How Much Does HVAC Installation Grading Affect HERS Index Scores?

How you can lower your HERS Index

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Background

- Multi-year effort by RESNET HVAC Working Group to define HERS Rater field inspection practices and procedures that can be used to evaluate HVAC installation quality

- Objective is to show HERS Index improvement (lower Index) for high quality HVAC installation

- Quality installation considerations:
  - ➢ Blower fan airflow
  - ➢ Blower fan power consumption
  - ➢ Refrigerant charge

- Three tiered grading system: Grade I, Grade II and & Grade III

Basic Grading Calculation Assumptions

- Grade III (poorest quality) is the HVAC installation quality for the Energy Rating Reference Home

- Grade III is also the HVAC installation quality for a Rated Homes whose HVAC systems are not tested or do not meet minimum duct leakage or blower fan airflow criteria (see Standard process flow chart)

- Since Energy Rating Reference Home is Grade III, there is no penalty for Grade III Rated Homes

- Rated Homes can achieve significant improvement in their HERS Index if HVAC systems are certified to be better than Grade III.

The Process Flow Chart
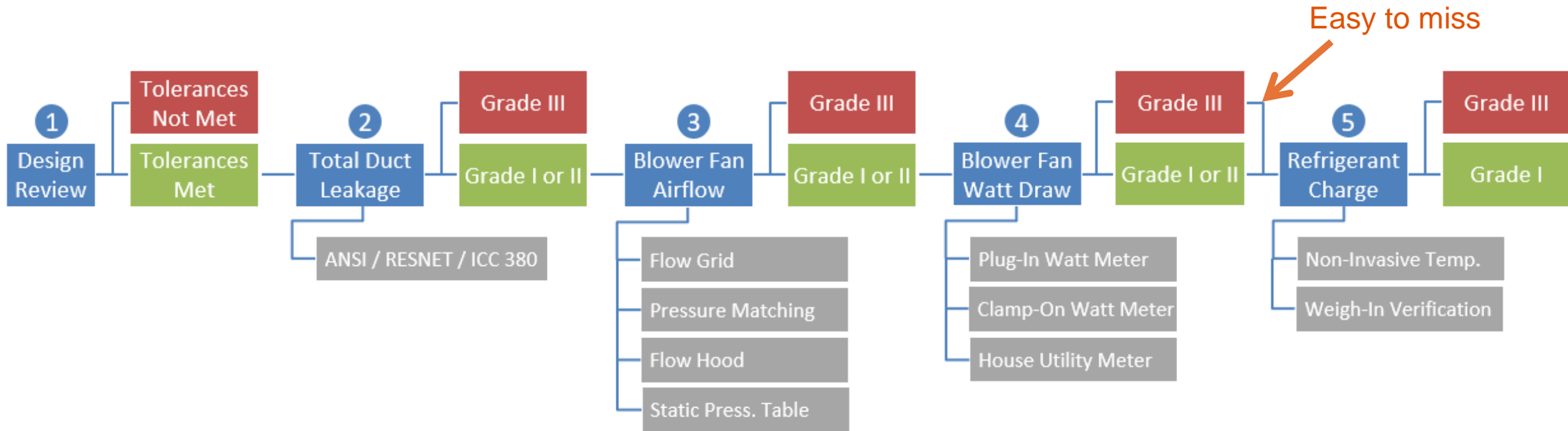
What do the Grades Mean

- Measured Total Duct Leakage needs to be within prescribed limits or HVAC Installation quality can not be determined
- Limits on Total Duct Leakage are fairly large and any new home that meets current codes should not have difficulty achieving the required Grade I or Grade II.

Table 2a – Duct Leakage Limits for Grade I (IP)

Time of Test	# of Returns	Leakage Limit (CFM at 25 Pa)
Rough-In	< 3	The greater of ≤ 4 per 100 ft^2 of CFA or ≤ 40
Rough-In	≥ 3	The greater of ≤ 6 per 100 ft^2 of CFA or ≤ 60
Final	< 3	The greater of ≤ 8 per 100 ft^2 of CFA or ≤ 80
Final	≥ 3	The greater of ≤ 12 per 100 ft^2 of CFA or ≤ 120

Table 3a – Duct Leakage Limits for Grade II (IP)

Time of Test	# of Returns	Leakage Limit (CFM at 25 Pa)
Rough-In	< 3	The greater of ≤ 6 per 100 ft^2 of CFA or ≤ 60
Rough-In	≥ 3	The greater of ≤ 8 per 100 ft^2 of CFA or ≤ 80
Final	< 3	The greater of ≤ 10 per 100 ft^2 of CFA or ≤ 100
Final	≥ 3	The greater of ≤ 14 per 100 ft^2 of CFA or ≤ 140

What do the Grades Mean (Cont'd)

• Blower Fan Airflow grade is dependent on the deviation from the design blower fan airflow (F_{AF}).

Table 4 – Grade Designations for Blower Fan Volumetric Airflow

Grade Designation	F_{AF} Range		
I	≤ 0 and $> -15\%$	or	≥ 0 and $< +15\%$
II	$\leq -15\%$ and $> -25\%$	or	$\geq +15\%$ and $< +25\%$
III	$\leq -25\%$	or	$\geq +25\%$

6.9.1 F_{AF}, the Deviation between the design-specified and field-measured Blower Fan volumetric airflow shall be calculated using Equation 1.

$$F_{AF} = \frac{(Q_{op} - Q_{design})}{Q_{design}} \qquad (1)$$

Where:

F_{AF} = The Deviation between the design-specified and field-measured Blower Fan volumetric airflow.

What do the Grades Mean (Cont'd)

- Blower Fan Watt Draw Grade (i.e. Blower Fan Efficiency) is determined by dividing the measured blower fan wattage by the measured blower fan airflow to yield Watt/CFM.

Table 1 – Grade Designations for Blower Fan Watt Draw

Grade Designation	Blower Fan Efficiency (Watts/CFM)
I	≤ 0.45
II	> 0.45 and ≤ 0.58
III	> 0.58

- Blower Fan Watt Draw can be Grade III and the Refrigerant Charge can still be considered by the HVAC grading system (see process flow chart).

What do the Grades Mean (Cont'd)

- Refrigerant charge is either Grade III or Grade I – there is no Grade II

- For Grade III the deviation from proper charge is 25% and for Grade I the deviation from proper charge is 0%

Table 4.2.2(6) Air Conditioner, Furnace, and Heat Pump Installation Quality Grade Non-Default Values for Rated Home

Parameter	Value
Blower Fan Airflow Deviation	F_{AF} = As Rated
Blower Fan Watt Draw Efficiency	Blower Fan Efficiency = As Rated
Refrigerant Charge Deviation	F_{CHG} = 0% if Rated Grade I F_{CHG} = -25% if Rated Grade III Undercharge F_{CHG} = +25% if Rated Grade III Overcharge

The Calculations (in essence)

- Based on the measured characteristics of the HVAC system, a set of HVAC fault calculations are performed for each hour of the year.

- Fault calculations are based on results from an HVAC fault study published by the National Institute of Standards and Technology

- Fault calculations degrade the capacity and efficiency of the HVAC system based on the deviation from the design condition of the blower fan airflow, blower fan wattage and refrigerant charge

- HVAC system performance calculations use the measured blower fan air flow and blower fan watt draw along with the degraded capacity and efficiency to calculate hourly energy use.

Example Simulations

- Prototype based on PNNL homes used for DOE Energy Code cost effectiveness analysis
- 2,376 sq.ft., 2-story, 3-bedroom homes on a crawlspace foundation
- 14 representative TMY cities across the 7 IECC climates across the contiguous US
- Prototypes configured to meet minimum prescriptive requirements of 2018 IECC with minimum equipment efficiencies
- Two different software engines: EnergyGauge USA v.7 (FSEC) and OS-ERI v1.1 (NREL).
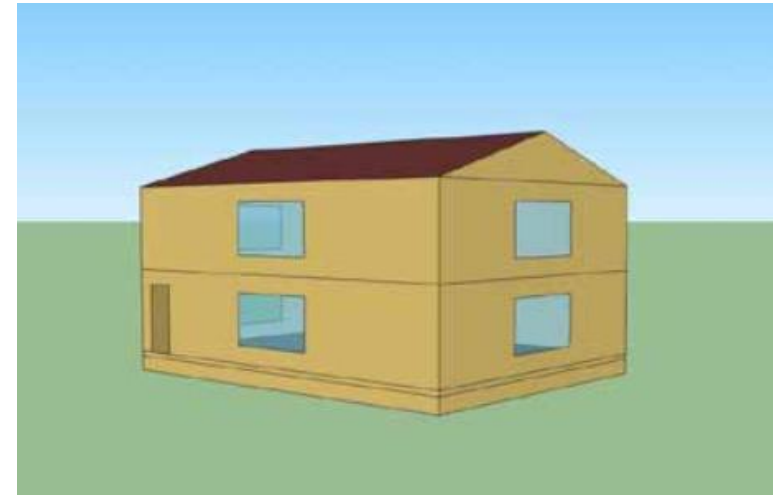
Example Simulations (Cont'd)

- 6 versions of Rated Home:

Rated Home	HVAC System	Fan Power	Airflow	Charge	Reference Home
HP, Original[1]	Air-source heat pump	--	--	--	--
HP, Grade I	Air-source heat pump	0.45 W/cfm[2]	0%	0%	Grade 3
HP, Grade III	Air-source heat pump	0.58 W/cfm	-25%	-25%	Grade 3
GF, Original	Air conditioner/gas furnace	--	--	--	--
GF, Grade I	Air conditioner/gas furnace	0.45 W/cfm	0%	0%	Grade 3
GF, Grade III	Air conditioner/gas furnace	0.58 W/cfm	-25%	-25%	Grade 3

[1] Original Rated Home refers to HERS Index prior to HVAC Installation Grading methodology.
[2] 0.45 W/cfm is the maximum fan power that meets the Grade I Blower Fan Watt Draw designation. Rated Homes with lower fan powers can achieve further HERS Index credit.
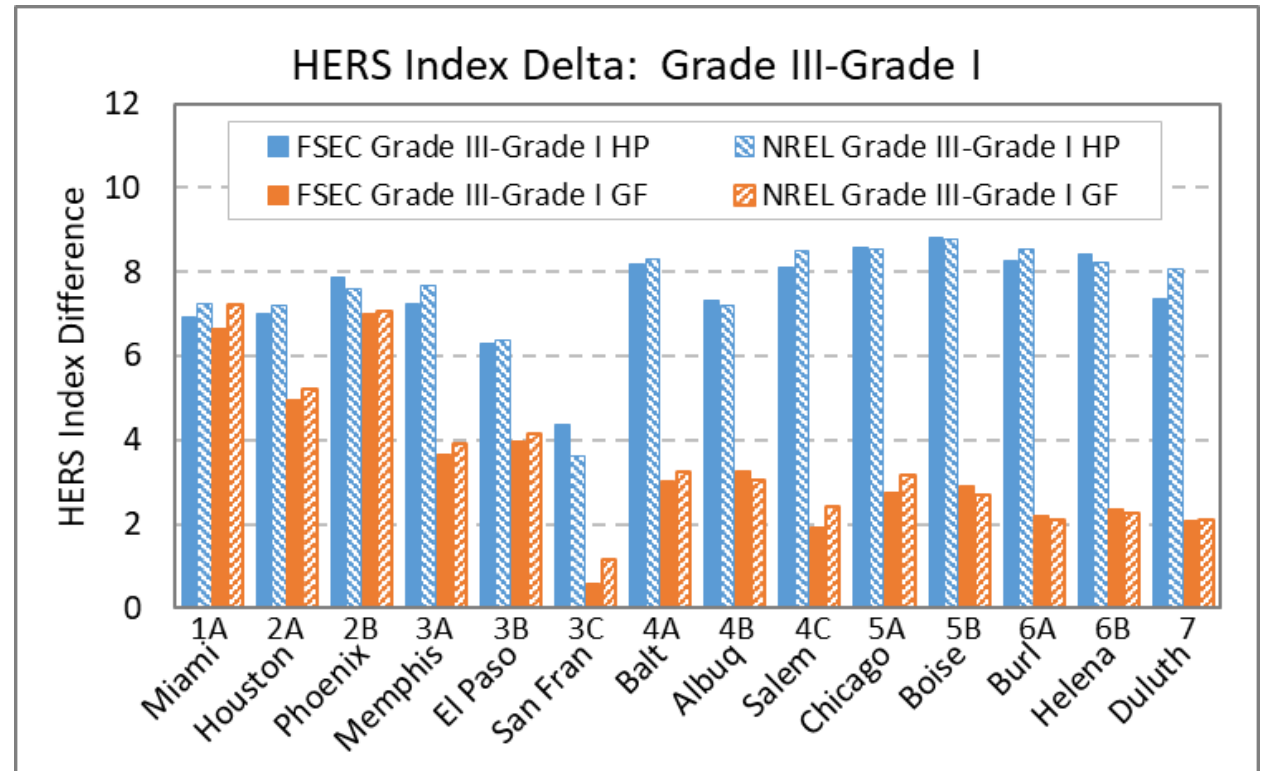
Example Simulations (Cont'd)

- 84 total configurations (14 cities x 6 Rated Homes)
- Results for Grade III and Grade I Rated homes show achievable HERS Index changes

PNNL Homes:	Inputs				Grade			HERS2019 (IAF) with HVACG							HERS2019 (IAF)						
Locations:	dsn cfm	prop cfm	W/cfm	prop W	airflow	W/cfm	refrig	TnML	TRL	IAD$_{ERI}$	IAD$_{SAVE}$	IAF	HERS$_{IAF}$	HERS$_{DIF}$	TnML	TRL	IAD$_{ERI}$	IAD$_{SAVE}$	IAF	HERS$_{IAF}$	HVACG$_{DIF}$
Miami	930	697	0.58	405	III	III	III	70.09	106.51	70.70	29.30%	1.001	65.74	---	69.85	106.79	70.70	29.30%	1.001	65.34	0.40
Heat Pump	930	930	0.45	418	I	I	I	62.69	106.51	70.70	29.30%	1.001	58.80	-6.94	69.85	106.79	70.70	29.30%	1.001	65.34	-6.54
Miami	930	697	0.58	405	III	III	III	70.01	106.51	70.70	29.30%	1.001	65.67	---	69.94	106.79	70.70	29.30%	1.001	65.43	0.24
Gas Furnace	930	930	0.45	418	I	I	I	62.92	106.51	70.70	29.30%	1.001	59.02	-6.65	69.94	106.79	70.70	29.30%	1.001	65.43	-6.41
Houston	960	719	0.58	418	III	III	III	64.90	97.74	70.30	29.70%	1.001	66.33	---	64.65	97.90	70.30	29.70%	1.001	65.97	0.36
Heat Pump	960	960	0.45	432	I	I	I	58.06	97.74	70.30	29.70%	1.001	59.34	-6.99	64.65	97.90	70.30	29.70%	1.001	65.97	-6.63
Houston	960	719	0.58	418	III	III	III	64.62	97.73	70.20	29.80%	1.001	66.05	---	64.51	97.91	70.20	29.80%	1.001	65.82	0.23
Gas Furnace	960	960	0.45	432	I	I	I	59.79	97.73	70.20	29.80%	1.001	61.12	-4.94	64.51	97.91	70.20	29.80%	1.001	65.82	-4.70
Phoenix	990	742	0.58	431	III	III	III	77.21	118.92	66.90	33.10%	1.001	64.86	---	74.84	119.16	67.00	33.00%	1.001	62.74	2.12
Heat Pump	990	990	0.45	445	I	I	I	67.84	118.92	66.90	33.10%	1.001	56.99	-7.87	74.84	119.16	67.00	33.00%	1.001	62.74	-5.75
Phoenix	990	742	0.58	431	III	III	III	77.18	118.92	66.70	33.30%	1.001	64.84	---	74.92	119.16	66.80	33.20%	1.001	62.81	2.03
Gas Furnace	990	990	0.45	445	I	I	I	68.86	118.92	66.70	33.30%	1.001	57.85	-6.99	74.92	119.16	66.80	33.20%	1.001	62.81	-4.96
Memphis	920	689	0.58	400	III	III	III	66.13	101.26	66.80	33.20%	1.001	65.24	---	65.56	101.22	66.80	33.20%	1.001	64.71	0.54
Heat Pump	920	920	0.45	414	I	I	I	58.81	101.26	66.80	33.20%	1.001	58.02	-7.22	65.56	101.22	66.80	33.20%	1.001	64.71	-6.68
Memphis	810	607	0.58	353	III	III	III	64.84	101.26	66.60	33.40%	1.001	63.97	---	64.50	101.22	66.50	33.50%	1.001	63.66	0.31
Gas Furnace	810	810	0.45	364	I	I	I	61.13	101.26	66.60	33.40%	1.001	60.31	-3.66	64.50	101.22	66.50	33.50%	1.001	63.66	-3.35

Example detailed simulation results in tabular form

Example Results: Grade III vs Grade I

- HERS Index change for achieving a Grade I Rated Home relative to a Grade III Rated Home (III – I):
  - ▷ 4-7 points reduction for air conditioners (hot climates)
  - ▷ 2-3 points reduction for gas furnaces (cold climates)
  - ▷ 6-9 points reduction for heat pumps (hot & cold climates)
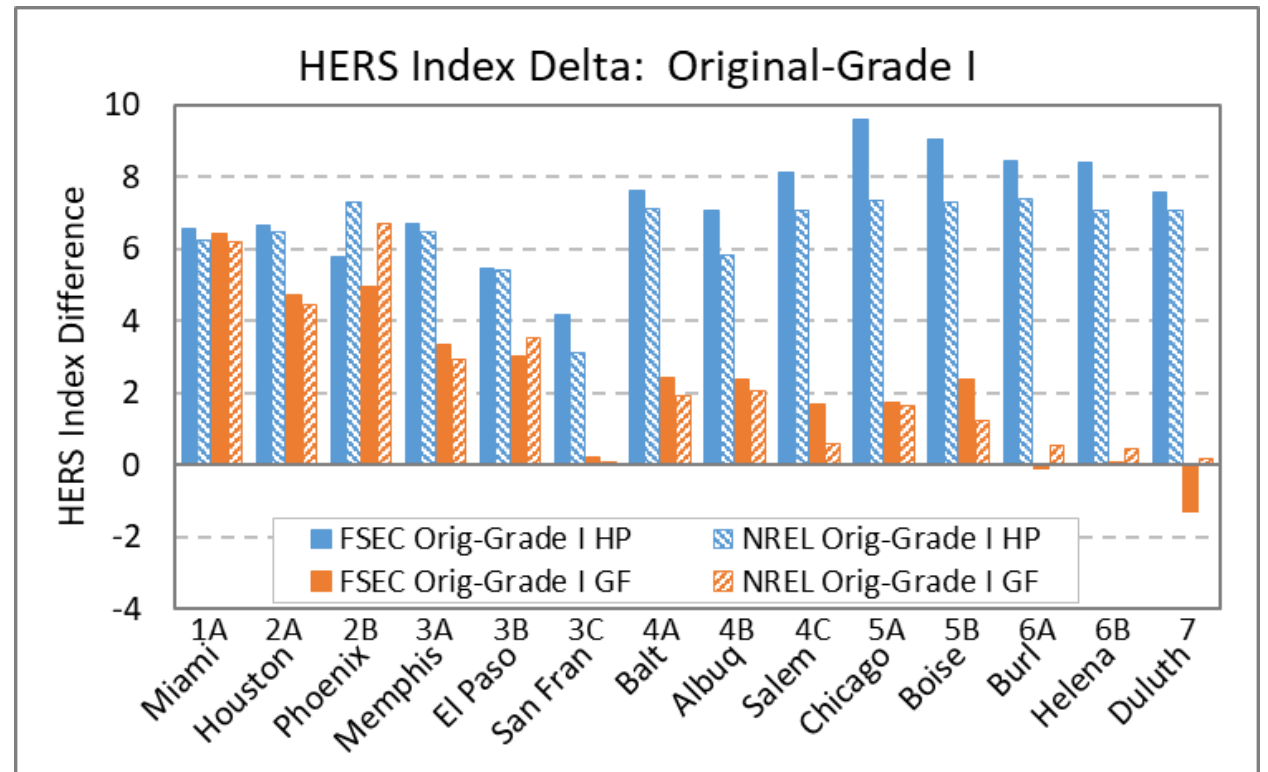- HPs achieve larger credits due to refrigerant charge credit for heating.

HERS Index Delta: Grade III-Grade I

- HERS Index change for a Grade III Rated Home relative to Original Rated Home (Orig – III):
  - ➢ 0-3 points increase across most climates
- Changes are specific to each software tool's original coil airflow and fan power (W/cfm) assumptions prior to HVAC Grading implementation.

HERS Index Delta: Original-Grade III
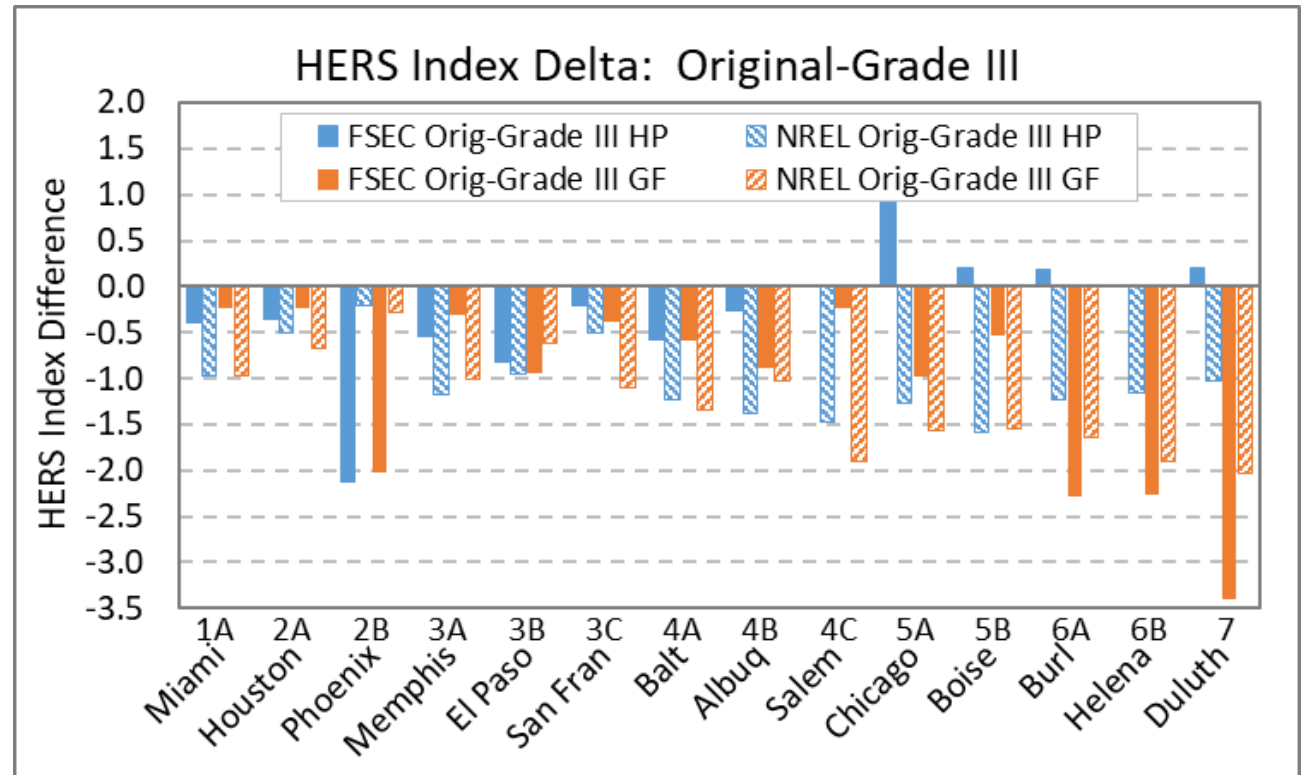
Example Results: Original vs Grade I

- HERS Index change for a Grade I Rated Home relative to Original Rated Home (Orig – I):

  ▻ 3-6 points reduction for air conditioners (hot climates)

  ▻ 0-2 points reduction for gas furnaces (cold climates)

  ▻ 5-10 points reduction for heat pumps (hot & cold climates)

- Changes are specific to each software tool's default (Original) assumptions prior to HVAC Grading.

HERS Index Delta: Original-Grade I

Legend: FSEC Orig-Grade I HP, NREL Orig-Grade I HP, FSEC Orig-Grade I GF, NREL Orig-Grade I GF

Some Caveats

- The starting point matters – more efficient homes with more efficient HVAC equipment (e.g. ENERGY STAR) may not see as large a change in HERS Index for Grade I HVAC systems

- Certain systems inherently will be classified as Grade I systems:
  - ➤ Hydronic baseboard heating systems (gas/oil boilers)
  - ➤ Strip resistance baseboard heating systems
  - ➤ Packaged HVAC systems (PTACs and PTHPs)

- Certain heating systems can not achieve Grade I refrigerant credits:
  - ➤ Gas furnaces
  - ➤ Electric furnaces

Conclusions

- Accepting Grade III results in no HERS Index penalty
- Significant HERS Index credit is available for a Grade I air conditioner and Grade I heat pump installation
  - ▷ Actual credit dependent on climate and overall home efficiency
- EnergyGauge USA v.7 (FSEC) and OS-ERI v1.1 (NREL) show excellent agreement on HERS Index credit
- All HERS Accredited software tools will include HVAC Installation Quality calculations by April 1, 2021
- RESNET Publication 001-2020 requires HVAC Installation Quality calculations for 45L Tax Credit accreditation.