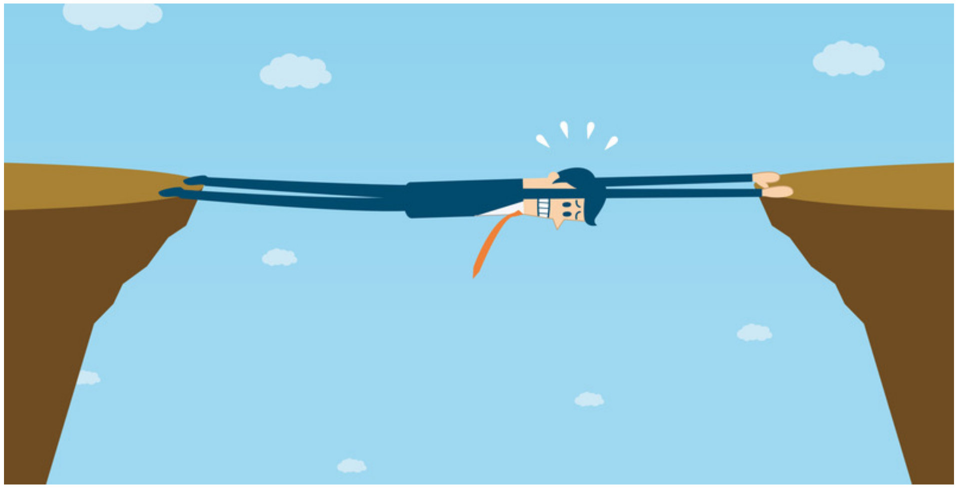
RESNET Building Performance Conference
February 26, 2019

Acknowledgement

- Jon Winkler, Ph.D.
  - Senior Research Engineer
  - Building Energy Science Group
  - National Renewable Energy Laboratory

Overview

RESNET 310
(Grading installation quality)



RESNET 301
(ERI calculation standard)

- Objectives
  - Implement an approach accounting for HVAC installation defects in building energy simulations
  - Estimate the ERI impact of various defect scenarios

Approach

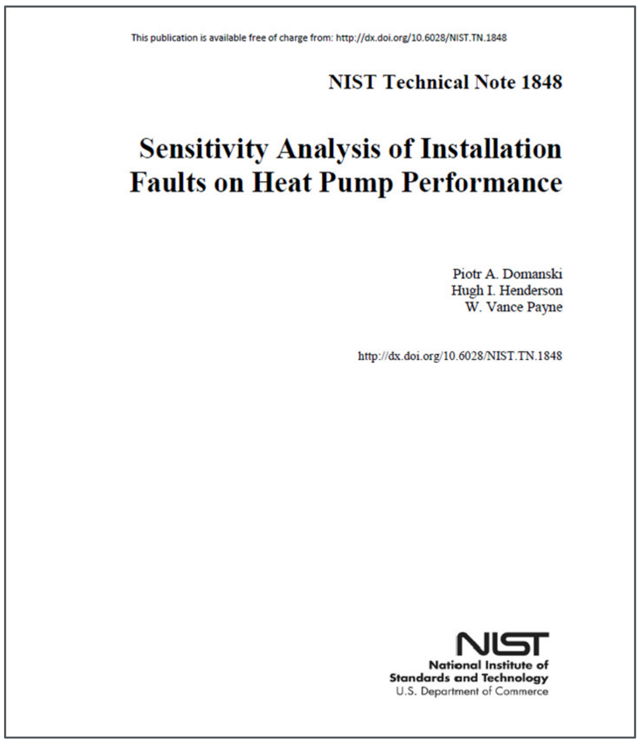
- Two defects of primary interest
  - Refrigerant charge
  - Indoor airflow

- Key steps
  1. Implement air conditioner and heat pump defect correlations in BEopt/EnergyPlus
  2. Construct appropriate new construction house models
  3. Simulate various defect scenarios in multiple climate zones
  4. Estimate the ERI impact

Defect Correlations

Refrigerant Charge

- *NIST Technical Note 1848*
- Experimental testing on one heat pump system
- Inputs: charge level and indoor and outdoor temperatures



This publication is available free of charge from: http://dx.doi.org/10.6028/NIST.TN.1848

NIST Technical Note 1848

Sensitivity Analysis of Installation Faults on Heat Pump Performance

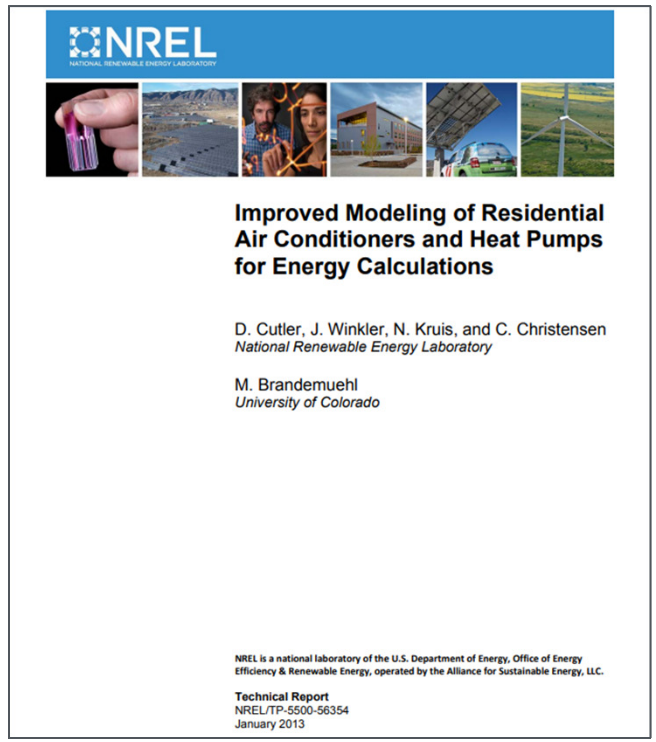
Piotr A. Domanski
Hugh I. Henderson
W. Vance Payne

http://dx.doi.org/10.6028/NIST.TN.1848

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Indoor Airflow

- *NREL Report 5500-56354*
- Manufacturer data on 460 AC and HP systems
- Input: fraction of rated airflow



NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations

D. Cutler, J. Winkler, N. Kruis, and C. Christensen
National Renewable Energy Laboratory

M. Brandemuehl
University of Colorado

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

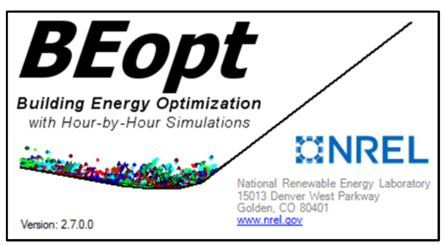
Technical Report
NREL/TP-5500-56354
January 2013

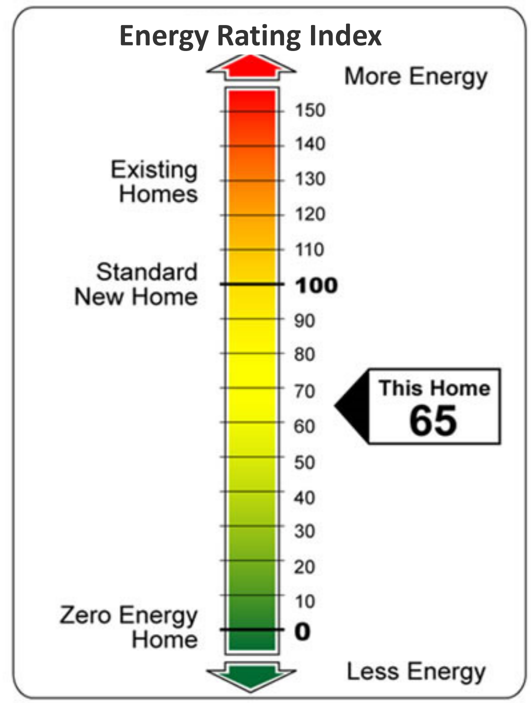
Simulation Methodology

- Implemented defect correlations in BEopt/EnergyPlus scripts using EnergyPlus Energy Management System
  - Impact of the defect was evaluated on a timestep basis
- General approach can be leveraged by other software programs

House Parameters
+
Defect Levels

EnergyPlus Simulations

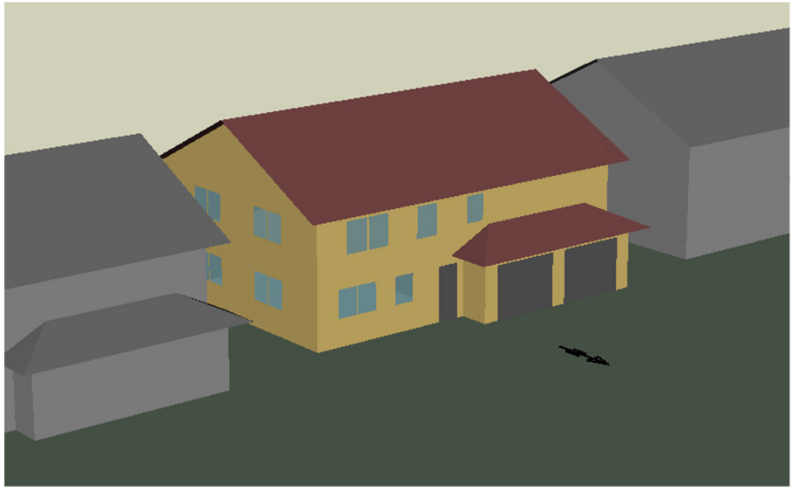




House Parameters

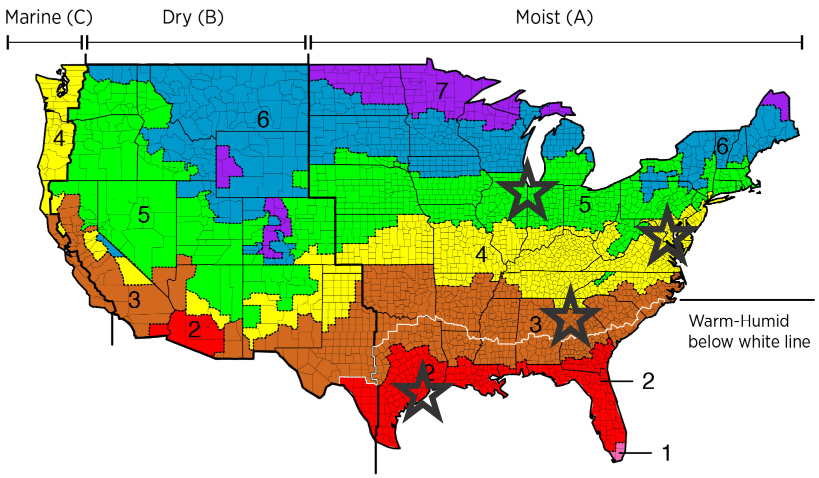
New construction, single-family home

- 3 bed + 2 bath; 2,500 sq. ft
- Construction based on IECC 2009
- Construction and foundation type varied by climate
- Simulations followed RESNET Standard 301



Simulated Locations

- CZ 2 – Houston, TX
- CZ 3 – Atlanta, GA
- CZ 4 – Washington, DC
- CZ 5 – Chicago, IL



Equipment Assumptions

Equipment types

- SEER 14 air conditioner and gas furnace
- SEER 14, 8.2 HSPF central heat pump

Equipment assumptions

- 0.5 W/cfm fan efficiency
- Manufacturer recommended airflow is 400 cfm/ton

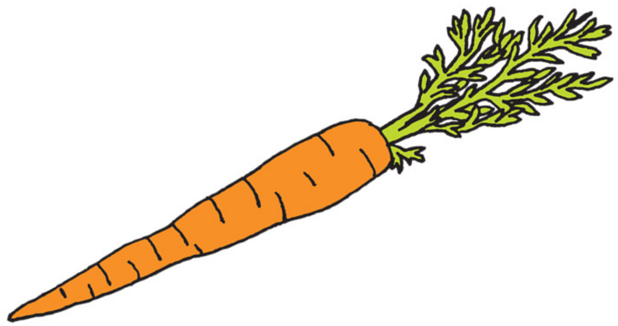
Defect Scenarios

- Percent deviation from manufacturer recommended value
- We included the default defects recommended by the RESNET 310 working group
  - -25% defect → Grade III
  - 0% defect → Grade I

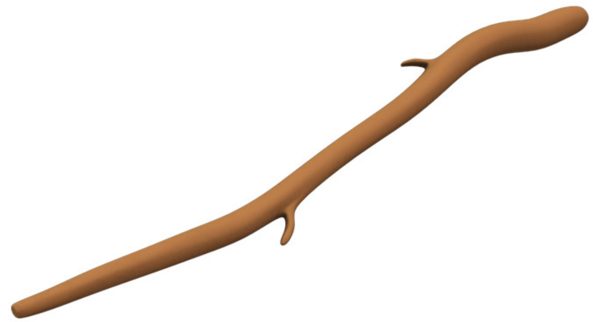
Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Airflow defect level	0%	-25%	0%	-25%
Refrigerant charge defect level	0%	0%	-25%	-25%

Methodology Caveat

- RESNET 310 proposes to apply default defect levels to the *Reference Home*

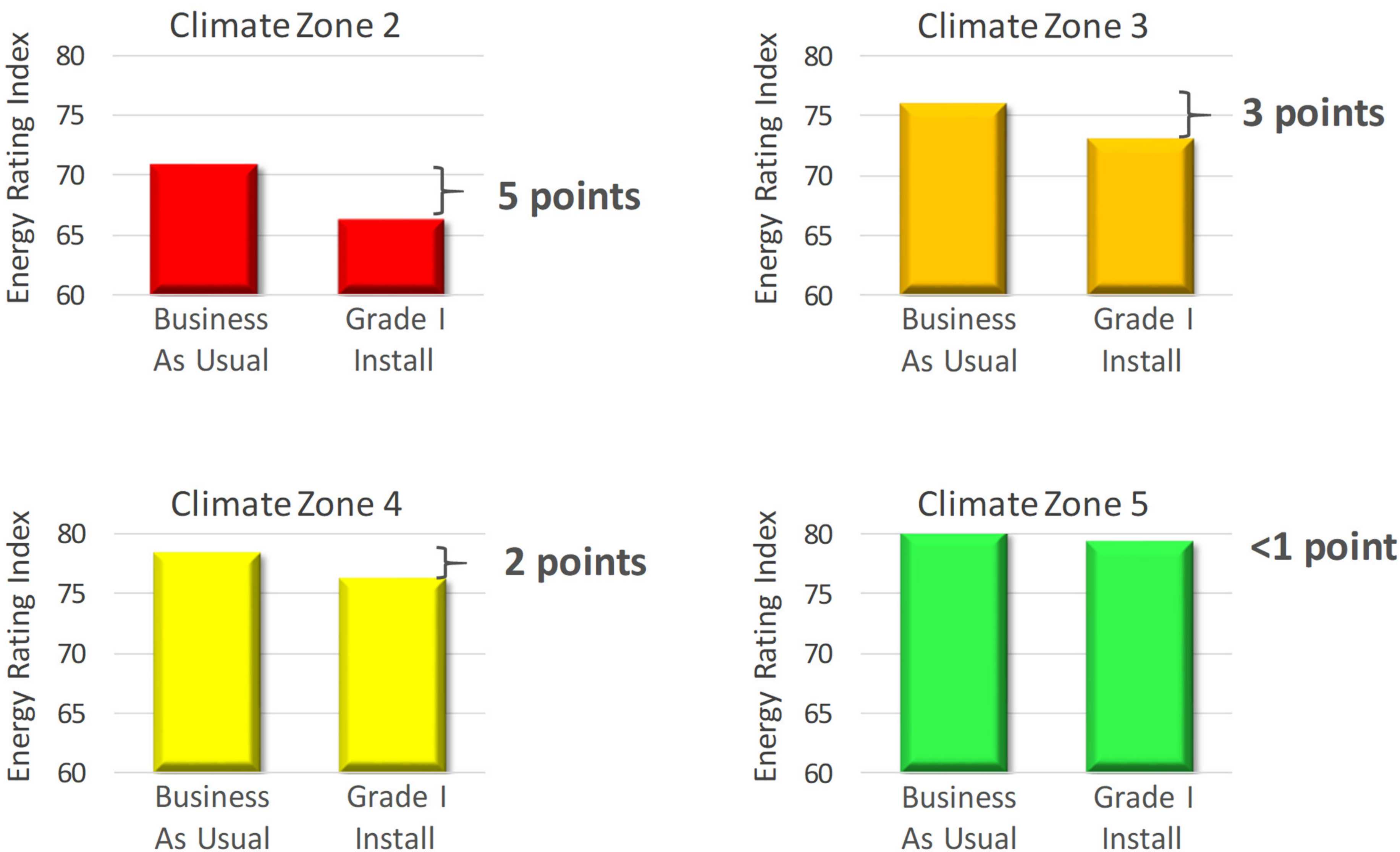


- We applied defects to the *Rated Home* and assumed the reference home did not have defects

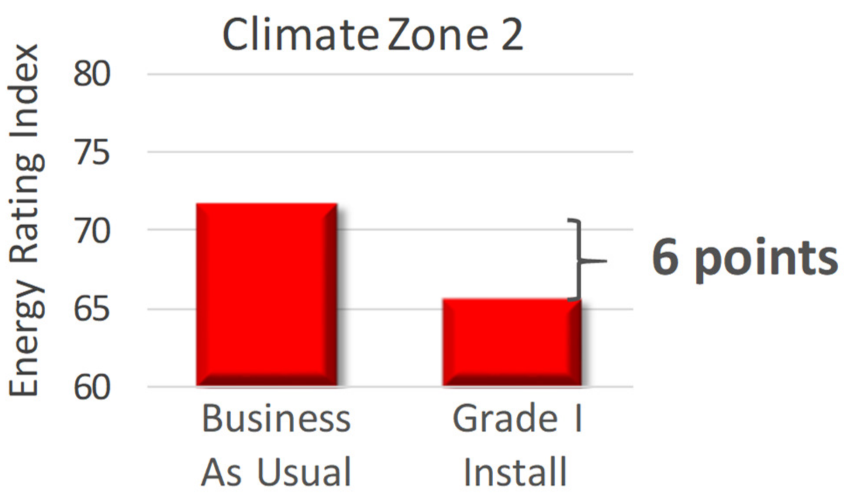


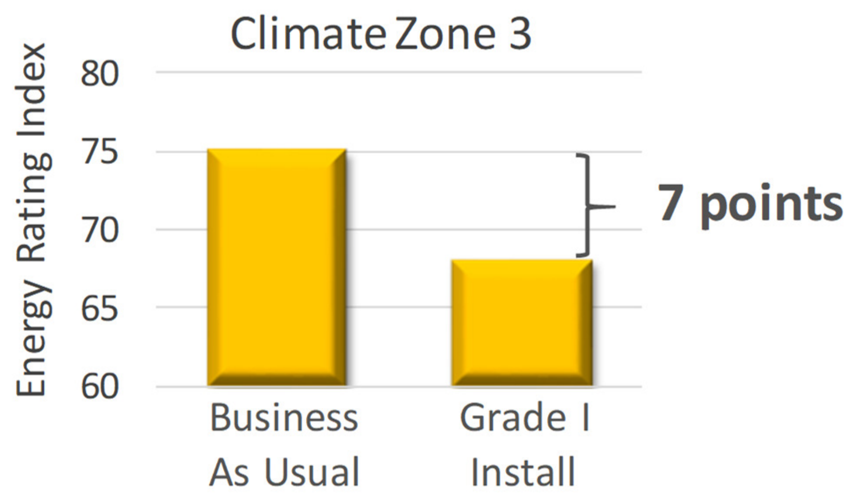
- ERI impact should be similar

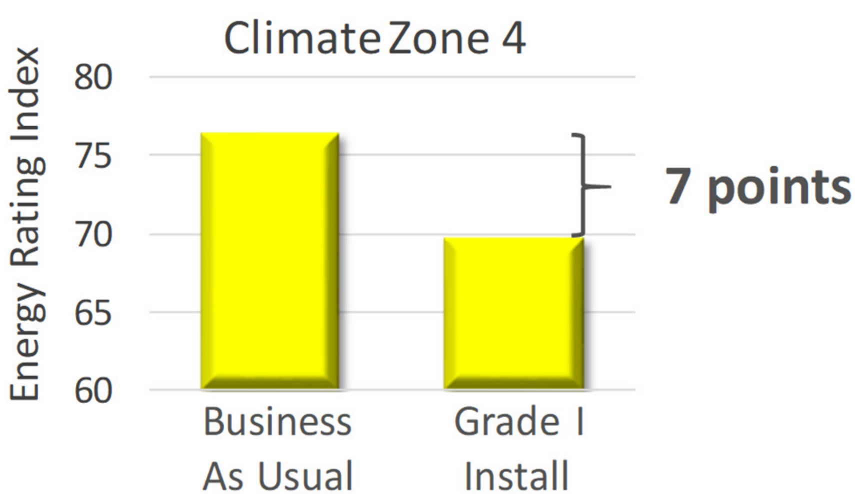
Point Potential – Air Conditioners

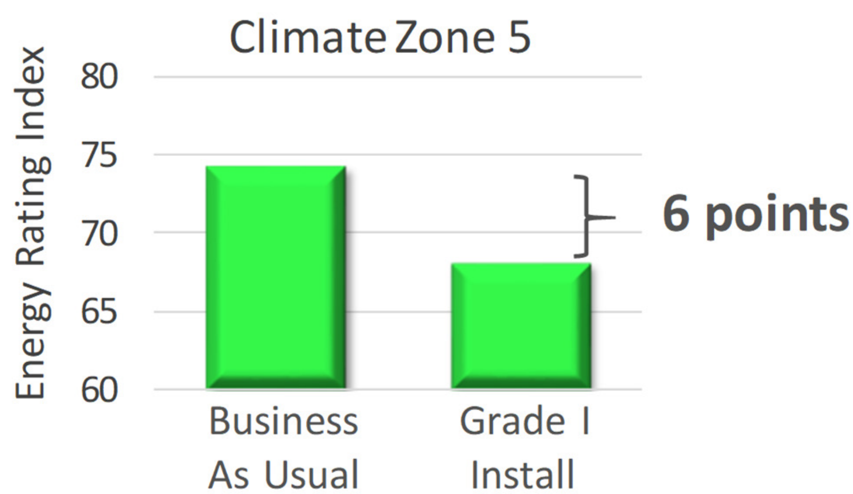


Point Potential – Heat Pumps









Estimated ERI Impact

System Type	Location		Baseline ERI	Defect Scenario Point Potential		
				-25% Airflow 0% Charge	0% Airflow -25% Charge	-25% Airflow -25% Charge
AC	Houston, TX	CZ 2	71	1.5	2.9	4.5
	Atlanta, GA	CZ 3	76	1.2	1.6	2.9
	Washington, DC	CZ 4	78	0.9	1.1	2.1
	Chicago, IL	CZ 5	80	0.5	0.3	0.8
HP	Houston, TX	CZ 2	72	1.9	4	6.0
	Atlanta, GA	CZ 3	75	2.8	4.7	7.0
	Washington, DC	CZ 4	77	3.3	4	6.7
	Chicago, IL	CZ 5	74	3.5	3.6	6.1

Trends (for an IECC 2009 Home)

- Air conditioners
  - Potential to earn more points in hotter climates
- Heat pumps
  - Potential to earn more points in mixed climates
  - Interactions between the heat pump and supplemental heat are important to consider
- Heat pumps have potential to earn more points than air conditioners

Summary

- Previous work
  - Working group estimated initial point potential based on cursory modeling
  - Air conditioners: Hot climates ~3 points; Mixed climates ~2 points; Cold climates ~1 point
  - Heat pumps: Low point potential in cold climates (non-intuitive)
- Our approach
  - Similar trends for air conditioners (higher point potential due to lower efficiency home)
  - More intuitive results for heat pumps
  - Lays the groundwork for HERS software programs to ensure installation quality impacts get modeled in a consistent manner


Questions?

ENERGY STAR. The simple choice for energy efficiency.

ENERGY STAR Certified Homes

Web:

Main: www.energystar.gov/newhomespartners
Technical: www.energystar.gov/newhomesrequirements
Training: www.energystar.gov/newhomestraining
Products: www.energystar.gov/products

Social Media:

@energystarhomes

facebook.com/energystar

Email:

energystarhomes@energystar.gov

Contacts:

Dean Gamble

EPA
Technical Manager
ENERGY STAR Certified Homes
Gamble.Dean@epa.gov

Michael Brown

ICF
Technical Support
ENERGY STAR Certified Homes
Michael.Brown2@icf.com