FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

The Technical Basis of Calculating the HERS Index or I am Curious (nMEUL): QAD Roundtable

2016 RESNET Building Performance Conference
Scottsdale, Arizona

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Objective

Provide a comprehensive understanding of exactly how the HERS Index is calculated and why it is calculated in this way.

Bad News – Good News

- The Bad News:
  - The subject matter contains some mathematical formulas and derivations
- The Good News:
  - It is just simple algebra
  - It explains the formulations found in the ANSI/RESNET/ICC 301 Standards

Indexing (in general)

- An Index is computed with respect to a Reference metric, such that an Actual metric value is divided by a Reference metric value and multiplied by 100

$$Index = (value_{Act} / value_{Ref}) * 100$$

- The term $(value_{Act} / value_{Ref})$ is often referred to as the "scoring fraction" of the index
- Thus, an index represents the Actual's percentage of the reference
  - For example, if the Actual metric value is 72 and the Reference metric value is 90:

$$Index = 72/90 * 100 = 80 \text{ (\% of the reference)}$$

Energy Consumption Basics

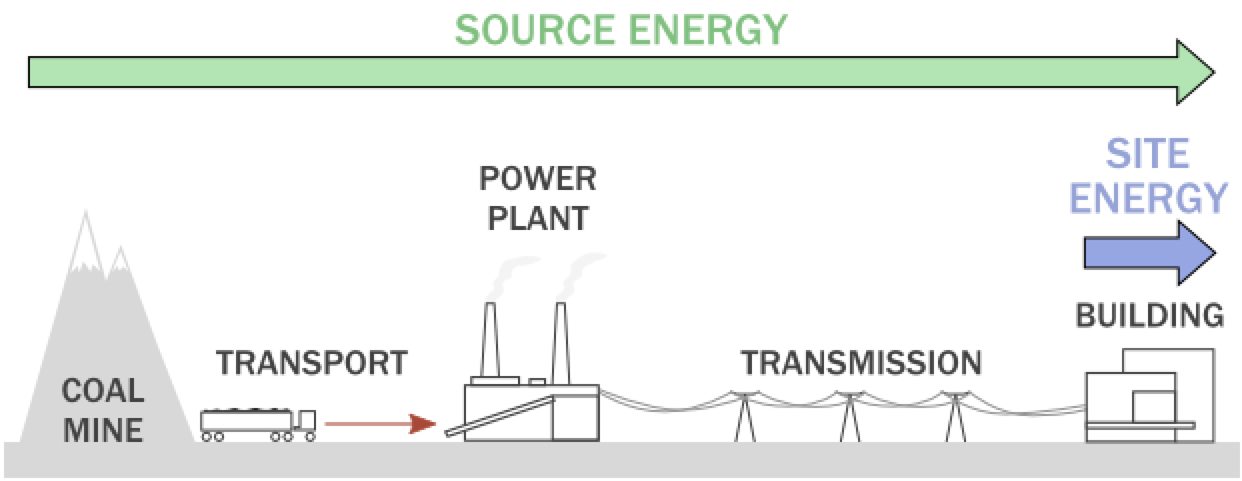
- Acronyms:
  - EC = Energy Consumption
  - EUL = End Use Load
  - COP = Coefficient of Performance (for equipment)

    = (Energy Output) / (Energy Input)

The Energy Consumption equation:

EC = EUL/COP

Site Energy vs. Source Energy



- For electricity, the source energy burden for production is relatively large, yielding a site-to-source energy multiplier of about 3.16 for electricity
- For fossil fuels, the source energy burden for production is relatively small, yielding a site-to-source energy multiplier of about 1.09 for natural gas.

Energy Metrics

- There are two distinct types of “fuels” used in homes – electricity & fossil fuels
- As a result, there is contention regarding the metric used to count home energy use
  - Site energy consumption
  - Source (or primary) energy consumption
  - Energy cost (or some representative of cost like TDV)
- ***All of these metrics are problematic*** when the Reference home fuel type is required to be the same as the Actual home fuel type (as in IECC Codes & HERS).

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Site Energy Example

Index = TaECsite / TrECsite * 100

	Actual Home			Reference Home		
All Electric Home:	**EUL**	**COP**	**aECsite**	**EUL**	**COP**	**rECsite**
Heating	40	2.40	16.64	50	2.26	22.16
Cooling	20	4.10	4.87	25	3.81	6.56
Hot Water - electric	15	**0.92**	16.30	15	**0.92**	16.30
Total Site Energy		TaECsite =	37.82		TrECsite =	45.02
Site Energy Index	**84**					
Mixed Fuel Home:	**EUL**	**COP**	**aECsite**	**EUL**	**COP**	**rECsite**
Heating	40	2.40	16.64	50	2.26	22.16
Cooling	20	4.10	4.87	25	3.81	6.56
Hot water - gas	15	**0.59**	25.42	15	**0.59**	25.42
Total Site Energy		TaECsite =	46.94		TrECsite =	54.14
Site Energy Index	**87**					

Δ = +3 for gas **Δ = 9.12** **Δ = 9.12**

Source Energy Example

Index = TaECsrc / TrECsrc * 100

	Actual Home			Reference Home		
All Electric Home:	**EUL**	**COP**	**aECsrc**	**EUL**	**COP**	**rECsrc**
Heating	40	2.40	52.59	50	2.26	70.01
Cooling	20	4.10	15.40	25	3.81	20.73
Hot Water - electric	15	**0.92**	51.52	15	**0.92**	51.52
Total Site Energy		TaECsrc =	119.52		TrECsrc =	142.27
Source Energy Index	**84**					
Mixed Fuel Home:	**EUL**	**COP**	**aECsrc**	**EUL**	**COP**	**rECsrc**
Heating	40	2.40	52.59	50	2.26	70.01
Cooling	20	4.10	15.40	25	3.81	20.73
Hot water - gas	15	**0.59**	27.71	15	**0.59**	27.71
Total Site Energy		TaECsrc =	95.71		TrECsrc =	118.46
Source Energy Index	**81**					

Δ = -3 for gas **Δ = -23.81** **Δ = -23.81**

The Issue

- Because the reference water heater COPs are different, the energy consumption of the gas water heater and the electric water heater are also different
  - For site energy: EC is 9.12 MBtu larger for gas
  - For source energy: EC is 23.81 MBtu smaller for gas
- **Hence, the "Fuel Wars" . . .**
- The issue is purely mathematical: Take any scoring fraction (say ¾) and then add the same quantity (say 1 for this example) to both the numerator and the denominator
- **Result:** you obtain a significantly different Index:

3/4 * 100 = 75

4/5 * 100 = 80

The Same for Energy Cost

Index = TaE$ / TrE$ * 100

	Actual Home			Reference Home		
All Electric Home:	**EUL**	**COP**	**aE$**	**EUL**	**COP**	**rE$**
Heating	40	2.40	$575	50	2.26	$766
Cooling	20	4.10	$169	25	3.81	$227
Hot Water - electric	15	**0.92**	$564	15	**0.92**	$564
Total Energy Cost		TaE$ =	$1,308		TrE$ =	$1,557
Energy Cost Index	**84**					
Mixed Fuel Home:	**EUL**	**COP**	**aE$**	**EUL**	**COP**	**rE$**
Heating	40	2.40	$575	50	2.26	$766
Cooling	20	4.10	$169	25	3.81	$227
Hot water - gas	15	**0.59**	$274	15	**0.59**	$274
Total Energy Cost		TaE$ =	$1,018		TrE$ =	$1,267
Energy Cost Index	**80**					

Δ = -4 for gas **Δ = -$290** **Δ = -$290**

Understanding MEUL

- MEUL = Modified End Use Loads
- Principles:
  - End Use Loads are agnostic to fuel type
  - Therefore, Reference End Use Loads (REUL) do not change as a function of fuel type
  - MEUL is a means of modifying the end use's Actual Energy Consumption (EC_{Act}) such that it is directly comparable to REUL as follows:

$$MEUL = REUL*(EC_{Act}/EC_{Ref})$$

Review

EC = Energy Consumption

EUL = End Use Load

COP = Coefficient of Performance (for equipment)

= (Energy Output) / (Energy Input)

REUL = Reference End Use Load

MEUL = Modified End Use Load

The Energy Consumption equation:

$$EC = EUL/COP$$

How Do We Get There?

- By definition:

$$(EC_{Act}/EC_{Ref}) = (EUL_{Act}/COP_{Act})/(REUL/COP_{Ref})$$

- Rearranging this equation yields:

$$REUL*(EC_{Act}/EC_{Ref}) = EUL_{Act}*(COP_{Ref}/COP_{Act})$$

- The right-hand side ***modifies*** EUL_{Act} by the ratio of the two COPs so therefore:

$$MEUL = EUL_{Act}*(COP_{Ref}/COP_{Act})$$

- And therefore:

$$MEUL = REUL*(EC_{Act}/EC_{Ref})$$

MEUL Site Energy Example

Index = TML / TRL * 100   (where MEUL = REUL * aECsite / rECsite)

	Actual Home			Reference Home		
All Electric Home:	**MEUL**	**COP**	**aECsite**	**REUL**	**COP**	**rECsite**
Heating	38	2.40	16.64	50	2.26	22.16
Cooling	19	4.10	4.87	25	3.81	6.56
Hot Water - electric	15	0.92	16.30	15	0.92	16.30
Total Building Loads	71 = TML			90 = TRL		
Modified Loads Index	**79**					
Mixed Fuel Home:	**MEUL**	**COP**	**aECsite**	**REUL**	**COP**	**rECsite**
Heating	38	2.40	16.64	50	2.26	22.16
Cooling	19	4.10	4.87	25	3.81	6.56
Hot water - gas	15	0.59	25.42	15	0.59	25.42
Total Building Loads	71 = TML			90 = TRL		
Modified Loads Index	**79**					

MEUL Source Energy Example

Index = TML / TRL * 100 (where MEUL = REUL * aECsrc / rECsrc)

	Actual Home			Reference Home		
All Electric Home:	**MEUL**	**COP**	**aECsrc**	**REUL**	**COP**	**rECsrc**
Heating	38	2.40	52.59	50	2.26	70.01
Cooling	19	4.10	15.40	25	3.81	20.73
Hot Water - electric	15	0.92	51.52	15	0.92	51.52
Total Building Loads	71 = TML			90 = TRL		
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Mixed Fuel Home:	**MEUL**	**COP**	**aECsrc**	**REUL**	**COP**	**rECsrc**
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Total Building Loads	71 = TML			90 = TRL		
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MEUL Energy Cost Example

Index = TML / TRL * 100   (where MEUL = REUL * aE$ / rE$)

	Actual Home			Reference Home		
All Electric Home:	**MEUL**	**COP**	**aE$**	**REUL**	**COP**	**rE$**
Heating	38	2.40	$575	50	2.26	$766
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Total Building Loads	71 = TML			90 = TRL		
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MEUL Summary

- *Modified End Use Loads* emphasize end use load efficiencies by using reference end use loads rather than reference energy consumption as the denominator of the scoring fraction
- *Modified End Use Loads* cause the energy metric to be irrelevant by converting the Actual Energy Consumption (EC_{Act}) metric to a Modified End Use Load (MEUL) that can be directly compared against a Reference End Use Load (REUL).

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Normalized MEUL (nMEUL)

- Modified End Use Loads for natural gas equipment are normalized to be relative to the Modified End Use Loads for electric equipment
- Normalization is linear between the Reference equipment efficiency and the best available equipment efficiency (circa 2006)
- Electric equipment efficiencies are taken as the basis against which natural gas equipment is normalized
- Reference citation:

    http://www.fsec.ucf.edu/en/publications/html/FSEC-RR-54-00/index.htm

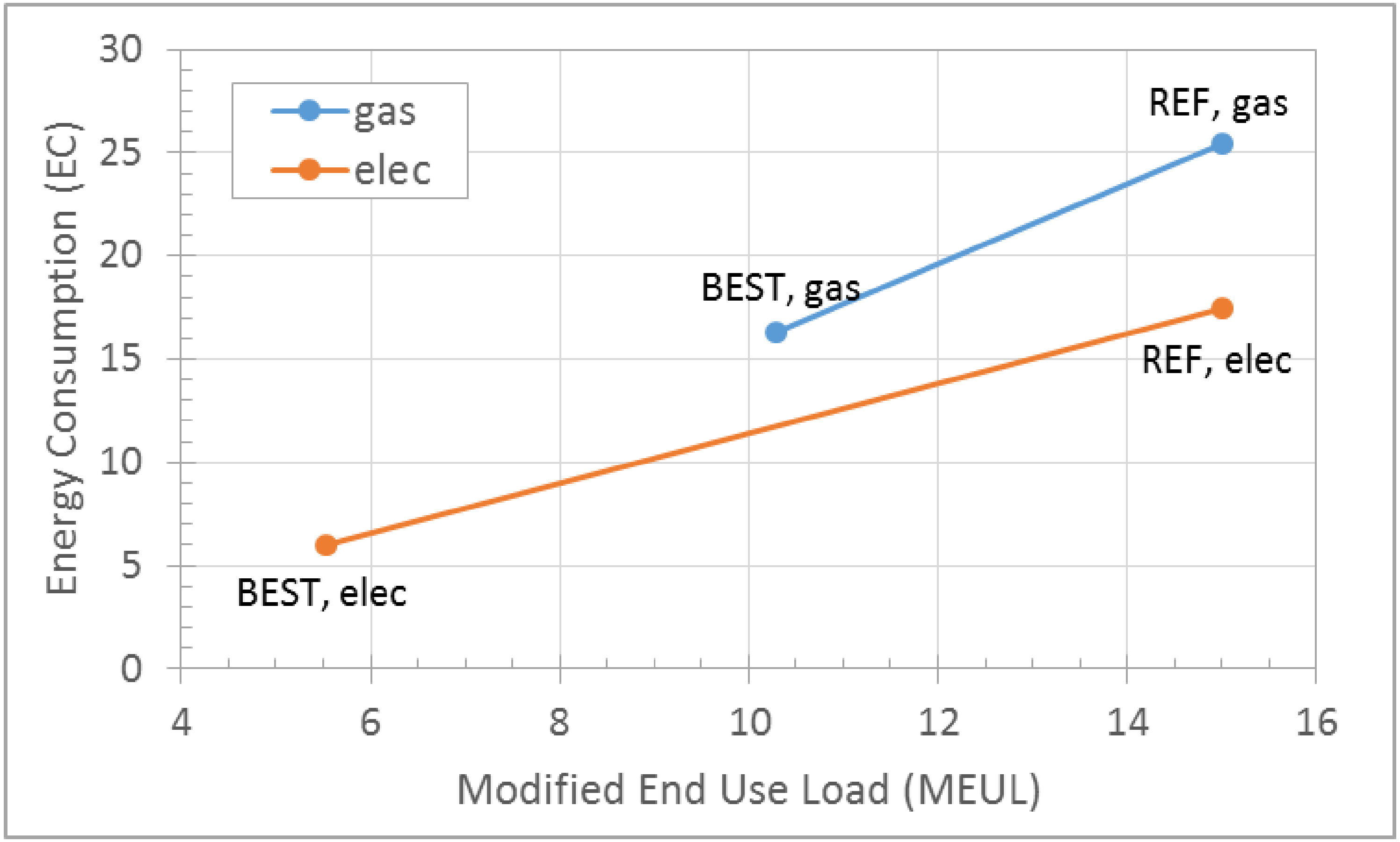
Why Normalize?

- For any given EUL, the difference in efficiency between the reference equipment and the best available equipment can result in a significantly unequal percentage EC change across fuel types

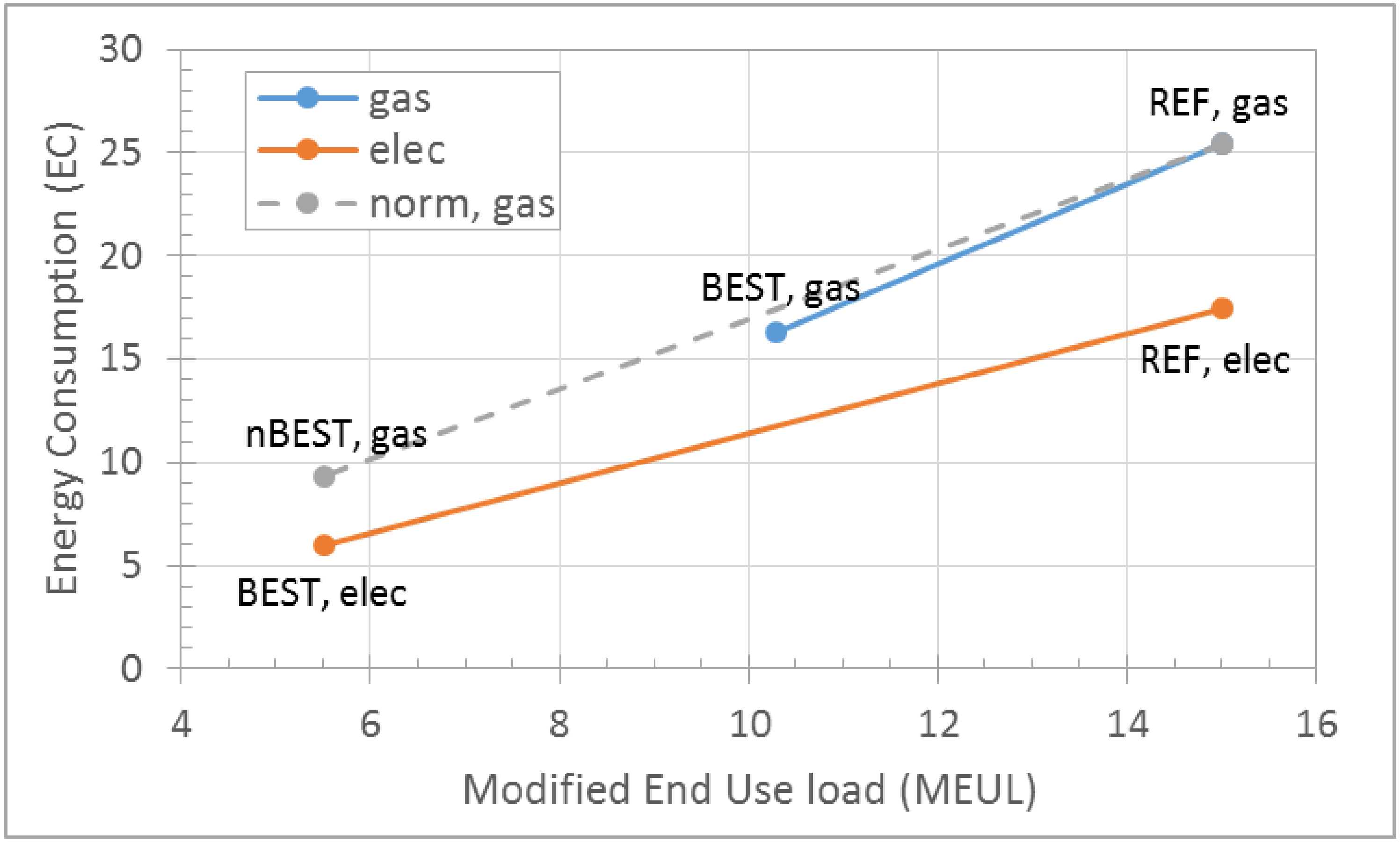
	Ref COP	Best COP	EUL	Ref EC	Best EC	%Change
Gas WH	0.59	0.86	**15**	25.42	17.44	**-31.4%**
Elec WH	0.92	2.50	**15**	16.30	6.00	**-63.2%**

This also results in significant differences in MEUL across fuel types.

How Do We Fix This?



Normalize BEST Gas to BEST Electric



Normalized Energy Consumption

- Using normalized energy consumption (nEC) results in an equal percentage EC change across fuel types

	Ref COP	Best COP	EUL	Ref nEC	Best nEC	%Change
Gas WH	0.59	0.86	**15**	25.42	9.36	**-63.2%**
Elec WH	0.92	2.50	**15**	16.30	6.00	**-63.2%**

The Normalization Calculation

$$nEC_x = (a^* \ EEC_x - b)^*(EC_x \ ^* \ EC_r \ ^* \ DSE_r) \ / \ (EEC_x \ ^* \ REUL)$$

where:

nEC_x = normalized Energy Consumption of Rated equipment

a & b = the normalization coefficients

EEC_x = Equipment Efficiency Coefficient of Rated equipment (=1/COP)

EC_x = Energy Consumption of Rated equipment

EC_r = Energy Consumption of Reference equipment

DSE_r = Distribution System Efficiency of Reference equipment

REUL = Reference End Use Load

The Normalization Coefficients

Table 4.2.1(1) Coefficients 'a' and 'b'

Fuel type and End Use	a	b
Electric space heating	2.2561	0
Fossil fuel* space heating	1.0943	0.4030
Biomass space heating	0.8850	0.4047
Electric air conditioning	3.8090	0
Electric water heating	0.9200	0
Fossil fuel* water heating	1.1877	1.0130

*Such as natural gas, liquid propane gas, fuel oil

How the Coefficients are Calculated

The calculation equations for the normalization coefficients are:

$a = (EEC_{e,r} - EEC_{e,b}) / [(EEC_{o,r} - EEC_{o,b}) * EEC_{e,r}]$

$b = [EEC_{o,r} * (EEC_{e,r} - EEC_{e,b})] / [EEC_{e,r} * (EEC_{o,r} - EEC_{o,b})] – 1$

where:

EEC = Equipment Efficiency Coefficient [=1/COP]

and the subscripts indicate:

e = electric equipment
o = other fueled equipment
r = reference equipment
b = best available equipment

How Well Does This Work?

- A simulation study was conducted to examine a large range of efficiency options in four different climates (Chicago, Phoenix, San Diego and Seattle)
- 2500 ft^2, 2-sty, 3-br, slab-on-grade, frame homes
- 24 simulation parametrics:
  - Heating fuel: natural gas and electricity
  - Equipment efficiency: Good, Standard and Poor
  - Shell efficiency: Good and Poor
  - On-site PV power (~4 kWp): Yes and No
- Simulation results provide a large range of HERS Index values (9 to 237)

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Gas-fueled Heating and Hot Water

Case #	Fuel	Shell	Equip	PV
1	Gas	Good	Good	No
2	Gas	Good	Good	Yes
3	Gas	Good	Poor	No
4	Gas	Good	Poor	Yes
5	Gas	Good	Std	No
6	Gas	Good	Std	Yes
7	Gas	Poor	Good	No
8	Gas	Poor	Good	Yes
9	Gas	Poor	Poor	No
10	Gas	Poor	Poor	Yes
11	Gas	Poor	Std	No
12	Gas	Poor	Std	Yes

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Electric Heating and Hot Water

Case #	Fuel	Shell	Equip	PV
13	Electricity	Good	Good	No
14	Electricity	Good	Good	Yes
15	Electricity	Good	Poor	No
16	Electricity	Good	Poor	Yes
17	Electricity	Good	Std	No
18	Electricity	Good	Std	Yes
19	Electricity	Poor	Good	No
20	Electricity	Poor	Good	Yes
21	Electricity	Poor	Poor	No
22	Electricity	Poor	Poor	Yes
23	Electricity	Poor	Std	No
24	Electricity	Poor	Std	Yes

Envelope Efficiencies

Type:	Wall R	Ceil R	Win U	SHGC	Slab R	UA
Good	20	49	0.35	0.25	0	369
Poor	0	0	1.31	0.8	0	1969

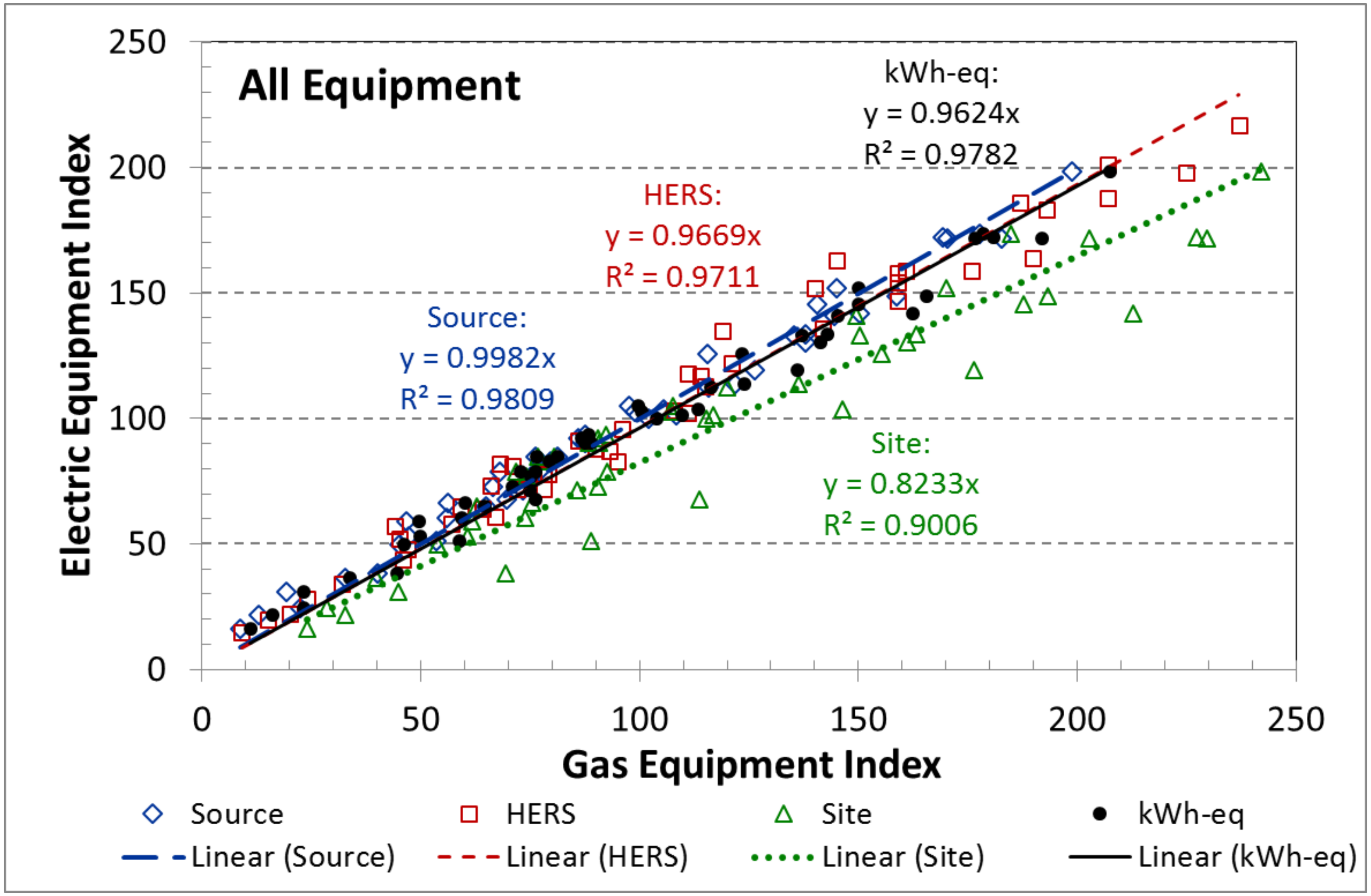
Equipment Efficiencies

Equip Rating:	Good	Std	Poor
Gas Furnace AFUE	0.94	0.78	0.65
Elec Heat Pump HSPF	9.25	7.70	6.41
Gas DHW EF	0.80	0.59	0.44
Elec DHW EF	1.25	0.92	0.68
Elec Cooling SEER	18.00	13.00	9.39

Energy Metrics Evaluated

- HERS Index (nMEUL)
- Site Index
  - Elec MBtu = kWh/293.08
  - Gas MBtu = therms/10
- Source Index (DOE Building America multipliers)
  - Elec MBtu = 3.365*(kWh/293.08)
  - Gas MBtu = 1.092*(therms/10)
- kWh-eq Index
  - Site gas use is converted to its electric equivalent assuming a 40% delivered conversion efficiency
  - kWh-eq MBtu = $[(Btu_{fossil}*0.40)/3412]/293.08$

Index Comparison Results



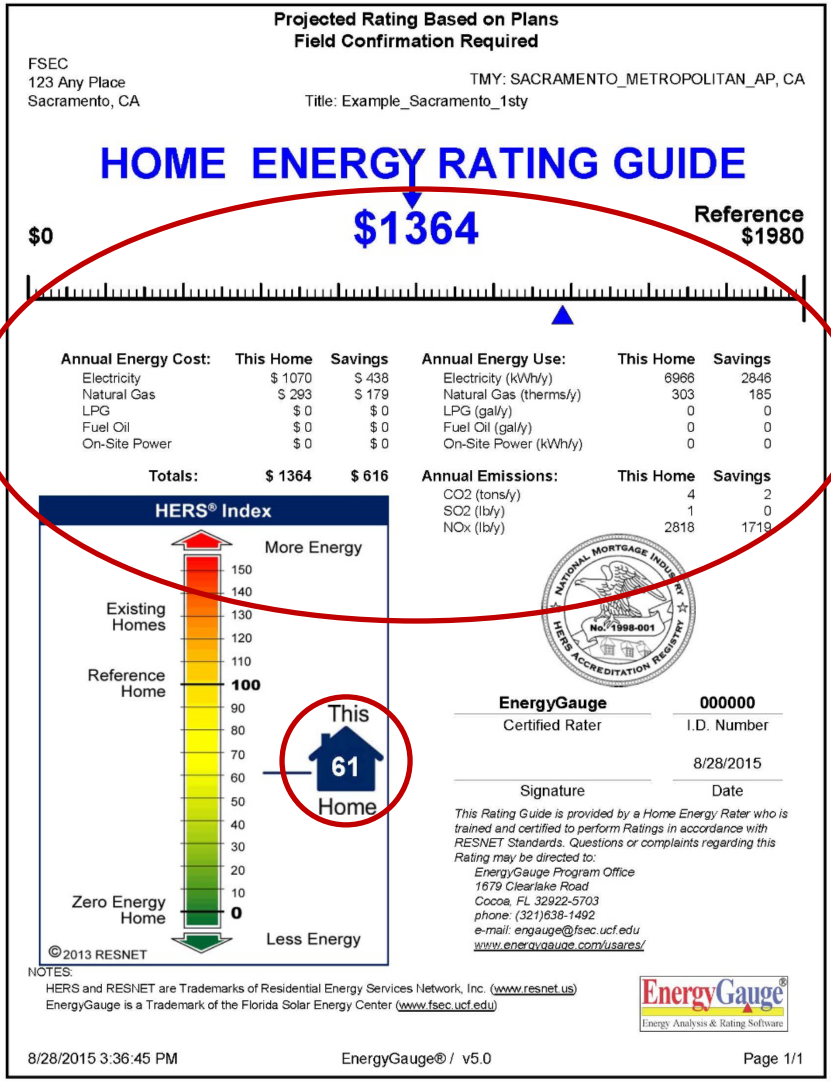
Conclusions

- Using site energy, source energy or energy cost as the HERS metric will provide a scoring advantage to one fuel type or another
  - *Which fuel type should receive the advantage?*
- Using MEUL as the HERS metric puts all fuel types on the same playing field
  - *Building loads are agnostic to fuel type*
- Normalization reduces the tendency for fuel switching
  - *An upgrade to the best available electrical equipment would otherwise be significantly more advantageous than a upgrade to the best available gas equipment.*

Please Note the Following

- The HERS Index is not the only evaluation provided by a HERS Rating
- Section 5.3, ANSI/RESNET/ICC 301-2014 requires the following on all Rating labels:
  - HERS Index score
  - (Actual) Projected annual site energy use by fuel type
  - (Actual) Projected annual energy cost of the home

EnergyGauge Implementation


Projected Rating Based on Plans
Field Confirmation Required

FSEC
123 Any Place
Sacramento, CA

TMY: SACRAMENTO_METROPOLITAN_AP, CA
Title: Example_Sacramento_1sty

HOME ENERGY RATING GUIDE

$0 **$1364** Reference $1980

Annual Energy Cost:	This Home	Savings
Electricity	$ 1070	$ 438
Natural Gas	$ 293	$ 179
LPG	$ 0	$ 0
Fuel Oil	$ 0	$ 0
On-Site Power	$ 0	$ 0
Totals:	$ 1364	$ 616

Annual Energy Use:	This Home	Savings
Electricity (kWh/y)	6966	2846
Natural Gas (therms/y)	303	185
LPG (gal/y)	0	0
Fuel Oil (gal/y)	0	0
On-Site Power (kWh/y)	0	0

Annual Emissions:	This Home	Savings
CO2 (tons/y)	4	2
SO2 (lb/y)	1	0
NOx (lb/y)	2818	1719

EnergyGauge	000000
Certified Rater	I.D. Number
	8/28/2015
Signature	Date

This Rating Guide is provided by a Home Energy Rater who is trained and certified to perform Ratings in accordance with RESNET Standards. Questions or complaints regarding this Rating may be directed to:
EnergyGauge Program Office
1679 Clearlake Road
Cocoa, FL 32922-5703
phone: (321)638-1492
e-mail: engauge@fsec.ucf.edu
www.energygauge.com/usares/

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EnergyGauge® Energy Analysis & Rating Software

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Detailed Energy & Cost Data

HERS Index

Rating Report Detail

Annual Energy Cost:	This Home	Savings
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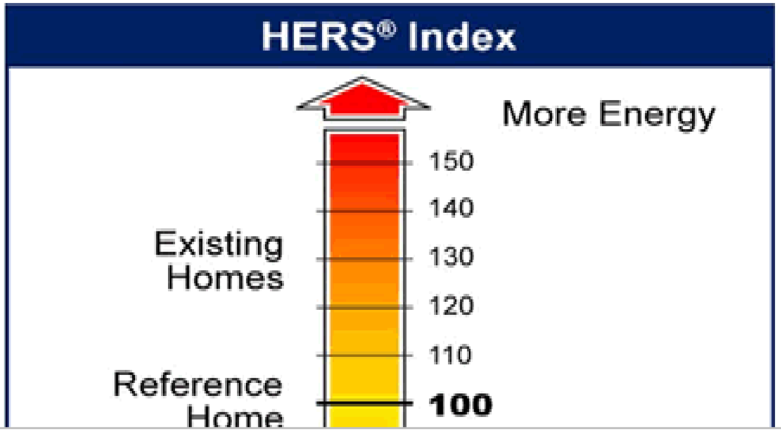
Annual Emissions:	This Home	Savings
CO_2 (tons/y)	4	2
SO_2 (lb/y)	1	0
NO_x (lb/y)	2818	1719



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Questions?