RESNET Cost-Based Rating Index Feasibility Report

Cost-Based Rating Index Task Group

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Executive Summary

The Standards Management Board developed a New Work Item (NWI) that established the Cost-Based Energy Rating Index Task Group (CBRITG). The purpose of the CBRITG was to investigate the feasibility of a cost-based rating index and, if feasible, to develop a concept and work plan for a calculation method. The NWI states that the need for this effort stems from the declared interest of stakeholder groups, as well as a Standards Development Committee (SDC) 300 Calculation Subcommittee determination that a cost-based rating calculation method would be an appropriate alternative to consider.

The success and stability of a residential energy performance rating relies on a rating structure that generates meaningful and transparent metrics. Such a structure would allow utilities/energy suppliers to leverage the program to incentivize energy conservation, energy efficiency, or energy production consistent with their infrastructure strategies. It could also provide consumers a holistic understanding of the costs associated with operating their homes.

Market circumstances, that any HERS structure must accommodate, include the following:

- The electric grid being replaced or updated with more renewable resources.
- Increased demand and cost effectiveness of distributed renewable resources.
- Movement toward low or net zero energy buildings.
- Increased awareness by the average consumer of the environmental benefits of conserving energy.
- Movement toward cleaner energies.

The RESNET Standards Management Board decision to examine the feasibility of a cost-based rating index is opportune as circumstances bring new market needs and important reasons to assess a potential transformation in the Program as a means of achieving the organization's long-term goals. From minimum regulated load energy code compliance to net zero, a transformed rating metric - or multiple metrics – based on costs, could fulfill the interests of multiple stakeholders for decades.

Informed by the Matrix of Potential Metrics for RESNET HERS Index provided to SDC 300 by the Calculation Subcommittee in 2015, the CBRITG developed a detailed list of parameters, along with a comparison of various ways to incorporate those parameters in a rating. A significant analytical effort by Philip Fairey and Martha Brook that compared different energy rating methods also informed the CBRITG during its deliberations.

The CBRITG identified key elements of a cost-based rating index, issues associated with the current normalized Modified End Use Loads (nMEUL) methodology, advantages and disadvantages of potential cost-based methodologies, analyses in support of Task Group needs, and provided joint and individual recommendations and viewpoints. The CBRITG worked to achieve consensus on issues, but did not always arrive at consensus. Key elements considered by the CBRITG include:

- Point of Use Annual Energy Reduction
- Time of Use Annual Energy Reduction

- Reference Home Methodology
- Renewable Energy Considerations
- Energy Prices

There were fundamental disagreements within the group on the reference home methodology, a critical element of a rating calculation. Detailed information is provided regarding multiple reference home and single reference home approaches for review. Pros and cons are also listed to help with RESNET deliberations.

The CBRITG discussed options for treating renewable energy in the rating. The consideration of appropriate energy costs for a realistic and reasonable evaluation of renewable technologies needs to be done carefully, as any decisions made in this regard today will likely remain in place for several years. The changing nature of the electric grid and the subsequent introduction of time-of-use rates are likely to fundamentally change the optimal technology mix used in homes in the future. It is important that these elements are weighed carefully so that the ERI remains valuable to stakeholders that rely on the ERI for their programmatic needs.

The CBRITG also discussed the relative merits of using national, regional, or local energy prices for a cost-based index. The consensus of the group was to use national average energy prices for consistency, acknowledging that national average energy prices will not align with local energy costs. However, a minority view within the TG expresses concern that employment of national average price as the rating basis creates limitations for critical use case applications such as energy supplier incentive programs. It would also limit – or perhaps mislead – the homeowner's understanding of the costs associated with operating their homes.

As evident by the above discussion, there are differences of opinion within the group over treatment of critical key elements for the cost-based rating index calculation methodology. **Therefore, it was not possible to provide SDC 300 a consensus work plan for a cost-based rating index calculation methodology.**

The information provided in this report is made available for use in RESNET deliberations. Members of the CBIRTG are available to answer questions as needed.

1 Introduction

During the last quarter of 2015, the Calculation Subcommittee of RESNET's SDC 300 compiled a list of Potential Metrics for RESNET HERS Index. The Calculation Subcommittee's Matrix of Potential Metrics for RESNET HERS Index was forwarded to SDC 300 on January 5, 2016, via the following motion:

"Rob Salcido made motion to send "Potential Metrics for RESNET HERS Index" to the SDC 300 for review and approval to send to the Board. Brian Christensen seconded motion. Motion passes."

During that same time period, RESNET received a continuous maintenance proposal proposing that an energy cost HERS Index be added to ANSI/RESNET/ICC 301-2014. RESNET was simultaneously working collaboratively with the California Energy Commission (CEC) in a joint effort to explore, understand and compare the differences between the RESNET HERS Index and the California HERS Index.

In response to the energy cost continuous maintenance proposal, the RESNET SMB voted at its February 29, 2016, meeting to "accept the proposed amendment as non-critical but refer to SDC 300 to appoint a Task Group to develop a draft concept and work plan for how it would be implemented." In response to the SMB motion, the SDC 300 Chairman, Brett Dillon, issued the NWI that established the CBRITG. The purpose of the CBRITG was to investigate the feasibility for development of a cost-based rating index and, if feasible, to develop a concept and work plan for a cost-based energy rating index calculation method. The scope of the CBRITG was to develop a single concept of a cost-based energy rating index calculation method as a proposed alternative to the normalized Modified End Use Load energy rating calculation method in ANSI/RESNET/ICC Standard 301-2014 and a work plan for further development by SDC 300.

The utility/energy supplier and the homeowner serve as the foundation for the supply and demand sides of energy consumption, energy costs, and emissions associated with residential buildings. As such, it is arguably these critical stakeholders' motivations that serve as fundamental drivers of a vibrant energy rating program.

The CBRITG commenced activities in June 2016. Through a series of conference calls, webinars, and meetings, the group identified key elements of a cost-based rating index, issues associated with the current nMEUL methodology, advantages and disadvantages (pros and cons) of potential cost-based methodologies, analyses in support of group needs, joint and individual recommendations and viewpoints, and a cost-based rating index calculation methodology. Table 1 lists the CBRITG members and their affiliations.

Table 1: Cost-Based Rating Index Task Group Members

Jerry Phelan (Chairman)	Covestro LLC
Craig Drumheller	National Association of Home Builders
Martha Brook	California Energy Commission
Neil Leslie	Gas Technology Institute
Philip Fairey	Florida Solar Energy Center
Steve Rosenstock	Edison Electric Institute
Vrushali Mendon	Pacific Northwest National Laboratory

2 Background

2.1 Energy Cost Index (ECI) Continuous Maintenance Proposal

On December 4, 2015, Steve Rosenstock (CBRITG member) submitted a Continuous Maintenance Proposal (CMP) to RESNET. The CMP modifies the on-site power production equation, updates the "normalization" equation to be more applicable to current choices being made for new electric generation, and adds an energy cost index option to the standard. As noted in the Rosenstock CMP, energy costs are used by several ANSI approved consensus standards, such as ASHRAE 90.1, ASHRAE 189.1, and others to show compliance with the requirements. One of the advantages of an energy cost index is that there is no need for any normalization or modification of energy usage by home appliances or equipment.

On January 7, 2016, Mr. Rosenstock received a confirmation that his proposal was received and would be considered. In February, 2016, the SMB met to consider the CMP (along with other proposals submitted by other stakeholders). They reviewed the proposal to determine whether it was to be deemed "critical" or to be placed in the que for consideration during the next update of the standard. The SMB carefully considered all aspects of the proposal. In the spring of 2016, RESNET announced the formation of the CBRITG to work on the issue of a cost based rating index, as well as issues shown in Section 2.2.

2.2 Harmonizing with California Home Energy Ratings

RESNET uses nMEUL as the basis of its ERI ratings, and the California Energy Commission (CEC) uses Time Dependent Valuation (TDV) for its Title 24 energy performance metric. Ratings using the RESNET HERS Index in California homes were often different from those using the TDV methodology. In 2015, Philip Fairey, Florida Solar Energy Center, and Martha Brook, California Energy Commission, conducted a detailed analysis to determine if and how California's HERS specifications can better align with the RESNET Standard, and to identify areas where RESNET and CA HERS can both benefit from ongoing collaboration. The approach used in that analysis and detailed results are included in a spreadsheet and accompanying presentation to RESNET in February 2016.

California policy issues driving the analysis included:

- Asset ratings should reflect relative energy performance across fuel types.
- Energy modeling of Rated Home should reflect expected CA home energy usage.

Recommendations provided by CEC to RESNET based on this analysis included:

- CEC should adopt IECC 2006 as reference level of efficiency in Reference Home.
- CEC must establish a fuel neutral water heater reference.
- CEC should focus CA specific assumptions on Rated Home.
- RESNET should consider modifying nMEUL to energy cost valuation and provide rating credit for ventilation cooling equipment.
- RESNET should add HVAC verification protocols to give appropriate credit to rated home HVAC quality installations.
- RESNET and CEC should continue to collaborate.

The NWI establishing the CBRITG and its scope of work provided an opportunity to implement these recommendations. The CEC, in its 2019 Title 24 Update, is proposing to use an Energy Design Rating (EDR) as the performance rating. The EDR is similar to the RESNET HERS, in that both are dimensionless indexes that compare a rated home's efficiency to the efficiency of an IECC 2006 reference home. However, there are notable differences. The primary difference is that the EDR uses a single fuel type in the reference building while HERS uses the multiple fuel type approach. Additionally, the EDR is a ratio of energy costs using the TDV metric, while the HERS uses the nMEUL metric.

3 Key Elements of a Cost-Based Rating Index

RESNET's HERS Index has been applied principally to voluntary new construction asset ratings by builders and utility energy efficiency programs. While this is a critical use case, it is not the only market segment and application for a home energy rating. Since a home energy rating has become a compliance pathway in the International Energy Conservation Code, RESNET has worked with ICC to ensure the rating provisions and methodology are consistent and useful for code compliance. In 2015, RESNET and ICC jointly agreed to change the terminology in Standard 301 from "HERS Index" to "energy rating index" (ERI) to permit any agency to implement the standard for code compliance. Different use cases with specific and sometimes conflicting purposes provide both a challenge and an opportunity for RESNET as it increases its breadth and impact in the marketplace. Known use cases for home energy asset ratings include the following:

- Performance-based energy code compliance
- Property valuation in the real estate market
- New construction "beyond-code" incentive programs
- Existing home retrofit incentive programs
- Building energy performance labels for regulatory and legislative initiatives
- Builder/developer company sustainability goals
- Energy Supplier incentive programs

Before discussing the benefits and pitfalls of a cost-based rating index, it is important to consider these home energy asset rating use cases. Where use cases have fundamentally different purposes, such as code compliance and property valuation, it may be difficult to achieve all use case objectives equitably and consistently with a single rating methodology or metric. The CBRITG examined key elements in the context of these use cases in an effort to identify one or more options for satisfying them with a cost-based index. Key elements considered by the CBRITG include:

- Point of Use Annual Energy Reduction
- Time of Use Annual Energy Reduction
- Reference Home Methodology
- Renewable Energy Considerations
- Energy Prices

3.1 Point of Use Annual Energy Reduction

An energy rating index frequently depends on the point-of-use energy reduction and the same is true for a cost-based index. Point-of-use energy reduction compares the absolute energy use in the proposed design to an accepted baseline design, for the end-uses considered by the rating system. The current HERS/ERI calculation methodology considers the total energy used by the home in the proposed design and compares it to the total energy used by the standard reference design. A cost-based calculation methodology would similarly require the point-of-use energy consumption of the rated home and reference home as the starting point for determining the cost-based rating index.

3.2 Time of Use Annual Energy Reduction

One area where an energy-cost-based rating index would potentially differ from an energy-based rating index is the consideration of time-of-use (TOU) energy reduction. The current HERS/ERI calculation does not consider TOU energy reduction. With the increasing uptake of renewables and other alternative sources of energy in the generation mix of the modern electric grid, electricity is valued differently at different points in time during a day. This is evidenced by the increase in residential customers with TOU electricity rate structures over the last decade.[1] HERS/ERI is used as an indicator of performance as well as an asset rating. Therefore, stability is an important characteristic of the metric. On the other hand, a consideration of TOU is likely to be important in the future energy landscape. The smart energy grid will enable widespread adoption of TOU rate structures. This topic requires further thought and work because such a consideration would require TOU tariffs which could be presumed to be relatively stable over a period of time. This is complicated by the volatility in the rapidly changing landscapes of energy production and pricing. For markets where TOU tariffs are established, this could be an option. For other markets monthly, seasonal, or annualized rates could be used. Further work is required to establish the calculation methodology.

3.2.1 Peak

Peak load reduction cannot be considered in an energy-cost based rating index unless demand charges are associated with a home's energy cost. Currently, very few residential customers have peak demand charges. However, if more residential customers are switched or voluntarily switch to rates with peak demand rates, then this issue should be revisited.

[1] EIA Form 861 2015 Dynamic Pricing Data https://www.eia.gov/electricity/data/eia861/

3.2.2 Frequency

Currently, most residential markets follow annual, monthly or seasonal energy prices. However, the proportion of residential customers with a TOU rate structure has been increasing over the last decade.[2] The frequency of the price signal used in the calculation will depend on whether a TOU consideration is implemented in the calculation. If the calculation provides for a TOU consideration, the price signal will need to be more detailed to match the utility price blocks.

3.3 Reference Home Methodology

Two different viewpoints on the characteristics of the reference home emerged during the task group deliberations. Martha Brook and Neil Leslie provided the rationale for a single reference home methodology. Steve Rosenstock and Craig Drumheller provided the rationale for a multiple baseline methodology. Both are discussed below and in more detail in Appendix A.

3.3.1 Single Reference Home Methodology (Brook and Leslie)

The primary intent of ANSI/ICC/RESNET Standard 301-2014 is to "provide a consistent, uniform methodology for evaluating and labeling the energy performance of residences. The methodology compares the energy performance of an actual home with the energy performance of a Reference Home of the same geometry, resulting in a relative energy rating called the Energy Rating Index." The primary intent of Standard 301 is likely to be achieved most effectively by doing the right thing (high performance) the right way (high efficiency) for the right reasons (uniformity and consistency).

Significant factors impacting the Standard's alignment with its primary intent include:

- Metric or metrics used in the implementation approach;
- Prescriptive component or equipment efficiency vs. modeled or actual system performance; and
- Single vs. multiple reference configurations for comparisons and compliance.

The impact of these factors is most significant for mixed fuel homes compared to all-electric homes, but is also important when comparing envelope performance to equipment performance, when comparing different product classes or subclasses serving the same function, or when considering on-site renewable power.

Standard 301 uses a performance methodology for ratings and code compliance, comparing the building under consideration (the Rated Home) to a defined set of components, equipment, and systems (the Reference Home). The means by which its Reference Home performance level is established is by incorporating a set of equipment and building components considered code minimum efficient in 2006. Modeling rules provide the conversion factors and values to be used in the calculations to determine the performance level of the Rated Home and Reference Home configurations. The end result is a Rated Home level of absolute performance compared to a Reference Home level of absolute performance. Efficiency is tightly aligned with performance, but it is not the same thing. The efficiency level of the Reference Home was selected by choice at IECC 2006 levels of performance, not by any

[2] EIA Form 861 2015 Dynamic Pricing Data https://www.eia.gov/electricity/data/eia861/

technical requirement. The Reference Home configuration needs to establish uniform and consistent performance for all comparisons to align with the primary intent of Standard 301.

The recommended single standard electric reference design would use current Standard 301 electric technologies as the baseline in all relevant component categories with a choice of energy form to serve the Rated Home loads. These component categories would include space heating, space cooling, service water heating, range/oven, dryer and on-site power production. Note that cooling, light fixtures, refrigerator, dishwasher, clothes washer, and ceiling fans already use a single electric reference system in the current Standard 301.

The key rationale for a single Reference Home methodology for RESNET is the Standard 301 primary intent to promulgate "uniform" and "consistent" ratings. A single electric Reference Home approach is as follows:

- Establishes a single Reference Home performance requirement for all rated systems independent of making system or fuel choices for the Rated Home.
- Provides a consistent, uniform methodology for evaluating and labeling energy performance of any load reduction, energy service, or on-site power generation strategies to achieve an unbiased score for overall home performance comparisons. Only cares about ultimate result (comparable home energy performance) based on metric(s) and value(s) of choice.
- Extends the single baseline methodology currently used in Standard 301 for performance comparisons of other load reduction, energy service, and on-site power options, including envelope (R-Value, glazing, doors, structural mass), distribution system (DSE), infiltration (SLA), electric heat pumps for electric heating, electric air conditioners for cooling, refrigerator, lighting, and on-site power production.
- Addresses equivalency biases caused by multiple Reference Home technology performance requirements depending on fuel type for gas and electric technologies that provide the same energy service (heating, water heating, cooking, clothes drying).
- Provides uniform and consistent treatment of all rated system options, including conventional, renewable energy, hybrid technology, and waste heat recovery options.
- Is indifferent to the relevant rated system choice in the Rated Home, comparing all relevant rated system options against a single electric Reference Home energy performance requirement.

Standard 301 currently uses multiple reference mechanical systems, with a different reference level of performance depending on fuel type, for systems with fuel choices for heating, service water heating, range/oven, and clothes dryer, (but not cooling) – considering all reference systems to be equivalent to each other for rating purposes. However, none of the reference systems have the same annual energy cost across fuel types, and these differences influence the HERS/ERI ratings that are derived from these multiple references.

The only equitable option to eliminate fuel bias and create a level playing field is to be agnostic about fuel choices (fuel-blind, not fuel neutral), not caring how the Rated Home achieves its energy performance, as long as it is done in a way that is aligned with the primary intent of the standard. A single Reference Home is the most consistent and uniform way for the standard to be fuel-blind, tightly aligning with the primary intent of Standard 301, and is critical for uniform and consistent rating and labeling using Standard 301. Shifting to a single reference design methodology provides an equitable credit to all technologies that have lower annual costs compared to the single reference level irrespective of energy form or technology design. It establishes fixed Reference Home performance requirements BEFORE making the technology and energy choices for the Rated Home. A single reference design methodology creates a level playing field for all technology and energy forms and provides equitable treatment of advanced renewable, waste heat recovery, hybrid, and multi-fuel technology options. It is especially important for equitable and consistent evaluation of on-site renewable power generation and combined heat and power systems in the Rated Home.

Multiple baselines treat comparable technologies that use different energy forms as if they are equal when they are not, in an attempt to be "fuel neutral." Standard 301 is not "fuel neutral" because it treats various technology options as equivalent to each other even though there are demonstrable and meaningful differences in energy cost among the fuel choice and technology options providing the same energy service. The HERS/ERI rating is meant to provide a singular indication of relative energy performance that builders, homeowners and other stakeholders can use to judge one home's energy assets compared to other homes' energy assets. Multiple baselines in Standard 301 do not achieve this goal.

Detailed component load information from EnergyGauge® simulations in five cities of Reference Homes and homes that were ~50% more efficient than the fuel-specific Reference Home enabled a comparison of methodologies for all-electric and natural gas home options. Table 2 and Figure 1 illustrate the challenges with both the nMEUL methodology and the multiple Reference Home methodology that a single reference methodology addresses. Only the single reference cost methodology aligns tightly with annual energy costs in all cases. The impact of shifting from a multiple baseline to a single baseline varies based on location and relative electric and gas prices. In heating dominated climates such as Chicago, the impact is much greater than in cooling dominated climates such as Miami. Single or multiple reference cost ratings for all-electric ~50% more efficient homes range from 3 to 7 points higher than nMEUL ratings for the same homes. Multiple Reference Home cost ratings for gas homes are 4 to 13 points higher than single electric Reference Home ratings for the same homes. nMEUL ratings for gas Reference Homes are 9 to 25 points higher than the single baseline cost ratings for the same home.

Table 2: Comparison of Energy Costs and Scores Using nMEUL and Cost Methods

City and Energy Choice	Miami		Houston		Atlanta		Albuquerque		Chicago	
	Elec	Gas	Elec	Gas	Elec	Gas	Elec	Gas	Elec	Gas
~50% Improved Home										
Annual Energy Cost ($)	1,052	979	1,094	994	1,109	969	1,155	981	1,493	1,176
nMEUL Multiple Reference Homes	42	43	45	46	44	43	49	48	48	46
Cost Single Electric Reference Home	49	46	51	47	49	43	52	45	50	39
Cost Multiple Reference Homes	49	50	51	53	49	50	52	55	50	53
Reference Home (nMEUL Index = 100)										
Annual Energy Cost ($)	2,141	1,957	2,132	1,874	2,274	1,925	2,201	1,778	2,994	2,237
nMEUL Multiple Reference Homes	100	100	100	100	100	100	100	100	100	100
Cost Single Electric Reference Home	100	91	100	88	100	85	100	81	100	75
Cost Multiple Reference Homes	100	100	100	100	100	100	100	100	100	100

Note: Electricity Cost $0.12/kWh; Natural Gas Cost $0.98/Therm

Figure 1: Impact of Metric and Reference Home on Rating – Chicago

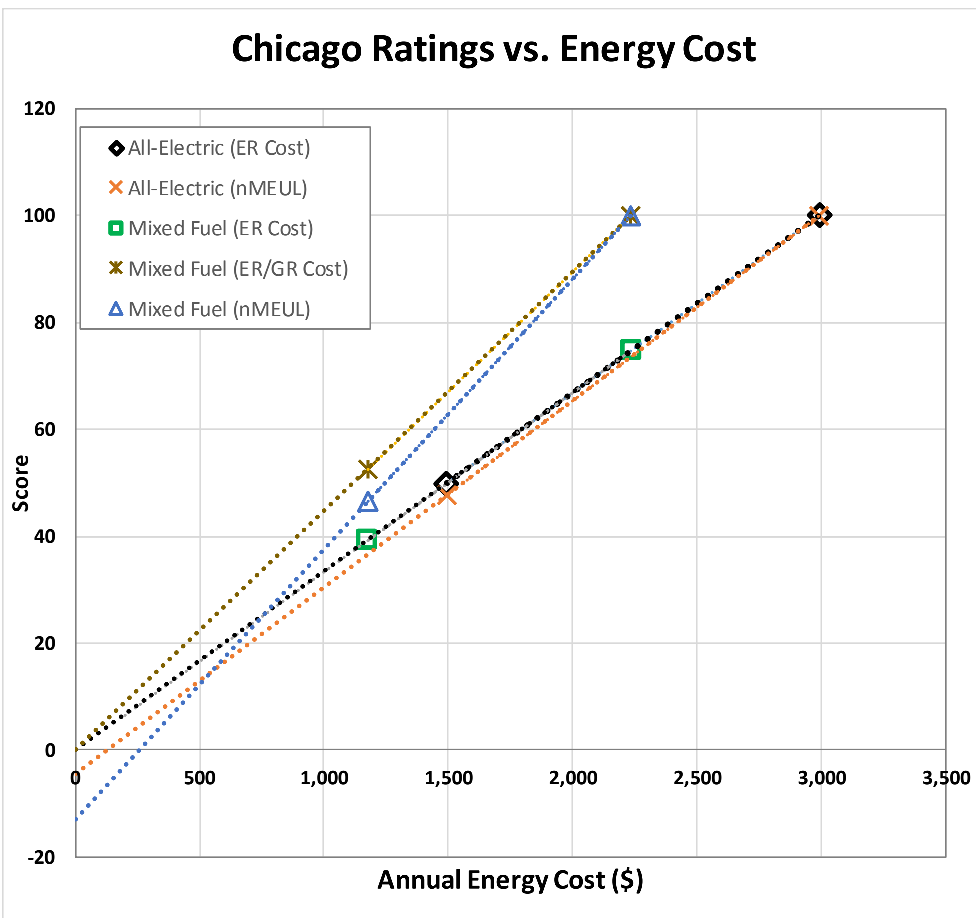


Table 3: Single Baseline Methodology – Pros and Cons

Element	Pro	Con
Single Baseline for heating, water heating, cooking, and clothes drying	Extends the single baseline methodology currently used in Standard 301 for performance comparisons of other load reduction, energy service, and on site power options, including envelope (R-Value, glazing, doors, structural mass), distribution system (DSE), infiltration (SLA), electric heat pumps for electric heating, electric air conditioners for cooling, refrigerator, lighting, and on-site power production. (Brook, Leslie) Addresses equivalency discrepancies caused by multiple Reference Home technology performance requirements depending on fuel type for gas and electric technologies that provide the same energy service (heating, water heating, cooking, clothes drying). (Brook, Leslie) Does not differentiate among load reduction, energy service, or on-site power generation strategies to achieve score. (Brook, Leslie) Provides a consistent, uniform methodology for evaluating and labeling energy performance of any load reduction, energy service, or on-site power generation strategies to achieve an unbiased score for overall home performance comparisons. Only cares about ultimate result (comparable home energy performance) based on metric(s) and value(s) of choice. (Brook, Leslie) Helps overcome split incentives among builders, realtors, homebuyers, and homeowners by providing consistent information for use by all stakeholder groups. (Brook, Leslie) Potential for tight alignment with consumer interests in understanding home energy performance based on metric(s) of choice. (Brook, Leslie) Treats fuel and technology options uniformly and consistently compared to a common, single performance level based on the metric(s) and value(s) of choice. (Brook, Leslie)	Metric(s) and associated factors and values can greatly impact scores when comparing mixed fuel home to all-electric home. Baseline needs to be selected and applied carefully to align with the primary intent of Standard 301 and avoid introducing new biases associated with split incentives. (Brook, Leslie) Education and careful implementation needed to address parochial concerns about "gaming" and "re-igniting the fuel wars." (Brook, Leslie) Significantly increases the "game playing" that could occur with any index. As shown in the attached spreadsheets, with a single baseline in Chicago, the starting point for an electric house is 100, but for a house with gas appliances, the starting point is 75. On the other hand, for homes in rural areas near Chicago using propane, when propane costs $3.06 per gallon, the starting point for an electric house is 100 but the starting point for a house with propane appliances is 122. Multiple baselines (where all homes start at 100) avoid these discrepancies. (Rosenstock, Drumheller) Creates "fuel wars" that can occur based on differential energy costs and different end-use efficiency potentials. (Rosenstock, Drumheller) Ignores the fact that home builders, home owners, developers, and property owners have a choice of fuels and equipment, does not allow choice of technologies and fuels, and usually forces one certain choice on them. (Rosenstock, Drumheller) Ignores the fact that certain fuel types are not available in certain parts of the country, and penalizes builders or homeowners or developers for that marketplace reality. (Rosenstock, Drumheller) Creates an inaccurate "apples to oranges" index comparison for builders; homeowners and other potential consumers. It provides much less stability compared to a multiple fuel baseline. (Rosenstock, Drumheller).

3.3.2 Multiple Reference Home Methodology (Rosenstock and Drumheller)

Steve Rosenstock, P.E., Senior Manager Energy Solutions, Edison Electric Institute
S. Craig Drumheller, Director, Construction, Codes & Standards, National Association of Home Builders

Background

The RESNET Standards Development Committee (SDC 300) formed the Cost-Based Rating Index Task Group (CBRITG) to develop recommendations regarding the potential use of a cost-based method to update the existing HERS Index for the ANSI/RESNET/ICC 301 Standard (301 Standard). The task group has reviewed many possible aspects of such a rating index, and this section discusses the rationale for using multiple fuel source baselines for the cost-based rating index.

Currently the fuel source baseline issue is avoided in the 301 Standard through the use of what is known as the Normalized Modified End Use Load (nMEUL). However, if a cost based index is to be used, the fuel source baseline will need to be addressed. The question is: Should a single fuel type be used to calculate the reference home for the HERS Index regardless of the fuel sources used in the house being rated?

Summary

The use of multiple baselines accomplishes the following goals:

- Significantly reduces the "game playing" that could occur with any index.
- Avoids the "fuel wars" that can occur based on differential energy costs and different end-use efficiency potentials.
- Accounts for the fact that home builders, home owners, developers, and property owners have a choice of fuels and equipment, allows maximum choice of technologies and fuels, and does not force one certain choice on them.
- Accounts for the fact that certain fuel types are not available in certain parts of the country, and does not penalize builders or homeowners or developers for that marketplace reality.
- Creates actual "apples to apples" index comparisons for builders; homeowners and other potential consumers.

Analysis

Home builders, developers, and property owners have many choices of baseline and advanced technologies for new (and existing) homes. In addition, they will usually have a choice of at least 2 types of fuel to use for the end-use products.

For example, the choices for a heating system could include the following:

- Central Warm Air Furnace
- Steam Boiler
- Hot Water Boiler
- Heat Pump
- Ground Source Heat Pump
- Electric Baseboard Heating
- Packaged Terminal Systems

- Zoned Systems (e.g., “mini-split” systems)

The choices of fuel may include all of the following:

- Electricity
- Natural Gas
- Fuel Oil
- Propane
- Wood
- Solar Thermal
- Solar Photovoltaic

It is a fact that in some / many (rural) parts of the United States, there will be fewer fuel type choices. In many rural areas, natural gas lines do not exist, or are prohibitively expensive to connect to a single or multiple homes. In other parts of the United States, there may be no distributors of fuel oil. Having a single baseline based on a fuel type that is not available (or not readily available) would create significant and unnecessary penalties for builders and homeowners.

With a multiple baseline system, the builder makes the choice of baseline technology and baseline fuel. Consistent with Standard 301, fuel switching is not allowed, so that there is an “apples to apples” comparison of energy costs that can be lowered with improved envelope design and equipment design.

As an example, based on the US Energy Information Administration’s *Residential Energy Consumption Survey 2009* report, a typical natural gas water heater uses 20 thousand cubic feet (205.6 Therms) of gas per year, while a typical electric water heater uses 2,663 kWh per year, a propane water heater uses 207 gallons per year, and a fuel oil water heater uses 134 gallons per year. If natural gas costs $1.50 per Therm, electricity costs $0.10 per kWh, propane costs $2.50 per gallon, and fuel oil costs $3.50 per gallon, the annual energy costs are estimated to be:

Natural Gas Water Heater:	$308.40
Electric Water Heater:	$266.30
Propane Water Heater:	$517.50
Fuel Oil Water Heater:	$469.00

With a multiple baseline system, the modeling requires the baseline water heating cost to be $266.30 if the builder chooses an electric water heater, and the water heating cost to be $308.40 if the builder chooses a natural gas water heater (or $469 to $517.50 for fuel oil or propane water heaters). The builder then has to choose technical / design options to either lower the energy costs of the actual chosen water heating equipment.

Under a single baseline system, if based on natural gas, the builder could “game” the system by “switching” to an electric water heater (something they were going to do anyway) and receive an energy cost credit of $42.10 while not improving house or end-use equipment efficiency at all. If based on propane gas, the energy cost credit would be $251.20.

Using 2016 national average prices ($0.932 per Therm for natural gas, $0.126 per kWh for electricity, $1.41 per gallon of propane, and $1.98 per gallon of fuel oil), the discrepancies would still be large (e.g., $144.94 between natural gas and electric), and depending on the baseline, the credit or penalty could be even more significant.

With the multiple baseline approach, this non-efficiency credit is eliminated.

Similar examples exist for space heating systems, cooking equipment, clothes dryers, and hearth products. By basing the cost baseline on actual equipment choices, it will provide the consumer with the most realistic cost comparison of efficiency upgrades.

When using a single (e.g. electric) baseline, an alternate fuel source can have a significant impact on the index for the same house. However, multiple fuel source baselines will provide a more stable index that is based on the performance of the house (and equipment relative to the fuel specific equipment baseline) rather than the total annual cost of the fuel. The fuel source impact is illustrated in Table 4 using a 1968 square foot single family house in College Park, Maryland.

In this analysis using REM/Design v15.2 simulation tool, the same home is used in all of the simulations. The only variables are the heating and water heating fuel source as well as the referenced energy code. The baseline was a minimally compliant 2006 IECC design (conceptually similar to the 301 Standard baseline) and the proposed design was minimally compliant with the 2015 IECC.

The results show that with a single (electric) baseline, there is a 24-point range strictly based on the heating and water heating fuel source when switching between electric, natural gas and propane. Using the multiple baseline approach, where the reference home has the same heating and water heating fuel source as the proposed home, the range is only 4 points.

Table 4: Impact of Reference Home Methodology on Score

		Total Fuel $						
		2006 IECC		Total Fuel $			Single Baseline	Multiple Baseline
	Fuel Cost	Baseline	Base Equip	2015 Code	2015 Equip		(Elect) Index	Index
Natural Gas	$1.21/therm	$ 1,906.00	78 AFUE	$ 1,664.00	80 AFUE		78	87
			13 SEER		13 SEER			
Propane	$2.36/gal	$ 2,624.00	78 AFUE	$ 2,190.00	80 AFUE		102	83
			13 SEER		13 SEER			
Electric	$0.1234/kWh	$ 2,139.00	7.7 HSPF	$ 1,793.00	8.2 HSPF		84	84
			13 SEER		14 SEER			
Propane prices	5 year average residentail price per gallon - EIA data (april 2012-march 2017)							
Natural Gas prices	5 year average residentail price per therm - EIA data (april 2012-march 2017)							
Electricity	5 year average residentail price per kWh - EIA data (feb 2012-jan 2017)							
Electric Water Heater (EF)			0.904		0.945			
Gas/LP Water Heater (EF)			0.575		0.6			

Conclusion

For any cost-based rating index, multiple baselines along with no fuel switching will provide the most benefit and be the most consistent with the current 301 Standard.

Not only will the multiple baseline approach be more stable, based on fuel source, than the single baseline, it will be more representative of the building performance. It will also track similar to the current nMEUL index.

There are often situations where natural gas is not available and in cold climates, where heat pumps do not perform as well, often making electric heat impractical. This leaves many situations where a homebuyer/homebuilder can be essentially forced to use propane resulting in a handicap (in this case) approaching 20% relative to electric. That means an additional 20% of energy savings with equipment efficiency, building envelope or renewables will be necessary just to bring the home on par with a minimally compliant home using electric space and hot water heat. If the target is beyond code, this can virtually eliminate some efficiency programs strictly based on fuel availability.

It should be clear that although the proposed index modification is being referred to as “cost based”, it should not imply that the index is representative of the total energy cost and comparable across all housing types, all locations, all fuel types and all size homes. The current methodology already compares a home to itself geometrically and by climate- essentially normalizing for those aspects. The multiple fuel source baseline adds fuel type functionally to normalize the fuel source in the baseline and proposed designs.

Finally, the multiple baseline approach is already being used in the IECC performance path for both residential and commercial as well as ASHRAE 90.1. To utilize a single baseline approach would be the exception rather than the rule. The competitive disadvantage it would create for different industries in different areas of the country makes it very problematic. The multiple baseline approach is more consistent with modeling practices, places less of a disadvantage to industries and best replicates the current HERS/ERI results.

Table 5: Multiple Baseline Methodology – Pros and Cons

Element	Pro	Con
Multiple Baselines for heating, water heating, cooking, and clothes drying.	Separates rating from fuel choice for energy services. Aligned with 2006 IECC multiple baseline performance path for heating and water heating. Significantly reduces the "game playing" that could occur with any index. As shown in the attached spreadsheets, with a single baseline in Chicago, the starting point for an electric house is 100, but for a house with gas appliances, the starting point is 75. On the other hand, for homes in rural areas near Chicago using propane, when propane costs $3.06 per gallon, the starting point for an electric house is 100 but the starting point for a house with propane appliances is 122. Multiple baselines (where all homes start at 100) avoid these discrepancies. (Rosenstock, Drumheller) Avoids the "fuel wars" that can occur based on differential energy costs and different end-use efficiency potentials. Using the values for Chicago in the above bullet point, and assuming that the code requirement is an energy cost index of 70, the house with gas appliances will only have to perform minimal efficiency to go from 75 to 70 (6.67% energy cost savings), while an electric house will have to reduce energy costs by 30% (100 to 70), and a propane house will have to reduce energy costs by 42.6% (122 to 70). (Rosenstock, Drumheller) Accounts for the fact that home builders, homeowners, developers, and property owners have a choice of fuels and equipment, allows maximum choice of technologies and fuels, and does not force one certain choice on them. (Rosenstock, Drumheller) Accounts for the fact that certain fuel types are not available in certain parts of the country, and does not penalize builders or homeowners or developers for that marketplace reality. (Rosenstock, Drumheller) Creates actual "apples to apples" index comparisons for builders; homeowners and other potential consumers. It provides more stability compared to a single fuel baseline. (Rosenstock, Drumheller)	Separates rating from fuel choice for energy services, leading to equivalency discrepancies in the home energy performance score that is not consistent with metric of interest, in an effort to be "fuel neutral." (Brook, Leslie) Aligned with "separate but equivalent" 2006 IECC baselines for electric and gas heating and water heating that have the same equivalency discrepancies caused by multiple Reference Home technology performance requirements. IECC is silent on cooking and clothes drying. (Brook, Leslie) Provides an inconsistent, variable methodology for evaluating and labeling energy performance of gas and electric technologies that provide the same energy service (heating, water heating, cooking, clothes drying). (Brook, Leslie) Inconsistent with nearly all other load reduction and energy service options in the standard of Standard 301 that use a single baseline for performance comparisons, including envelope (R-Value, glazing, doors, structural mass), distribution system (DSE), ventilation, electric heat pumps for electric heating, electric air conditioners for cooling, refrigerator, and lighting. (Brook, Leslie) Treats baseline electric and gas technologies as if they have equal performance for the identical energy service, even though they are unequal on any performance metric, including site energy, source energy, energy cost, or greenhouse gas emissions. The resulting scores do not align with the metric across fuel choices. (Brook, Leslie) Assumes fuel choice has already been made. Scores are subsequently used by builders to differentiate their homes from other comparable homes with different fuel choices to help consumers (and builders) make purchase decisions, including fuel choice, for comparable homes. (Brook, Leslie) Assumes that consumers have fuel type preferences that override their valuation of energy efficiency or energy costs. Assumes that consumers understand that home energy ratings have fuel type biases such that homes cannot be compared to each other unless they have the same fuel types for space heating, water heating, cooking and clothes drying. (Brook, Leslie) Provides unearned advantages that promulgate split incentives among builders, realtors, home buyers, and homeowners. (Brook, Leslie) Does not differentiate among load reduction, energy service, or on-site power generation strategies to achieve score. (Brook, Leslie)

3.4 Renewable Energy Considerations (Phelan and Mendon)

Background

This section discusses the consideration and implications of renewable energy in the context of a cost-based rating index. Currently, the HERS Index calculation fully credits on-site power production in the proposed design assuming the reference design has no renewables. It does not account for off-site renewables or the time of generation.

Discussion

With the advances in technology, renewable energy systems, especially photovoltaic (PV) systems and solar thermal are becoming more affordable and more common in the national housing sector. Certain states and utilities across the nation have been promoting the use of these renewable distributed energy resources (DERs) and incentivizing the flow of the generated power back into the grid. However, with the rising popularity of these systems, as well as central station renewables, the grid is under increasing pressure to maintain a feasible solution.

Aside from the practical challenges of integrating DERs into the grid, the consideration of renewable energy in the context of a cost-based index is complex given the constantly changing nature of tariffs and federal/state incentives for renewable energy. An important aspect of the HERS index is the stability of the index over years so that houses or assets rated under the system can be compared on a common ground. It is thus desirable to select a stable basis to compute the index, which means the variability in the costs associated with renewable energy credit will have to be controlled in the calculation.

An additional complexity is the consideration of on-site versus off-site renewable production. For example, some multifamily buildings find it more feasible to invest in a community based renewable energy production setup. However, the HERS index confines itself to the building site. This is further complicated by the variability in the terms of the production of off-site renewable energy over time. The current HERS index calculation does not address this question of off-site renewable energy being partially or fully owned by a building owner.

Furthermore, efficient measures, components and integrated design characteristics minimize building energy consumption, heating/cooling, and equipment size; reduce peak loads; and are an essential facet of a building energy performance rating system. Providing motivation to maximize the amount of energy that never has to be consumed by building systems or equipment – i.e. is conserved – should serve as the foundation for the cost-based rating index. In addition to annual energy cost savings, energy efficient design provides other economic and non-economic benefits that are important to every homeowner: lower life cycle cost, improved comfort, environmental protection, reduced equipment first costs (where equipment can be downsized) and maintenance costs, as well as improved resale value. To structure a cost based rating system that allows trade-off of effective conservation measures with on-site renewables energy production is misleading to the consumer.

The cost-based rating index should be structured to provide consumer transparent reward for synergistic optimization of conservation measures and on-site renewable energy production. Conservation and renewable synergy should be inherent in the rating that can be achieved through a strategy that incentivizes minimization of the capacity of an on-site renewable energy production system. Besides the conservation benefits described above, this will provide annual cost savings as well as system maintenance and replacement cost savings. It would also serve to reduce the net metering dilemma described above. The authors of this discussion are cognizant of the fact that federal and state incentives are designed to incentivize the maximization of on-site renewable energy systems based on size, not site-specific annual output (e.g., fixed-plate PV systems facing due North and mostly shaded by other buildings or trees will still receive the maximum incentives that are solely based on the investment).

The importance of incorporating building energy efficiency measures and renewable energy sources to the future of our nation's impact on the environment, energy security and energy infrastructure welfare, is highly recognized. Furthermore, it is critical that required investments in the electricity grid are closely connected with improvements in energy efficiency and the increasing feasibility and applicability of distributed renewable energy sources, especially solar PV. Harmonization of end-use efficiency and distributed and central station renewable energy sources with infrastructure strategies are essential to addressing these challenges. In this broad perspective, success would be achieved when a building operates efficiently all year while exhibiting minimal power, thermal energy, and process energy demands during peak hours throughout its lifetime.

A building energy rating system must be structured to enable its users to make informed, effective energy saving choices. Of course, how a system is leveraged can be much different between one type of user and another. Key user types of a builder and a utility / energy supplier may be interested in applying a rating for purposes of marketing the energy efficiency of its products versus interested in applying a rating as a basis for customer incentives in order to align energy demand with production strategies, respectively. The evolving landscapes of energy conservation and renewable energy generation pose new challenges and opportunities for a next generation rating system. Developing a rating that provides consumer meaning, stability and rigor along with the versatility of diverse user type interests for many years to come is essential to its success.

The consideration of appropriate energy costs for a realistic and reasonable evaluation of renewable technologies needs to be done carefully, as any decisions made in this regard today will likely remain in place for several years. The changing nature of the electric grid and the subsequent introduction of time-of-use rates are likely to fundamentally change the optimal technology mix used in homes in the future. It is important that these elements are weighed carefully so that the ERI remains valuable to stakeholders that rely on the ERI for their programmatic needs.

3.5 Energy Prices

The CBRITG discussed the relative merits of using national, regional, or local prices for a cost-based index. TG consensus (with a minority dissenting) was to recommend national energy prices for all ratings. The Parameter Matrix in Appendix B provides additional information and TG member preferences.

Table 6: Energy Price Basis – Pros and Cons

Element	Pro	Con
Energy Price Basis: National Average	Simple approach, easily understood. (Brook, Leslie) Avoids rewarding or punishing a home solely based on its specific location (city, state). (Brook, Leslie) Easily implemented options for quick updates to accommodate short, medium or long term price volatility. (Brook, Leslie) Facilitates comparisons within and across fuel types to meet primary intent of standard with limited unintended consequences. (Brook, Leslie) Directionally tracks local energy price volatility for the most part, aligning score-based decisions with local annual energy costs, especially when comparing existing housing stock performance relative to new construction performance. (Brook, Leslie)	Does not align tightly with actual local costs, potentially leading to suboptimal home purchases and energy investments; supplemental energy cost information can ameliorate this effect. (Brook, Leslie) May not always directionally track local energy price volatility, complicating comparisons based on scores. (Brook, Leslie)

3.6 Parameter Matrix

To help guide the overall effort, the CBRITG developed a detailed list of parameters, along with a comparison of various ways to incorporate those parameters in a rating. The parameter matrix and related group observations are summarized in Appendix B. The CBRITG was also informed by a Matrix of Potential Metrics for RESNET HERS Index provided to SDC 300 by the Calculation Subcommittee in 2015. Appendix A includes that matrix for SDC 300 reference.

4 Analysis of nMUEL and California TDV Methodologies (Fairey and Brook)

A significant analytical effort on energy rating methods supported RESNET and CBRITG objectives. In 2015, Philip Fairey (FSEC) and Martha Brook (CEC) conducted analysis of homes with differing envelope efficiencies and differing equipment efficiencies in five California climates in response to a request from RESNET. The analysis compared simulation results using the HERS nMEUL method and the California TDV method. The HERS simulations used EnergyGauge® USA software and the California TDV simulations used CBECC-Res software.

As shown in Figure 2, overall results are remarkably similar considering the major differences in analysis and rating methods.

Fairey and Brook conducted similar analysis using California and HERS methods during 2016 and 2017 in response to requests from CBRITG members. Compared to the 2015 analysis, there is a major difference in the CBRITG analysis results due to use of a "California Energy Design Rating" in the CEC performance method for code compliance. In the California Energy Design Rating, the reference case is always an all-electric home, regardless of the proposed home equipment.

The Energy Design Rating method results vary significantly from the results using the TDV method shown in Figure 2. For example, Figure 2 shows that standard or better homes with standard or better gas equipment score better than identical homes with standard or better electric equipment. While the CA TDV method scores align closely with the HERS scores with x-coefficients very near unity, the CA Energy Design Ratings method scores show about a 17% difference for homes with gas equipment.

Figure 2: Comparison of HERS and TDV Ratings in 5 California Climates – Multiple Reference Homes

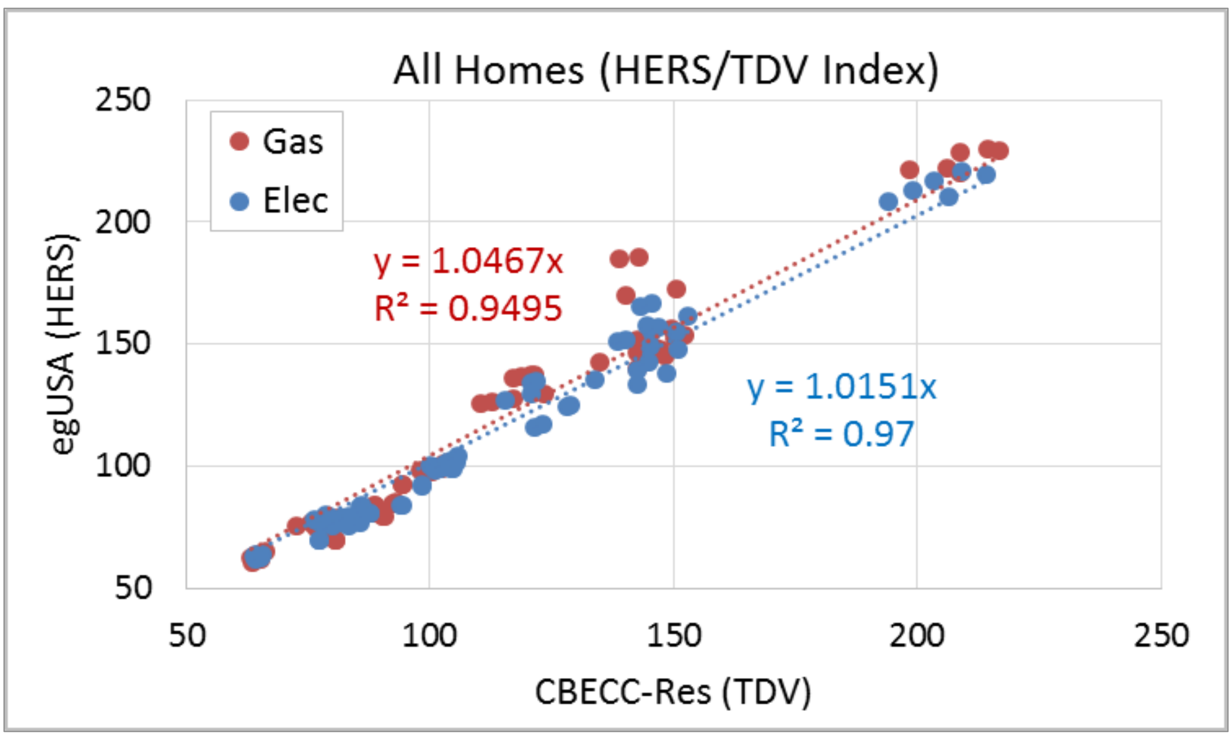
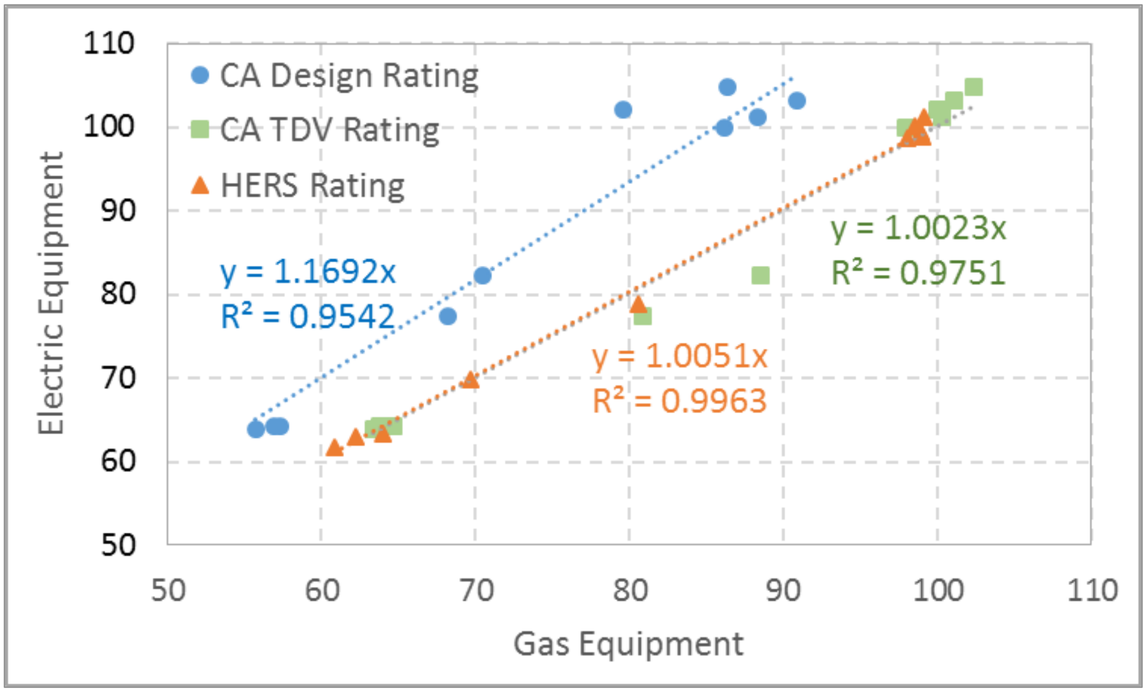


Figure 3: HERS, CA TDV, and CA Design Method Rating Comparison



For cost-based rating methods, the California data provided to the CBRITG by the CEC were analyzed and compared against the TDV Rating and the Design Rating.

Figure 4 and Figure 5 show that there is similarity in these data sets, with each having an x-coefficient significantly smaller than unity and a substantial y-axis offset.

Figure 4: CEC TDV Rating and Cost-based Rating Comparison – Multiple Reference Homes

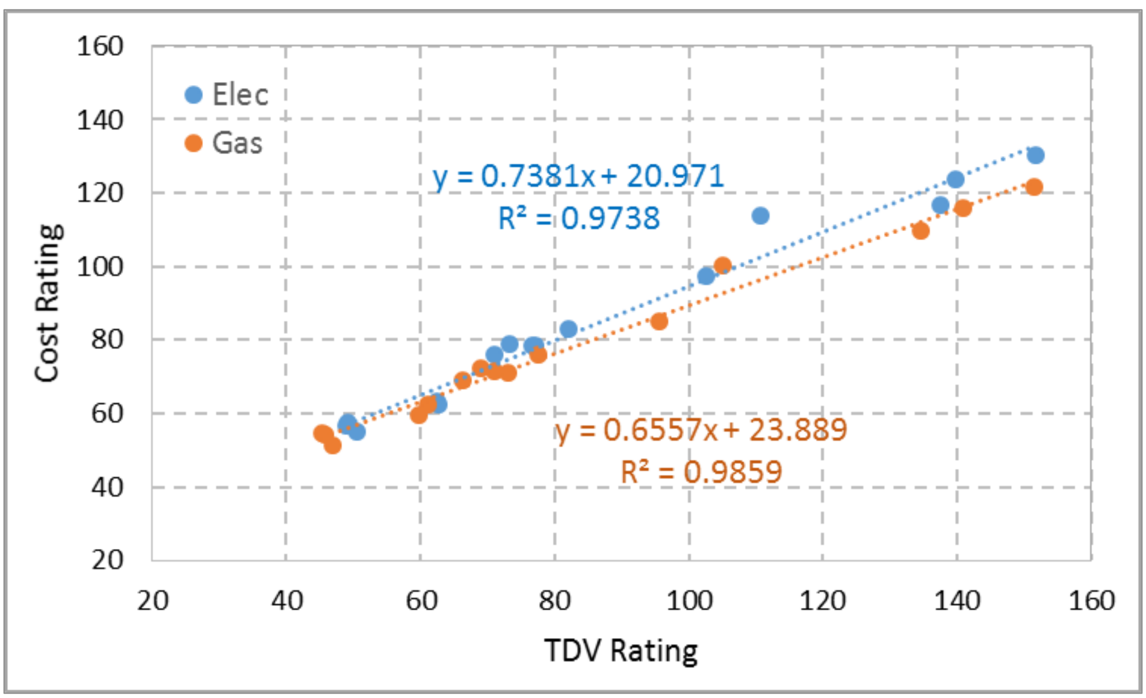
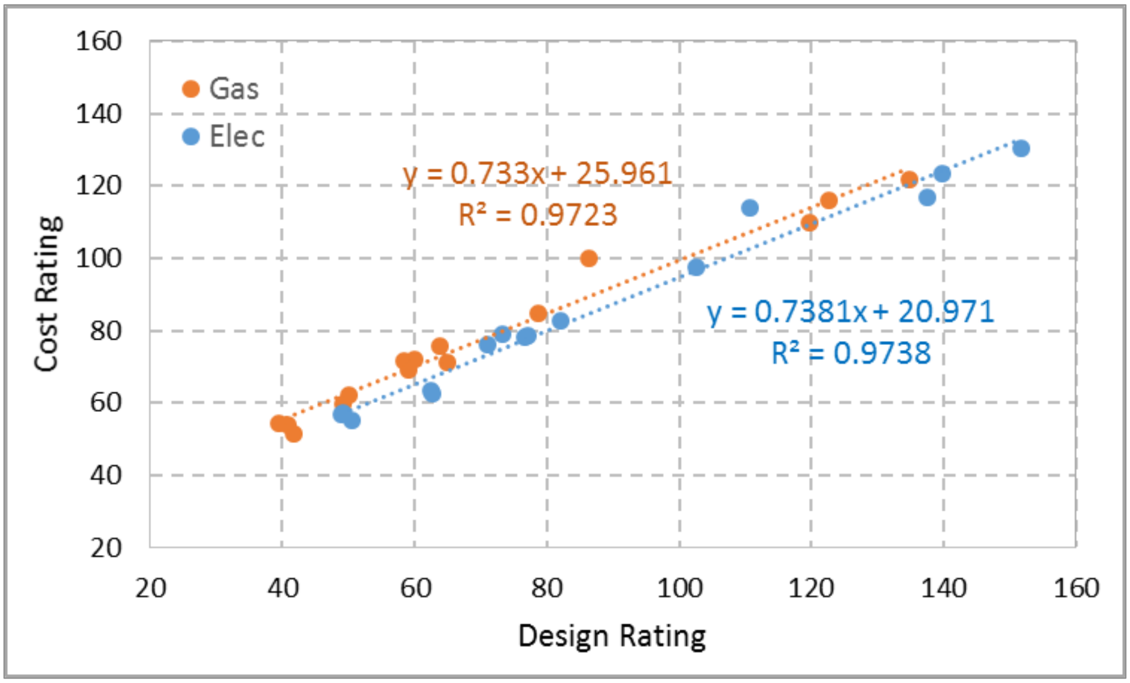


Figure 5: CEC Design Rating and Cost-based Rating Comparison



In addition to these analyses, both RESNET and ASHRAE SSPC 90.2 have conducted analysis to show that home geometry and operating parameters can have a significant impact on the Energy Rating Index, which will be important for any of the metrics or methods. The ASHRAE SSPC 90.2 analysis examined multiple indexing methods (HERS, Source Energy, Site Energy and Cost) in 15 representative climates ranging from Miami, FL to Fairbanks, AK. Figure 5 and 6 show characteristic results from the ASHRAE SSPC 90.2 study. Figure 5 shows results for Source Energy Index and HERS Index for all 15 climates, showing the regressions for the full data sets. The correlation coefficients are in the 60-70% range, due principally to the fairly large variation across climates. Figure 6 shows the home size regression equations for each of the four Index metrics examined by the ASHRAE SSPC 90.2 analysis. Note that the Index values vary by the metric used to calculate it.

Finally, Philip Fairey provided detailed EnergyGauge® USA v.5.1 simulation data to the working group with respect to "typical" 2-story, 2400 ft2, 3-bedroom highly efficient homes located in 5 different climates. Identical homes were simulated with highly efficient electric equipment and with highly efficient gas equipment in each climate. These data provide the basis for analysis results in Table 1, Figure 1, and Appendix A. The full detailed data set is in Appendix C.

Figure 6: Source Energy and HERS Index Regression Results for 15 Climates

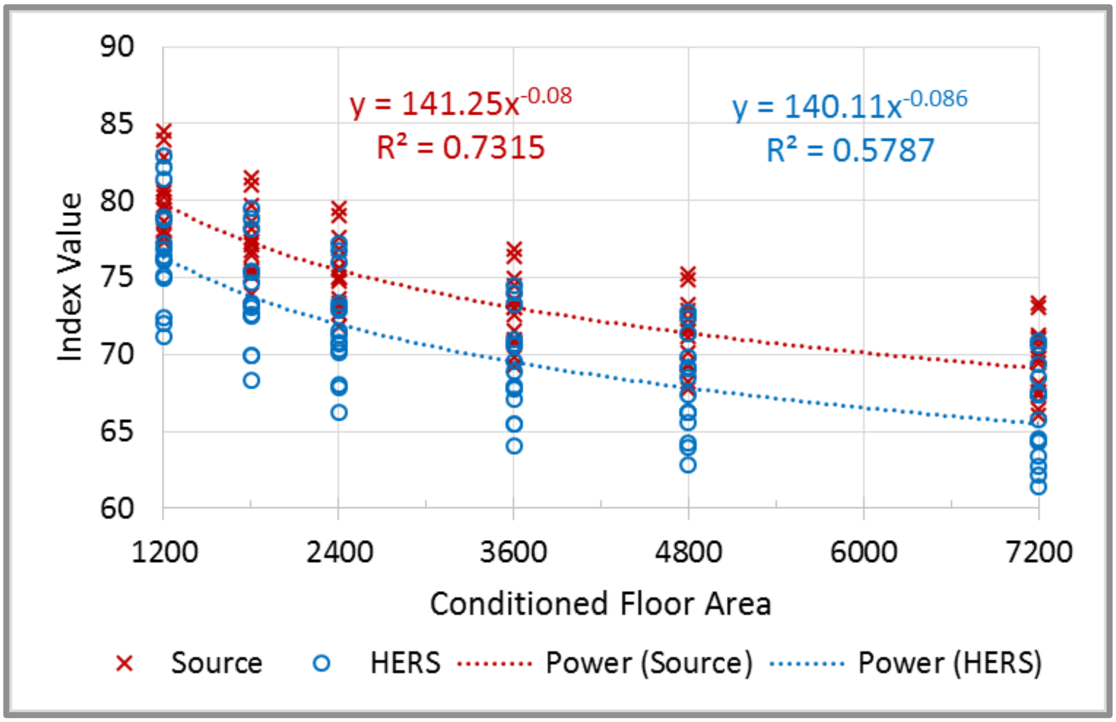
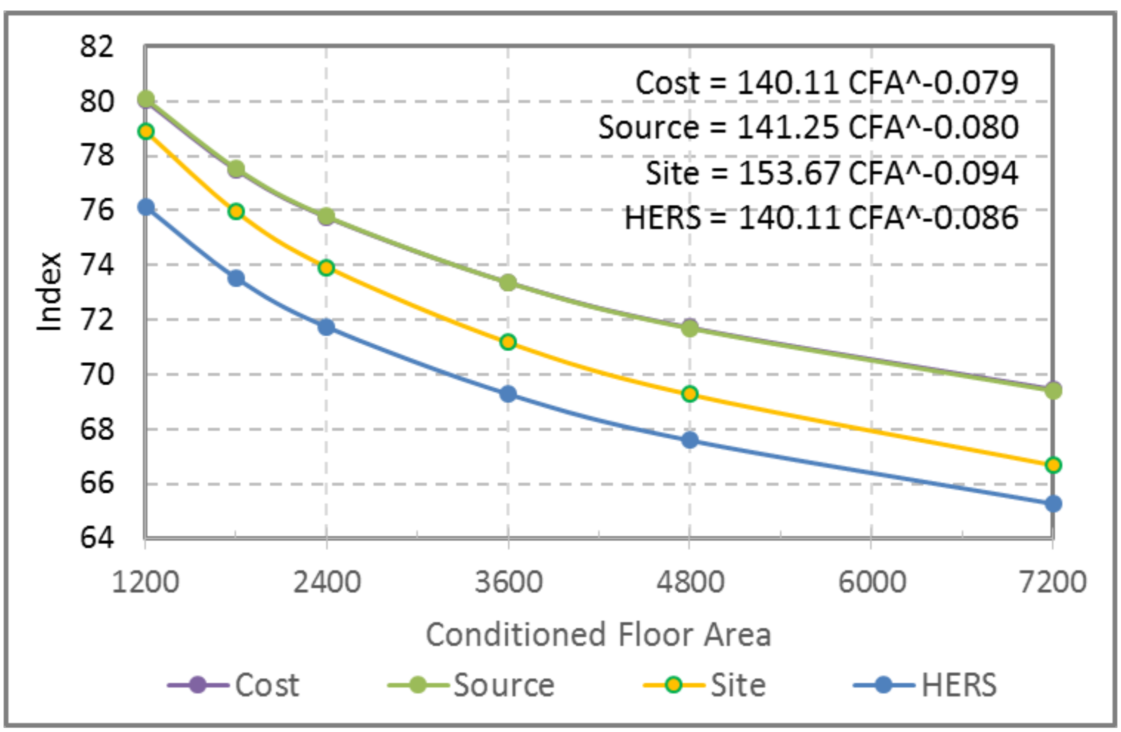


Figure 7: Regression Equations for Four Different Index Metrics



5 Recommendations

The CBRITG identified key elements of a cost-based rating index, issues associated with the current normalized modified end use loads (nMEUL) methodology, advantages and disadvantages of potential cost-based methodologies, analyses in support of Task Group needs, and provided joint and individual recommendations and viewpoints. The CBRITG worked to achieve consensus on all issues, but on a few critical aspects could not reach an agreement. Key elements considered by the CBRITG include:

- Point of Use Annual Energy Reduction
- Time of Use Annual Energy Reduction
- Reference Home Methodology
- Renewable Energy Considerations
- Energy Prices

There were fundamental disagreements within the group on the reference home methodology, a critical element of a rating calculation. Detailed information is provided regarding multiple reference home and single reference home approaches for review. Pros and cons are also listed to help with RESNET deliberations.

The CBRITG discussed options for treating renewable energy in the rating. The consideration of appropriate energy costs for a realistic and reasonable evaluation of renewable technologies needs to be done carefully, as any decisions made in this regard today will likely remain in place for many years. The changing nature of the electric grid and the subsequent introduction of time-of-use rates are likely to fundamentally change the optimal technology mix used in homes in the future. It is important that these elements are weighed carefully so that the ERI remains valuable to stakeholders that rely on the ERI for their programmatic needs.

The CBRITG also discussed the relative merits of using national, regional, or local energy prices for a cost-based index. The group reached an agreement that the recommendation for an initial cost-based index system would be to use national average energy prices, acknowledging that national average energy prices will not align with local energy costs. However, a minority view within the TG expressed concern that employment of national average price as the rating basis creates limitations for critical use case applications such as California Energy Commission harmonization and energy supplier incentive programs.

As a result of fundamental disagreements within the group about the reference home characteristics and treatment of renewable energy, it was not possible to provide a consensus work plan for a cost-based rating index calculation methodology.

Appendix A

Supplemental Information

Calculation Subcommittee Analysis

Table 7: Partial List of Potential Metrics for RESNET HERS Index

Note: No single metric on its own should be expected to provide a long term ideal outcome for society

Metric	Pros	Cons	Notes
nMEUL (currently in ANSI/RESNET 301-2014)	Used in home energy ratings except in California since 1999. Compromise solution to contentious issues between gas and electric industries in the 1990's. Adopted in IECC 2015 as a compliance option.	Challenging to fully understand the calculation method. Inconsistent with California HERS score that is based on TDV. May not reflect best economic interest of individual consumer. May be challenged within the IECC.	ASHRAE 90.2 committee voted to include nMEUL methodology as basis of compliance. Mixed fuel homes with minimum efficiency gas appliances are likely to have lower source energy, energy costs and greenhouse gas emissions than for a comparable all-electric home with minimum efficiency electric appliances. Greater incremental credit (>1 point per % improvement) for gas heating or water heating improvements relative to envelope or electric heating or water heating improvements credit (1 point per % improvement).
Equivalent Site Energy (currently in ANSI/RESNET 301-2014)	Same Pros as for "Source/Primary Energy" metric.	Same issues as for "Source/Primary Energy" metric.	A fossil fuel to electricity conversion efficiency of 40% for site fossil fuel use is applied within the site energy metric calculation in 301. Same notes as for "Source/Primary Energy" metric.
Source/Primary Energy	Metric used by the OECD Countries to measure overall energy consumption. Can align reasonably well with energy cost, TDV, and GHG emissions. Commercial benchmarking ordinances and other initiatives use this metric.	Potentially contentious across industry groups. Requires policy decisions on energy conversion factors for equitable treatment and application. May not reflect best economic interest of individual consumer.	May provide alignment with societal benefit using energy as the direct metric. Electric industry opposition is possible Recently published materials such as ASHRAE Standard 105-2014 can help facilitate the development of source/primary energy rating metric. IGCC uses primary energy and greenhouse gas emissions in its performance compliance pathway for commercial and high-rise residential buildings.
Greenhouse Gas Emissions	Can align reasonably well with energy cost, TDV, and source/primary energy metrics. May align well with other stakeholder initiatives. Metric used by some OECD Countries to measure overall building energy performance.	Potentially contentious across industry groups. Requires policy decisions on greenhouse gas emissions factors for equitable treatment and application. May not reflect best economic interest of individual consumer. Not an energy metric.	May provide alignment with societal benefit using greenhouse gas emissions as the direct metric. Recently published materials such as ASHRAE Standard 105-2014 can help facilitate the development of greenhouse gas emissions rating metric. IGCC uses primary energy and greenhouse gas emissions in its performance compliance pathway for commercial and high-rise residential buildings. ASHRAE Standard 189.1 uses energy cost and greenhouse gas emissions in its performance compliance pathway for commercial and high-rise residential buildings.

Metric	Pros	Cons	Notes
Time Dependent Valuation	Consistent w/ CA Values time of use Can align well with energy cost Can provide cost valuation of societal parameters (e.g., GHG costs) May provide alignment with long term societal objectives	May not reflect economic interest of individual consumer. Potentially politically contentious. Effort needed to develop national TDV values. Needs technical and policy decisions on conversion factors for equitable treatment and application, especially with renewable technologies and evolving electricity generation mix.	TDV is tied to hourly cost of energy, and can incorporate societal valuation of energy. This drives solutions that reduce energy costs as well as coincident peak, and may help address some societal equity issues if correctly implemented. 20-year valuation in CA provides a stable metric. State and national information exists for implementation, potentially with modest incremental effort.
Energy Cost	Most readily understood metric by all stakeholders. Reflects economic interest of individual consumers. Energy cost data is widely available. Can align well with source energy and GHG metrics.	Needs technical and policy decisions on energy cost calculations for equitable treatment and application, especially with renewable technologies and evolving electricity generation mix. Establishing and maintaining consistent utility energy cost values nationally. Energy cost data can be difficult to interpret and apply.	Energy cost is not currently tied to carbon output. However, this metric would automatically reflect any changes in pricing driven by policy. ASHRAE uses an Energy Cost Budget (ECB) or a Performance Cost Index (PCI) as performance compliance pathways in ASHRAE Standard 90.1 for commercial and high-rise residential buildings. IECC uses energy cost as a performance compliance pathway in both commercial and residential building energy codes. ASHRAE Standard 189.1 uses energy cost and greenhouse gas emissions in its performance compliance pathway for commercial and high-rise residential buildings.
		Additional Considerations	
Normalization	Normalizes out features not considered related to efficiency.	Resulting metric may not reflect energy cost for whole home. Can encourage construction of larger homes.	For example, energy use per square foot or energy use per bedroom.
Variable reference home	Normalizes out features not considered related to efficiency.	Resulting metric may not reflect energy cost. Reference appliance efficiencies for electric and gas equipment are not consistent with one another where reference home is required to have the same fuel type as the rated home.	Floor area is good example of this. Defining a reference home to have floor area that equals floor area of rated home means two different sized homes can have same Index and very different energy costs. A fixed sized reference would cause the Index to more closely reflect energy cost. Rating methodologies that use a reference home are inconsistent with DOE Home Energy Score Tool ASHRAE standard 90.1-2013 performance path in normative appendix G uses a single fuel reference building for HVAC and service water heating systems.
Geometry dependencies	No restrictions on home size or geometry.	More difficult for smaller homes than larger homes to achieve targets.	Has been an issue for EPA ENERGY STAR program and many others. Potential solutions are being considered by ASHRAE and others.

A2 Single Reference Home Methodology

A2.1 Single Reference Home Methodology Rationale – Supporting Information

Martha Brook, P.E., Advisor to Commissioner Andrew McAllister
California Energy Commission

Neil P. Leslie, P.E., Sr. R&D Director,
Gas Technology Institute

"The worst form of inequality is to try to make unequal things equal." Aristotle

The Cost-Based Rating Index Task Group (CBRITG) is developing recommendations to the RESNET Standards Development Committee (SDC 300) regarding the possible use of a cost based rating index in upcoming revisions to Standard 301. The following information elaborates differences between home energy efficiency and home energy performance, and supports the rationale for an all-electric single Reference Home approach to such a cost based rating index.

Primary Intent of Standard 301

The purpose of Standard 301 is to "establish residential energy rating and labeling Standards, consistent with the provisions of the Energy Policy Act of 1992, which provides for uniformity and consistency in the rating and labeling of such buildings." As further elaborated, in the foreword, the primary intent of ICC/RESNET Standard 301-2014 is to provide a consistent, uniform methodology for evaluating and labeling the energy performance of residences. The methodology compares the energy performance of an actual home with the energy performance of a Reference Home of the same geometry, resulting in a relative energy rating called the Energy Rating Index.

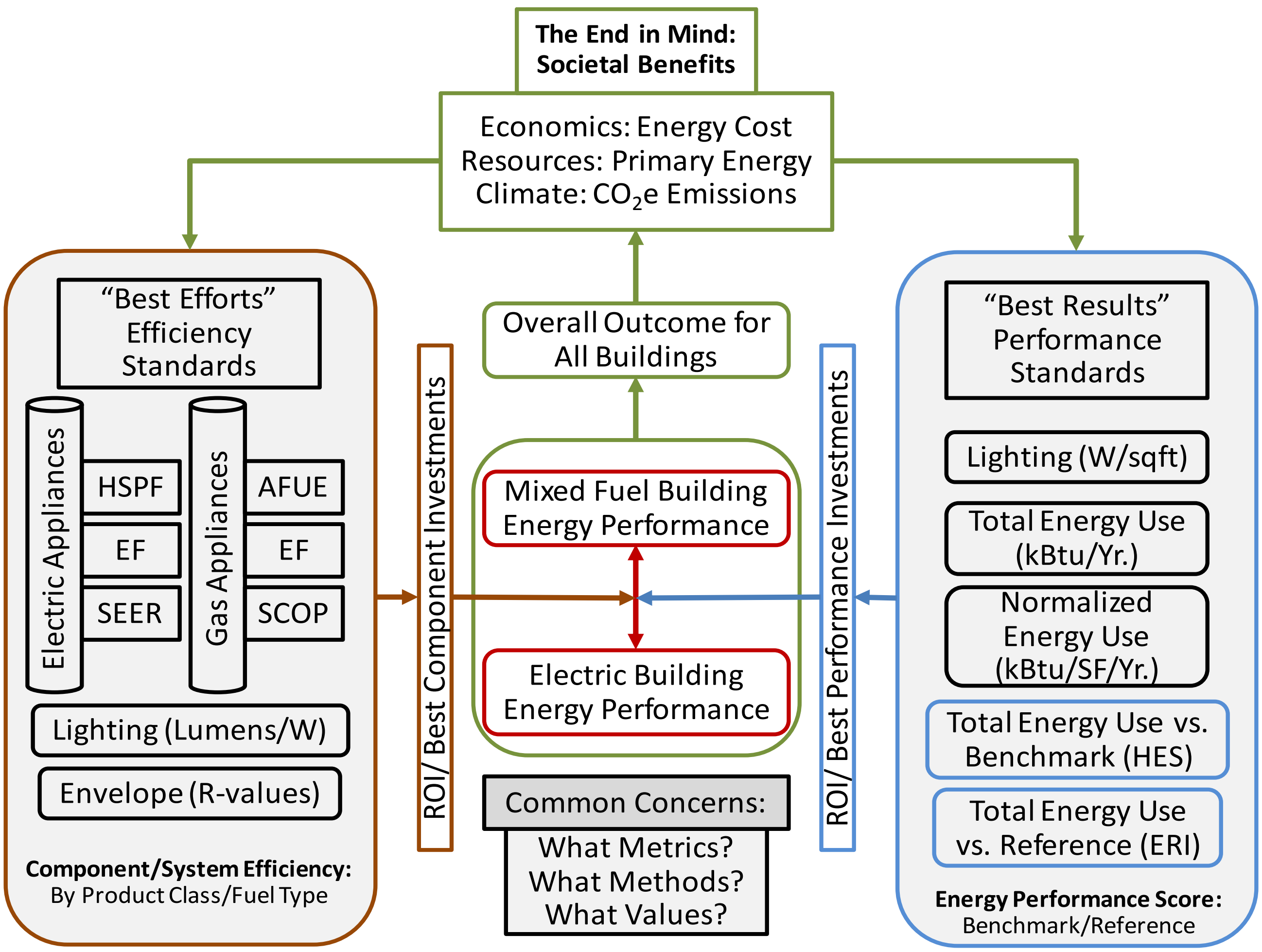
Background on Baselines used in Standards and Rating Systems

As shown in Figure 7, standards, performance ratings and other initiatives can provide conflicting market signals and consumer information, depending on the metric, methodology, and values chosen for energy-related parameters. Significant factors that must be considered when communicating the primary intent of an initiative include:

- Metric or metrics used in the implementation approach;
- Prescriptive component or equipment efficiency vs. modeled or actual system performance;
- Single vs. multiple baseline for comparisons and compliance; and
- Choice of specific conversion factors and parameters used in performance calculations.

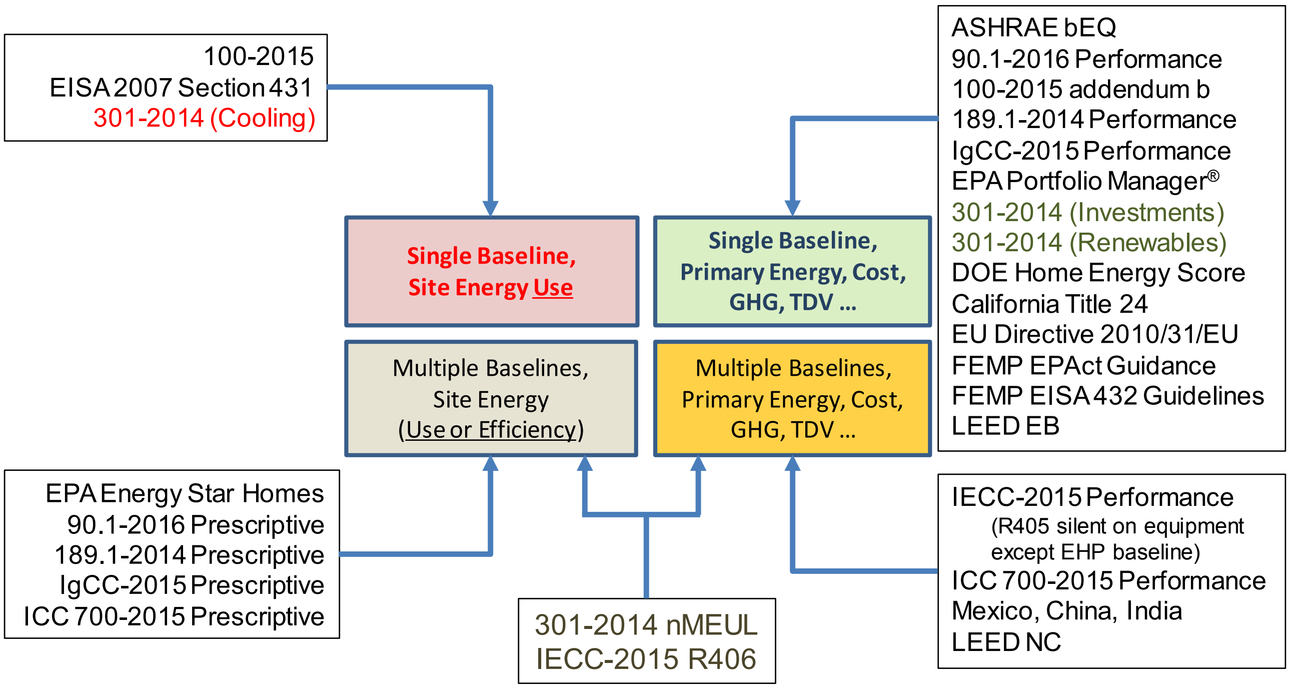
The metrics chosen, a focus on efficiency or performance, the methodology used in the calculations, and the values selected for calculations can all yield significantly different rating outcomes. Typically these differences are most significant for mixed fuel buildings compared to all-electric buildings, but also when comparing envelope performance (or efficiency) to equipment performance (or efficiency), when comparing different product classes or subclasses serving the same function, such as heat pumps versus resistance heat options, or when considering on-site renewable power. Prescriptive compliance requirements reward best efforts, typically at a component or equipment level, to achieve the primary intent, and almost always separate compliance requirements by both appliance subcategory and energy type. In contrast, performance compliance requirements reward best delivered results, typically at a larger system (e.g., lighting) or whole building level. The two paths can lead to similar outcomes, but often can yield different outcomes, especially for performance compliance based on empirical data such as the DOE Home Energy Score, ASHRAE Standard 100, and EPA Portfolio Manager. Within the performance path, the choice of absolute or normalized energy use can also impact the outcome significantly. For these reasons, it is critical to align these choices with the primary intent of the initiative to achieve its objectives with minimum adverse impacts.

Figure 8: Comparing Energy Performance Using Prescriptive and Performance Options



As shown in Figure, codes, standards, and programs promulgated by ICC, RESNET, ASHRAE, DOE, California, EPA, USGBC, and international agencies employ various combinations of metrics and methodologies for prescriptive or performance compliance requirements. The two main paths in many codes and standards, including ASHRAE Standard 90.1, 90.2, 189.1, IECC, ICC 700, and IgCC, are prescriptive and performance paths. On the other hand, ASHRAE Standard 100, EPA Portfolio Manager, and ICC/RESNET Standard 301 use only a performance methodology for compliance, comparing the building under consideration to a standard baseline building (Standard 100 and Portfolio Manager) or to a defined set of components, equipment, and systems (Standard 301 Reference Home).

Figure 9: Stakeholder Initiatives Using Different Metrics and Methodologies



Over the past five years, there has been a significant migration from multiple baseline methodologies to single baseline methodologies by these agencies for performance requirements, but not prescriptive requirements. In this regard, the rationale for Standard 90.1 performance rating method calculations to change from multiple baselines to a single baseline for heating and service water heating in Standard 90.1-2010 Addendum AL is instructive.

Prior to incorporation of Addendum AL, Standard 90.1-2010 Appendix G (Performance Rating Method) used multiple baseline building systems for the mechanical system performance requirements. For example, Standard 90.1-2010 Appendix G had 14 different baselines for the six service water heating (SHW) system categories, none of which resulted in the same annual energy cost budget for Appendix G performance rating method calculations. Addendum AL completely decoupled the proposed building mechanical system design choices from the standard reference design building's energy cost performance requirement. Shifting to a single baseline design provided an equitable credit to all technologies that have lower annual energy costs compared to the single baseline level irrespective of proposed technology design. It also aligned the SHW and HVAC system performance requirement methodology with the envelope and lighting single baseline performance requirement methodology used in Standard 90.1-2010 Appendix G.

The Addendum AL baseline systems were selected to provide a practical, equitable, and effective requirement to meet the energy performance goals of the standard while offering consistent credit for best available technologies based on their energy cost benefits. As quoted from the Addendum AL Foreword:

"Currently in Appendix G, the choice of space heating energy source (either electricity or fossil fuel) in the proposed design determines the energy source in the baseline building design, and similarly the choice of service water heating energy source in the proposed design determines the water heating energy source in the baseline building design.

For some buildings, this results in wide variations in baseline energy cost budgets depending on whether electricity or fossil fuel is specified for the proposed design. In some cases, the choice of either electricity or fossil fuel in the proposed design provides a much higher baseline energy cost budget than if the alternative energy source were used. This provides an incentive to use one energy source over the other in order to claim greater savings.

To prevent this opportunity for "gaming" the energy savings projected using Appendix G, this addendum specifies the energy source for space heating and water heating to be used in the baseline building design regardless of the type of energy specified for space heating or water heating in the proposed design.

The space heating energy source is determined by climate zone, and the water heating energy source is determined by the type of activity that is proposed for that area of the building. (Building area, rather than whole building, is used for water heating in order to accommodate mixed use buildings.)

Electric space heating is specified for the baseline building design for climate zones where electric space heating is most common (climate zones 1 through 3a) and fossil fuel space heating is specified in the baseline building design where they are more common (climate zones 3b through 8.)

Similarly, building areas such as offices where electricity is most often used for water heating specify electric water heating for the baseline building design, and uses such as hotels where fossil fuels are used more often for service water heating specify fossil fuel water heating for the baseline building design.

Where fossil fuels are specified using this procedure, the baseline building energy costs will be based on natural gas costs, unless natural gas is not available at the building location, in which case propane is used for energy costs

The choices of space heating and service water heating energy sources were based on most common energy source found for that application in the most recent (2003) DOE EIA CBECS survey and on professional judgment of current standard practice.

The specification of a consistent baseline building energy budget for a particular proposed building, regardless of the energy source chosen for actual installation in the proposed building, should make energy savings determined using Appendix G more consistent and equitable."

Differences between Efficiency and Performance

The terms "efficiency" and "performance" are often used interchangeably as if they mean the same thing, adding a great deal of confusion to an already challenging analytical problem. Definitions, illustrations, and implications of the terms efficiency and performance are offered here to highlight similarities, and more importantly, meaningful differences, in these two complementary, and often conflicting terms as applied to home energy ratings.

Efficiency definitions:

1. Ratio of the effective or useful output to the total input
2. Ability to do something or produce something without wasting materials, time, or energy
3. Process that uses the lowest amount of inputs to create the greatest amount of outputs
4. Doing the thing right (Focus on how to help achieve the primary intent)

Performance definitions:

1. Accomplishment of a given task measured against preset known standards of accuracy, completeness, cost, and speed
2. Standard to which someone does something such as a job or an examination
3. Accomplishing an action, task, or function
4. Producing a desired result
5. Doing the right thing (Focus on achieving the primary intent)

As indicated in these definitions, efficiency can be aligned with performance, but it is not the same thing. The primary intent of Standard 301 is likely to be achieved most effectively by doing the right thing (high performance) the right way (high efficiency) for the right reasons (uniformity and consistency). Further, as shown in the definitions, there are a number of elements of efficiency and performance that can result in different outcomes, both within and across the two terms. For instance, there are several ways in which efficiency can be judged since it depends on the metric of interest (e.g., energy, cost, time, materials). Similarly, "preset standards" or "examinations" against which to measure performance to produce the desired result need to be developed carefully to align with the desired result (outcome) in addition to aligning with the metric of interest.

Absolute, Normalized, and Relative Performance; Benchmarking; and Reference Homes

Another area of confusion between efficiency and performance is the difference between absolute performance, normalized performance, and relative performance, none of which directly incorporate efficiency to measure performance (the result). However, all three ways of measuring performance can be improved by using efficient appliances, components, and structures (smart ways to achieve the result).

An example of absolute performance is DOE's Home Energy Score, which rates performance based on the home's total annual energy consumption (source kBtu/Year), as modeled by the Home Energy Score software tool. This annual energy use performance is then benchmarked against the RECS database distribution of energy consumption (source kBtu/Year) for homes in that location to establish the home's score. Home Energy Score does not normalize energy consumption based on size, number of bedrooms, or other parameter of interest, making it insensitive to home size and other individual home characteristics.

DOE's Home Energy Score absolute performance basis is in contrast to ASHRAE Standard 100, ASHRAE bEQ, and EPA Energy Star Buildings ratings that benchmark against the CBECS database using normalized energy consumption based on building area (site or source kBtu/SF/Yr. in Standard 100, and source kBtu/SF/Yr in ASHRAE bEQ and EPA Energy Star Buildings). This approach is intended to avoid penalizing a building's performance based on its size, but it does not provide any information about total annual consumption or cost or other individual building characteristics.

In contrast to the highlighted DOE, ASHRAE, and EPA programs, RESNET's ERI, along with the performance paths in IECC, IgCC, ASHRAE Standard 90.1, and ASHRAE Standard 189.1 compare the proposed building's absolute performance relative to a reference or baseline configuration of the same building in the same location. This is distinct from normalized performance, because relative performance compares the absolute performance of the rated building with the absolute performance of the reference building. In the case of Standard 301, the basis of the absolute performance is normalized modified end use loads. For ASHRAE Standard 90.1, it is cost. For ASHRAE Standard 189.1, it is cost and GHG emissions. For IgCC, it is source energy and GHG emissions.

Benchmarking against existing buildings provides a link to real world performance, but does not necessarily align with efficiency indicators for building elements providing comparable energy services in comparable buildings if the benchmark database is incomplete or skewed. Comparing a building's performance against a reference level of performance for the same building configuration may provide a better indicator of the relative energy efficiency of the building compared to a standard, prescribed set of efficient components. But it may not track the "as operated" actual measured performance as well as desired for decision making. All of these parameters need appropriate boundary conditions to avoid misleading consumers or otherwise providing inconsistent ratings.

Analogies

Education provides an analogy to energy efficiency and performance. In the case of education, absolute performance could be a grade of 92 on a report card. It might also be benchmarked performance if it starts with your actual performance and is adjusted based on a comparison with your classmates (i.e., graded on a curve). How you get the 92 on the report card is an indicator of efficiency. Internet searches and textbooks each may provide a different way to find the information of interest for the learning objective, and represent information efficiency options. One may be quicker than the other, so if time is the parameter of interest to determine learning efficiency, one could judge the value of a book vs. the Internet as a way to get at the desired information more efficiently. On the other hand, if a textured understanding of the information is the parameter of interest, a book may be a more efficient resource than a broad Internet search that misses key pieces of information contained in the book. Another efficiency element is aptitude, which is an indicator of student efficiency. Achieving the same 92 score can occur in the same amount of learning time by a high aptitude student with inefficient information options that slow down the learning process, or by a lower aptitude student with access to high efficiency information options that speed up the learning process.

Similar analogies are available for sports, including golf (score is the performance measure, club design and skill level are efficiency measures). In tennis, the score is the performance measure, and racquet style (wood vs. oversized composite frame) and player skill level are efficiency measures.

A further sports analogy involves competition and fairness. In golf, the tee location (women's tees are closer than men's tees) acknowledges that it may not be fair to expect women to be able to hit the ball as far as men off the tee. Once on the fairway, no further handicap is provided because fairway to green shots are more a matter of skill than physical strength. Age grouping and handicaps based on skill level often occur to "level the playing field" when known differences in skill level are competing for the same prize. Whether this is fair or not depends on the rules of the game, and the desire to allow different skill levels to compete with each other by adding handicaps or other methods.

Implications

Standard 301 uses a performance methodology for ratings and code compliance, comparing the building under consideration (the Rated Home) to a defined set of components, equipment, and systems (the Reference Home). The means by which its Reference Home performance level is established is by incorporating a set of equipment and building components considered efficient in 2006. Modeling rules provide the conversion factors and values to be used in the calculations to determine the performance level of the rated and Reference Home configurations. The end result is a Rated Home level of absolute performance compared to a Reference Home level of absolute performance. The efficiency level of the Reference Home was selected by choice at IECC 2006 levels of performance, not by any technical requirement. The Reference Home configuration needs to establish uniform and consistent performance for all comparisons to align with the primary intent of Standard 301.

Rationale for Single Reference Methodology in ICC/RESNET Standard 301

In this discussion, a single standard electric reference design would use current Standard 301 electric technologies as the reference in all relevant component categories with a choice of energy form to serve the Rated Home loads. These component categories would include space heating, space cooling, service water heating, range/oven, dryer, and on site power production. Note that cooling, light fixtures, refrigerator, dishwasher, clothes washer, and ceiling fans already use a single electric reference system in the current Standard 301.

The key rationale for a single Reference Home methodology for RESNET is the Standard 301 primary intent to promulgate “uniform” and “consistent” ratings. A single electric Reference Home approach:

- Establishes a single Reference Home performance requirement for all rated systems independent of making system or fuel choices for the Rated Home
- Provides a consistent, uniform methodology for evaluating and labeling energy performance of any load reduction, energy service, or on-site power generation strategies to achieve an unbiased score for overall home performance comparisons. Only cares about ultimate result (comparable home energy performance) based on metric(s) and value(s) of choice.
- Extends the single baseline methodology currently used in Standard 301 for performance comparisons of other load reduction, energy service, and on site power options, including envelope (R-Value, glazing, doors, structural mass), distribution system (DSE), infiltration (SLA), electric heat pumps for electric heating, electric air conditioners for cooling, refrigerator, lighting, and on-site power production.
- Addresses equivalency biases caused by multiple Reference Home technology performance requirements depending on fuel type for gas and electric technologies that provide the same energy service (heating, water heating, cooking, clothes drying).
- Provides uniform and consistent treatment of all rated system options, including conventional, renewable energy, hybrid technology, and waste heat recovery options.

- Is indifferent to the relevant rated system choice in the Rated Home, comparing all relevant rated system options against a single electric Reference Home energy performance requirement.

Standard 301 currently uses multiple reference mechanical systems, with a different baseline for performance depending on fuel type, for systems with fuel choices for heating, service water heating, range/oven, and clothes dryer, (but not cooling) – considering all reference systems to be equivalent to each other for rating purposes. However, none of the reference systems have the same annual energy cost across fuel types. These energy cost differences create misleading HERS ratings that are not consistent with annual energy cost performance when derived from these multiple references.

Figure 10 and Table 8 compare energy costs of gas and electric components in four cities using Standard 301 electric Reference Home and natural gas Reference Home configurations, each of which would receive an ERI score of 100 both under the Standard 301 nMEUL multiple reference methodology and under a cost-based multiple reference methodology. The stacked bar chart illustrates the incremental impact of rated and non-rated features on cost-based rating scores and summarizes the difference in ERI scores using cost as the metric with single and multiple baselines. As shown in Figure 10, the impact of shifting from a multiple Reference Home to a single Reference Home varies based on location and relative electric and gas prices. In heating dominated climates such as Chicago and Minneapolis, the impact is much greater than in cooling dominated climates such as Phoenix. The relative costs of electric and gas in Atlanta, a mixed heating/cooling climate, illustrate the impact of lower electric to gas price ratios (roughly 2 in the three southern cities vs. roughly 4 in the two northern cities) when heating and water heating are more meaningful loads.

Figure 10: Cost-Based ERI Scores with a Single Electric Reference Home

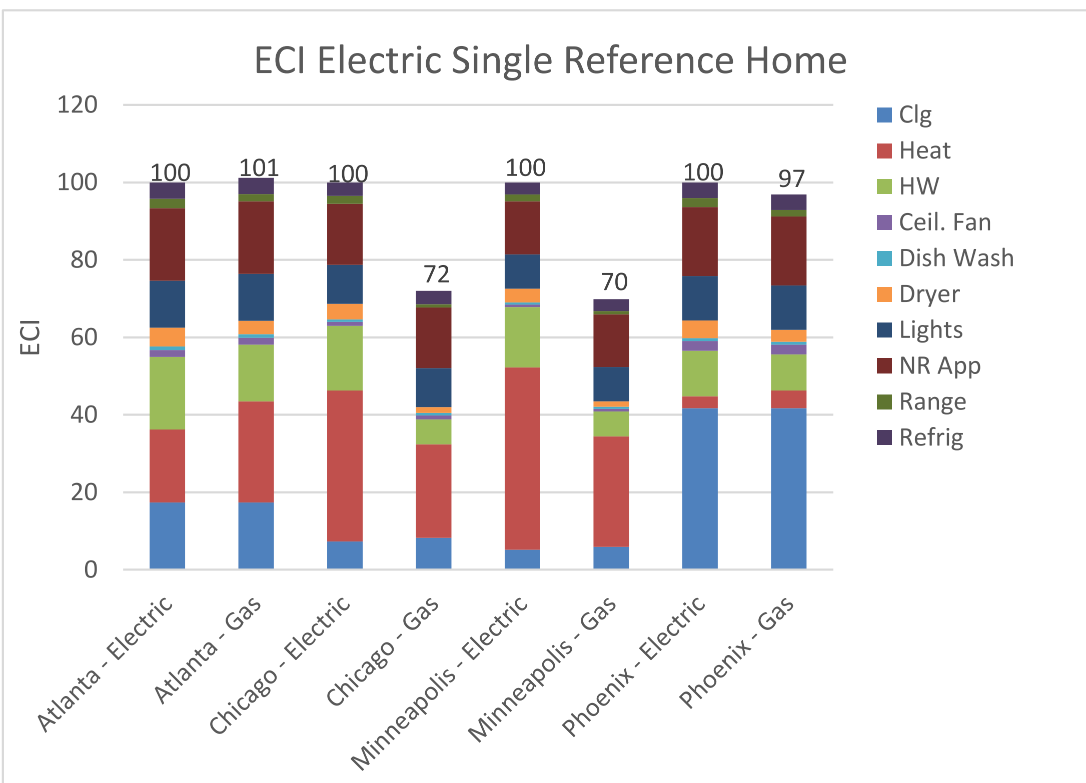


Table 8: Energy Costs and Score Elements with a Single Electric Reference Home

Reference Home (ERI = 100)	SEER/EF C/H/WH	$/kWh	$/therm	E/G ratio	HERS	ECI	Clg	Heat	HW	Ceil. Fan	Dish Wash	Dryer	Lights	NR App	Range	Refrig	Total Cost
Atlanta Elec	13/7.7/.92	0.11	1.60	2.0	100	100	352	382	379	36	19	98	245	379	49	86	2,025
Atlanta Gas	13/.78/.59	0.11	1.60	2.0	100	101	351	530	296	36	19	70	245	379	38	86	2,050
Chicago Elec	13/7.7/.92	0.12	0.86	4.0	100	100	189	1,009	433	26	17	105	261	406	53	91	2,590
Chicago Gas	13/.78/.59	0.12	0.86	4.0	100	72	214	625	167	26	17	38	261	406	21	91	1,866
Minneapolis Elec	13/7.7/.92	0.11	0.87	3.7	100	100	143	1,295	428	18	16	98	243	377	49	85	2,752
Minneapolis Gas	13/.78/.59	0.11	0.87	3.7	100	70	162	785	177	18	16	38	243	377	21	85	1,922
Phoenix Elec	13/7.7/.92	0.11	1.50	2.2	100	100	892	66	251	54	16	99	245	381	50	86	2,140
Phoenix Gas	13/.78/.59	0.11	1.50	2.2	100	97	892	98	200	54	16	66	245	381	36	86	2,074

Reference Home (ERI = 100)	Energy Factor	$/kWh	$/therm	E/G ratio	HERS	ECI	Clg	Heat	HW	Ceil. Fan	Dish Wash	Dryer	Lights	NR App	Range	Refrig	Total ECI
Atlanta Elec	13/7.7/.92	0.11	1.60	2.0	100	100	17.4	18.9	18.7	1.8	0.9	4.8	12.1	18.7	2.4	4.2	100
Atlanta Gas	13/.78/.59	0.11	1.60	2.0	100	101	17.3	26.2	14.6	1.8	0.9	3.5	12.1	18.7	1.9	4.2	101
Chicago Elec	13/7.7/.92	0.12	0.86	4.0	100	100	7.3	39.0	16.7	1.0	0.7	4.1	10.1	15.7	2.0	3.5	100
Chicago Gas	13/.78/.59	0.12	0.86	4.0	100	72	8.3	24.1	6.4	1.0	0.7	1.5	10.1	15.7	0.8	3.5	72
Minneapolis Elec	13/7.7/.92	0.11	0.87	3.7	100	100	5.2	47.1	15.6	0.7	0.6	3.6	8.8	13.7	1.8	3.1	100
Minneapolis Gas	13/.78/.59	0.11	0.87	3.7	100	70	5.9	28.5	6.4	0.7	0.6	1.4	8.8	13.7	0.8	3.1	70
Phoenix Elec	13/7.7/.92	0.11	1.50	2.2	100	100	41.7	3.1	11.7	2.5	0.7	4.6	11.4	17.8	2.3	4.0	100
Phoenix Gas	13/.78/.59	0.11	1.50	2.2	100	97	41.7	4.6	9.3	2.5	0.7	3.1	11.4	17.8	1.7	4.0	97

A single technology-blind reference performance requirement is critical for a uniform and consistent implementation of the Standard 301 primary intent. Shifting to a single reference design methodology provides an equitable credit to all technologies that have lower annual costs compared to the single reference level irrespective of energy form or technology design. It establishes fixed Reference Home performance requirements BEFORE making the technology and energy choices for the Rated Home. A single reference design methodology creates a level playing field for all technology and energy forms and provides equitable treatment of advanced renewable, waste heat recovery, hybrid, and multi-fuel technology options. It is especially important for equitable and consistent evaluation of on-site power generation and combined heat and power systems.

A single Reference Home methodology is consistent with the single reference building methodologies in stakeholder initiatives noted above and shown in Figure 8. Each of these methodologies establishes a single reference building as the basis of their energy rating or performance compliance requirements. A consistent single standard reference design methodology based on energy cost will improve the adoptability of Standard 301, especially in the existing home market, by ensuring transparency and consistency for all energy related features valued in real estate transactions.

Multiple baselines treat comparable technologies that use different energy forms as if they are equal when they are not, in an attempt to be “fuel neutral.” Standard 301 is not “fuel neutral” because it treats various technology options as equivalent to each other even though there are demonstrable and meaningful differences in energy cost among the fuel choice and technology options providing the same energy service. The RESNET HERS rating is meant to provide a singular indication of relative energy performance that builders, home owners and other stakeholders can use to judge one home’s energy assets compared to other homes’ energy assets. Multiple baselines in Standard 301 do not achieve this goal.

A useful comparison illustrating the inherent flaw in the multiple reference methodology is a minimally compliant electric storage water heater compared to a minimally compliant gas storage water heater. Homes using NAECA minimum efficiency electric resistance storage water heating qualify equally as a NAECA minimum gas storage water heater, even though the annual energy costs are much higher for the resistance water heater than for the gas water heater (typically twice as high). Based on a typical home in the Midwest, annual energy use for an NAECA minimum electric resistance water heater is 3,920 kWh, while a NAECA minimum gas water heater uses 205 Therms. Using average Missouri energy rates available from EIA of $0.098 per kWh and $1.05 per Therm, the electric water heater annual cost of operation is $384, while the natural gas water heater costs only $215 per year, a 79% increase in the energy cost budget for the electric water heater. Standard 301 considers them equal for compliance purposes because it uses a separate Reference Home for determining compliance for electric water heating systems than for gas water heating systems. The lower energy cost for the reference gas water heater represents a clear benefit to consumers, yet they are not rewarded in the Standard 301 methodology. It is this “best efforts” negative impact of the Standard 301 attempt to be “fuel neutral” that a shift to a single reference system methodology corrects. It is not possible to be fuel neutral whenever competing technologies are available to perform the identical energy service such as water heating. It is, however, possible to be fuel-blind, which can be achieved only through a single reference methodology.

Detailed component load information from EnergyGauge® simulations in five cities of Reference Homes and homes that were ~50% more efficient than the fuel-specific Reference Home enabled a comparison of methodologies for all-electric and natural gas home options. The only equitable option to eliminate fuel bias and create a level playing field is to be agnostic about fuel choices (fuel-blind), not caring how the home achieves its energy performance, as long as it is done in a way that is aligned with the primary intent of the standard. A single Reference Home is the most consistent and uniform way for the standard to be fuel-blind, tightly aligning with the primary intent of Standard 301. The single Reference Home establishes one baseline for all comparisons. It doesn’t matter from an equity standpoint what the baseline is as long as the rationale for the reference level is aligned with the primary intent of the standard. Using an all-electric Reference Home has the advantage of availability in all Rated Homes, unlike natural gas that may not be available in some locations.

Table 9 and Figure 11 through Figure 15 illustrate the challenges with both the nMEUL methodology and the multiple reference methodology that a single reference methodology addresses. Only the single reference cost methodology aligns tightly with annual energy costs (the performance metric) in all cases. Single reference or multiple reference cost ratings for all-electric ~50% improved homes range from 3 to 7 points higher than nMEUL ratings for the same home. Multiple Reference Home cost ratings for gas homes are 4 to 13 points higher than single electric Reference Home ratings for the same gas homes. nMEUL ratings for gas Reference Homes range from 9 to 25 points higher than the single reference cost ratings for the same gas homes.

The only equitable option to eliminate fuel bias and create a level playing field is to be agnostic about fuel choices (fuel-blind), not caring how the home achieves its energy performance, as long as it is done in a way that is aligned with the primary intent of the standard. A single Reference Home is the most consistent and uniform way for the standard to be fuel-blind, tightly aligning with the primary intent of Standard 301. The single Reference Home establishes one baseline for all comparisons. It doesn’t matter from an equity standpoint what the baseline is as long as the rationale for the baseline level is aligned with the primary intent of the standard. Using an all-electric Reference Home has the advantage of availability in all Rated Homes, unlike natural gas that may not be available in some locations.

Table 9: Comparison of Energy Costs and Scores Using nMEUL and Cost Methods

City and Energy Choice	Miami		Houston		Atlanta		Albuquerque		Chicago	
	Elec	Gas	Elec	Gas	Elec	Gas	Elec	Gas	Elec	Gas
~50% Improved Home										
Annual Energy Cost ($)	1,052	979	1,094	994	1,109	969	1,155	981	1,493	1,176
nMEUL Multiple Reference Homes	42	43	45	46	44	43	49	48	48	46
Cost Single Electric Reference Home	49	46	51	47	49	43	52	45	50	39
Cost Multiple Reference Homes	49	50	51	53	49	50	52	55	50	53
Reference Home (nMEUL Index = 100)										
Annual Energy Cost ($)	2,141	1,957	2,132	1,874	2,274	1,925	2,201	1,778	2,994	2,237
nMEUL Multiple Reference Homes	100	100	100	100	100	100	100	100	100	100
Cost Single Electric Reference Home	100	91	100	88	100	85	100	81	100	75
Cost Multiple Reference Homes	100	100	100	100	100	100	100	100	100	100

Note: Electricity Cost $0.12/kWh; Natural Gas Cost $0.98/Therm

Figure 11: Impact of Metric and Reference Home on Rating – Miami

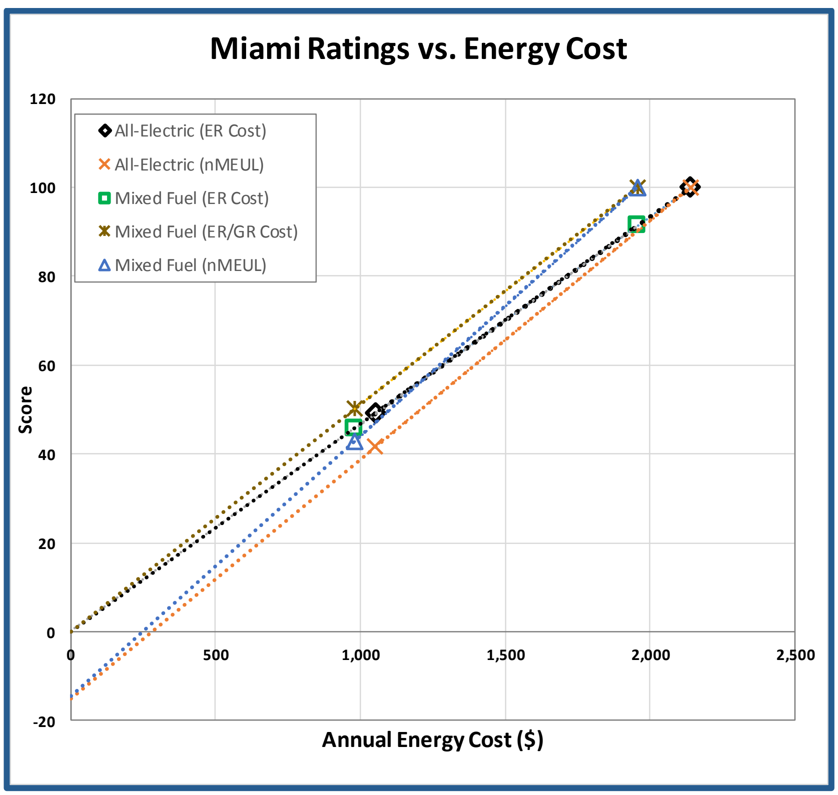


Figure 12: Impact of Metric and Reference Home on Rating – Houston

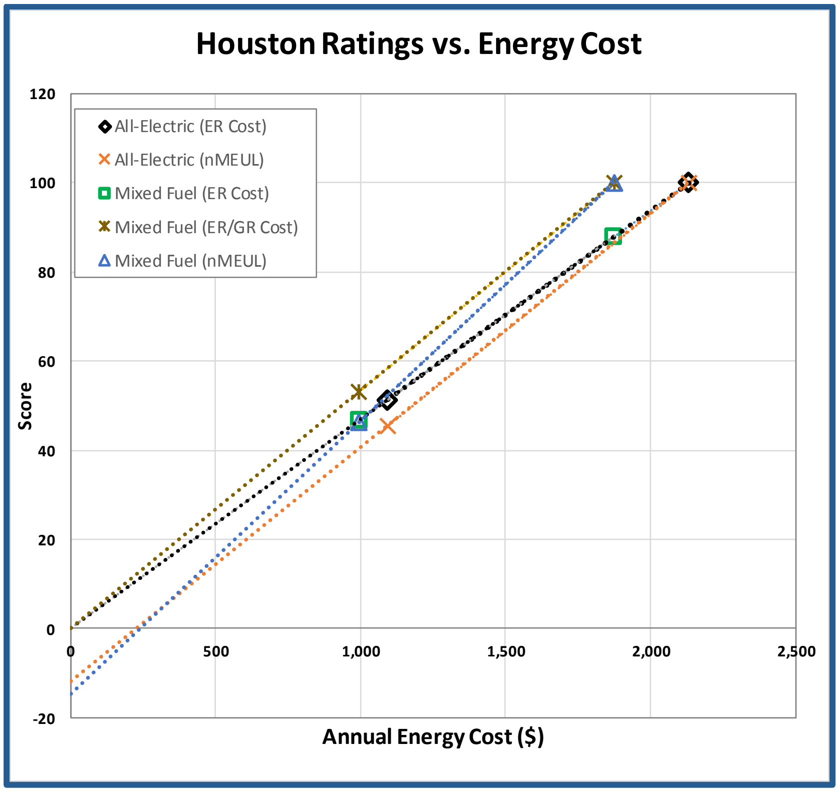


Figure 13: Impact of Metric and Reference Home on Rating – Atlanta

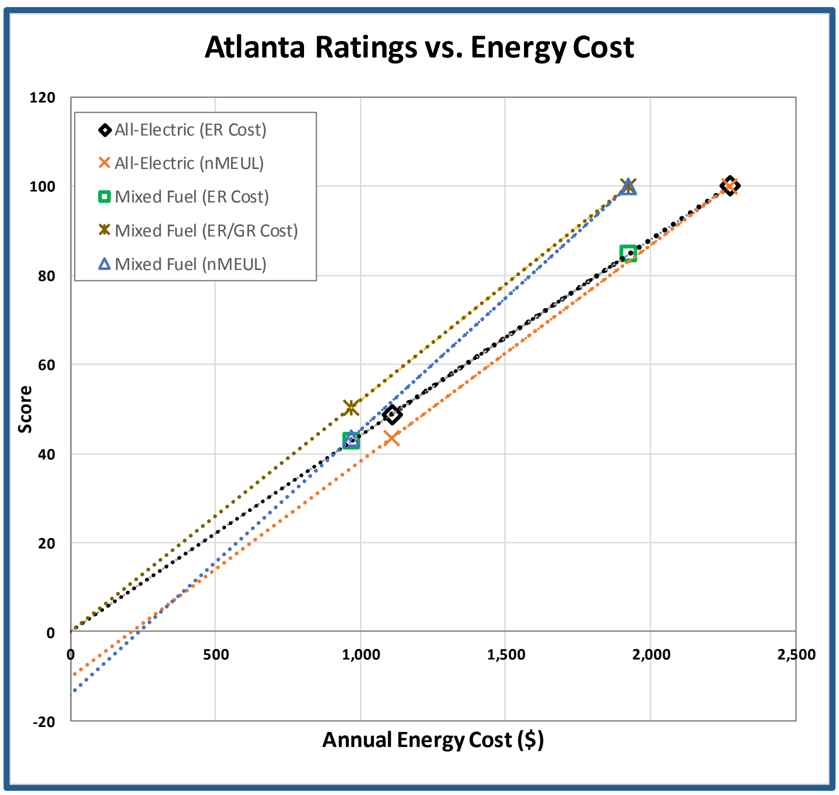


Figure 14: Impact of Metric and Reference Home on Rating – Albuquerque

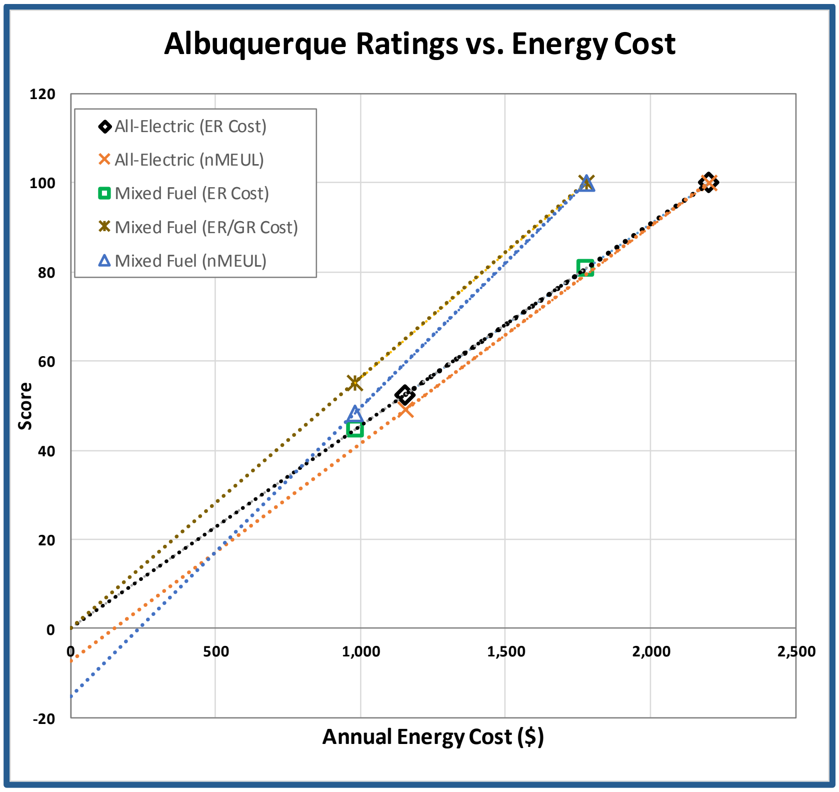
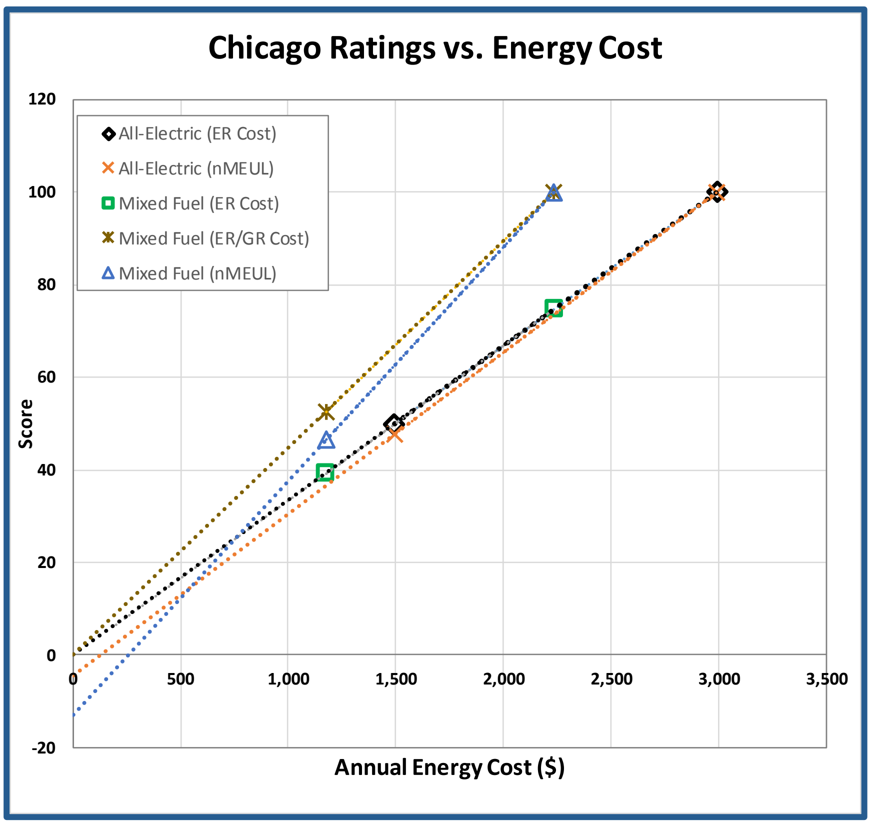


Figure 15: Impact of Metric and Reference Home on Rating – Chicago



A3 Multiple Reference Home Analytical Methodology and Supporting Information

The analysis of the impacts of the Multiple Reference Home Methodology relied on the use of the REM/Design v15.2 software tool. Information on the desktop version of the software can be accessed at http://www.remrate.com/home/desktop.

According to the company web site, REM/Design™ was developed specifically with the needs of homebuilders, remodelers, energy consultants and designers in mind. REM/Design™ calculates heating, cooling, hot water, lights and appliance loads, consumption and costs for single and multi-family designs in over 600 North American cities. The company that created the tool, NORESCO, continually upgrades REM/Design™ to become more applicable for existing homes.

This software is a Windows®-based software that automatically analyzes the energy and economic performance of multiple energy design features including envelope insulation, air leakage control, duct leakage control, active and passive solar systems, heating and cooling equipment, mechanical ventilation and other end-uses. In addition to calculating energy performance, REM/Design™ sizes heating and cooling equipment, and automatically determines compliance with the International Energy Conservation Code (IECC) for both the prescriptive and performance compliance paths.

There are 2 levels of input that have been designed for REM/Design™ users: Simplified and Detailed. In the “Simplified” version, inputs use the general building design characteristics (e.g., house type) and built-in algorithms to determine building shell areas and other characteristics.

In the “Detailed” version, the inputs provide the user much greater control over building specifications. Inputs include opaque wall construction details, window conduction and solar gain values, HVAC efficiencies, duct system characteristics, passive and active solar design features, infiltration rates (measured or estimated).

REM/Design™ helps the user evaluate and promote the most cost-effective energy features for new home construction. The software analyzes the energy and economic performance of traditional and innovative design features, including active and passive solar systems, infiltration and duct leakage reduction packages, high-performance windows, efficient heating and cooling equipment, and panelized construction.

REM/Design™ also identifies cost-effective energy improvements to existing homes. Using economic criteria that a user specifies, it automatically ranks energy efficiency improvements from the list of measures that have been created. Once the treatments (energy efficiency improvements) and the rule base (i.e., if existing ceiling insulation is R-11, install R-19 to achieve R-30) have been created, they can be saved and used on future projects. The software also offers utility bill analysis, which facilitates calibration of the model.

In this analysis using REM/Design v15.2 simulation tool, the same home was used in all of the simulations. The only variables were the heating and water heating fuel source as well as the referenced energy code. The baseline home was a minimally compliant 2006 IECC design (conceptually similar to the 301 Standard baseline) and the proposed design was a home that was minimally compliant with the 2015 IECC.

Supplemental Information

The US Energy Information Administration (EIA) collects detailed information on energy used in residential facilities in the United States. EIA has published numerous reports based on their detailed Residential Energy Consumption Surveys (RECS) that EIA has performed since the late 1970's. Information showing the wide range of energy used for various key end-use applications is shown below.

EIA "Today in Energy" April 6, 2017 https://www.eia.gov/todayinenergy/detail.php?id=30672

U.S. households' heating equipment choices are diverse and vary by climate region

"Data from the 2015 Residential Energy Consumption Survey (RECS) show that the majority of American households use one of three types of equipment as their main source of heat during the winter: natural gas furnaces, electric furnaces, or electric heat pumps. The range of equipment and fuels, however, varies across and within U.S. climate regions. The use of secondary heating sources, such as portable electric heaters and fireplaces, further adds to the diverse ways households consume fuel to stay warm in the winter."

"Broad ranges in winter temperatures and capabilities of different technologies mean that certain heating choices are better suited to certain climates. Overall, 47% of households rely on natural gas as their main heating fuel, compared with 36% who rely on electricity. Natural gas furnaces are the most common main space heating equipment used in every climate region except the hot-humid region of the Southeast, where heating needs are lower and electric furnaces are more prevalent. In the mixed-dry/hot-dry climate region in the southwestern United States, 15% of homes do not use heating equipment at all, compared with the national average of 4%."

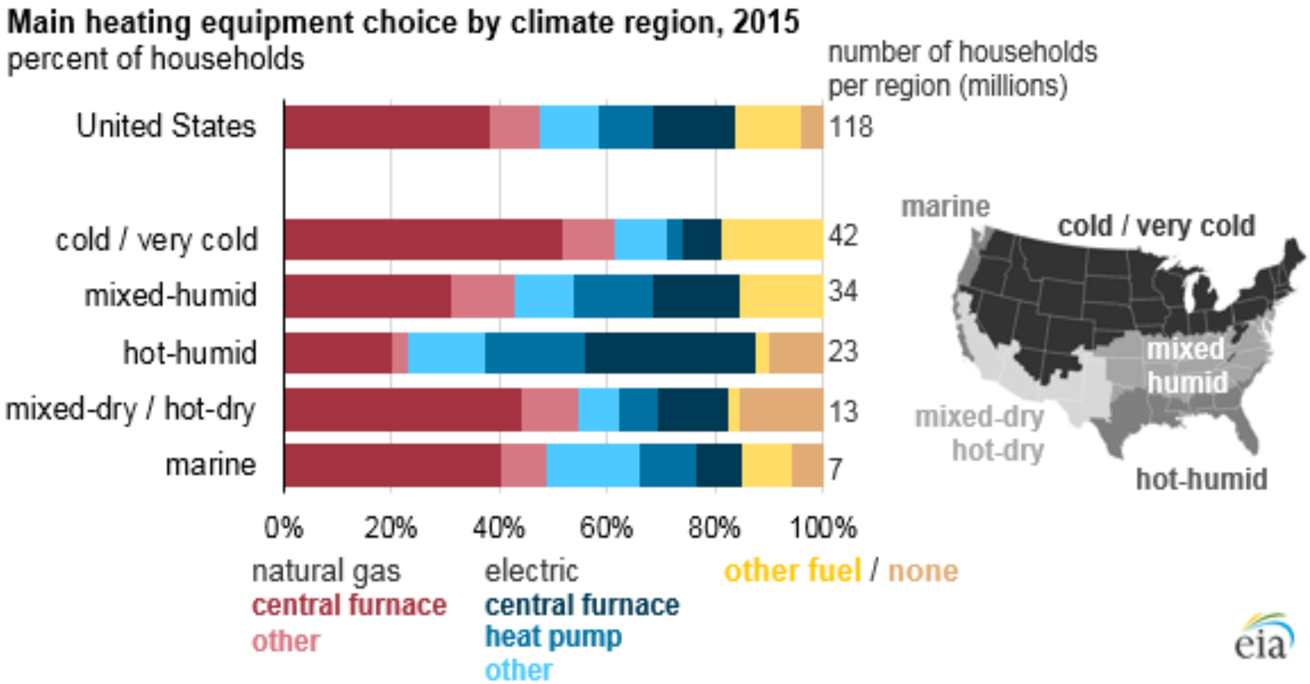
"Electric heat pumps are well-suited to the relatively mild winters in hot-humid areas and some mixed-humid areas. Of the 12.1 million households that use electric heat pumps, 9.3 million are in these two regions, which cover much of the Southeast."

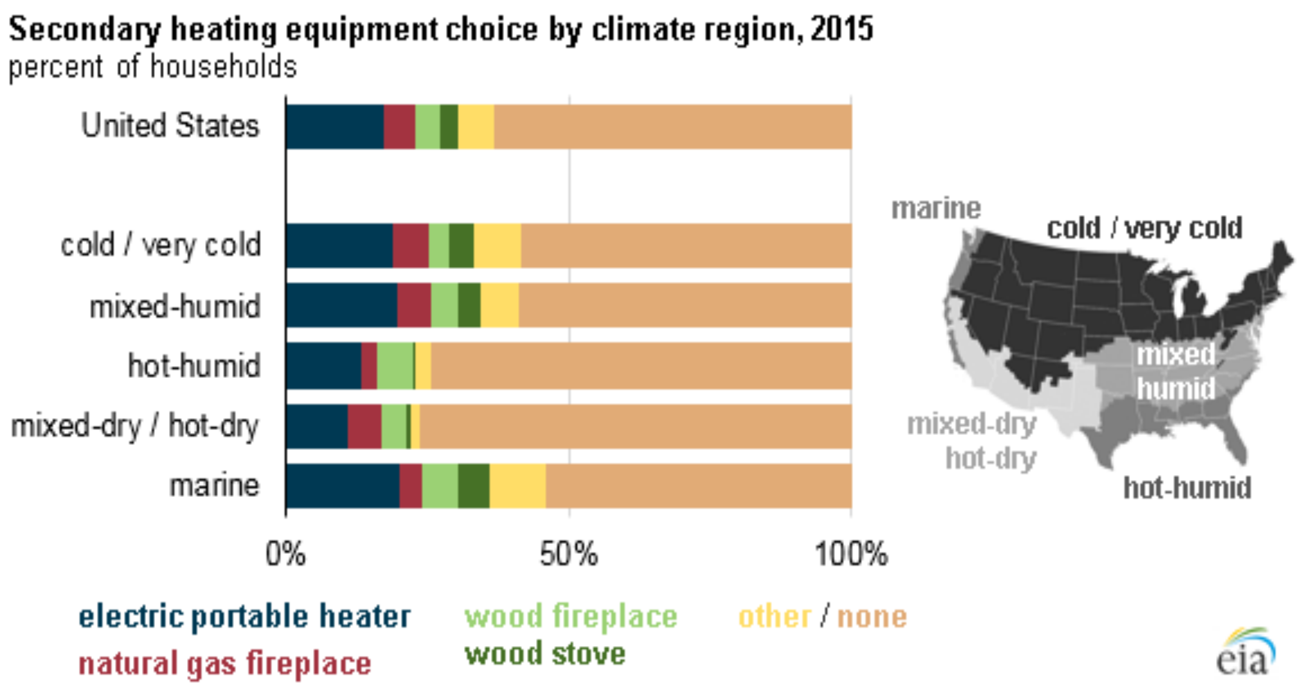
"The high cost of electric heating in colder climates has often limited the use of heat pumps and other electric equipment in those areas. However, advances in heat pump technology, including cold-climate heat pumps, have enabled more efficient electric space heating in areas with lower winter temperatures. In 2015, 1.3 million households in the cold/very cold climate region had electric heat pumps, or about 3% of the regional total."

"Other fuels, such as distillate fuel oil and kerosene, are more commonly used for space heating in the cold/very cold region, but the use of these fuels continues to decline. In the 2015 RECS survey, 5.9 million homes in the United States reported using fuel oil or kerosene as their main heating fuel, a 20% decline from the results of the 2009 RECS survey."

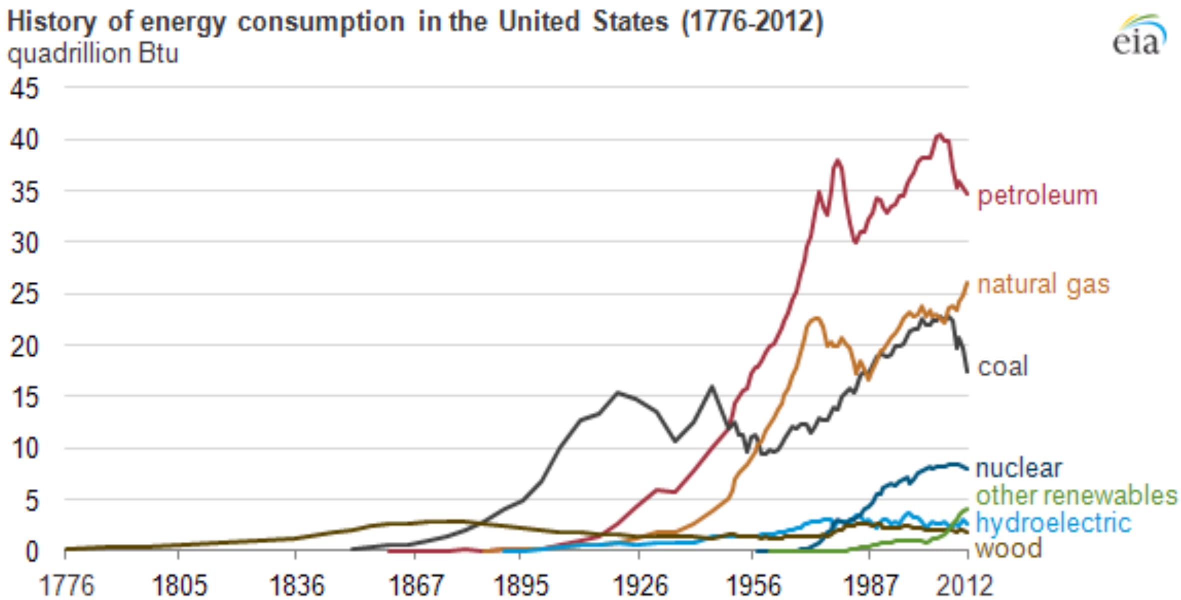
"Nationwide, 37% of U.S. households supplement their main equipment with a secondary source of heat. Almost half of these households use portable electric heaters, the most common secondary heating choice in every climate region. Fireplaces using natural gas or wood are the next most popular choices. Some households use furnaces or heat pumps as their back-up heating source, equipment types that are more commonly used as the main source of heat."

"When considering both main and secondary heating equipment and fuels, U.S. households choose a diverse set of heating scenarios. Among the 5,687 households that were surveyed in the 2015 RECS, EIA observed over 150 unique combinations of heating equipment and fuels." (*emphasis added*)





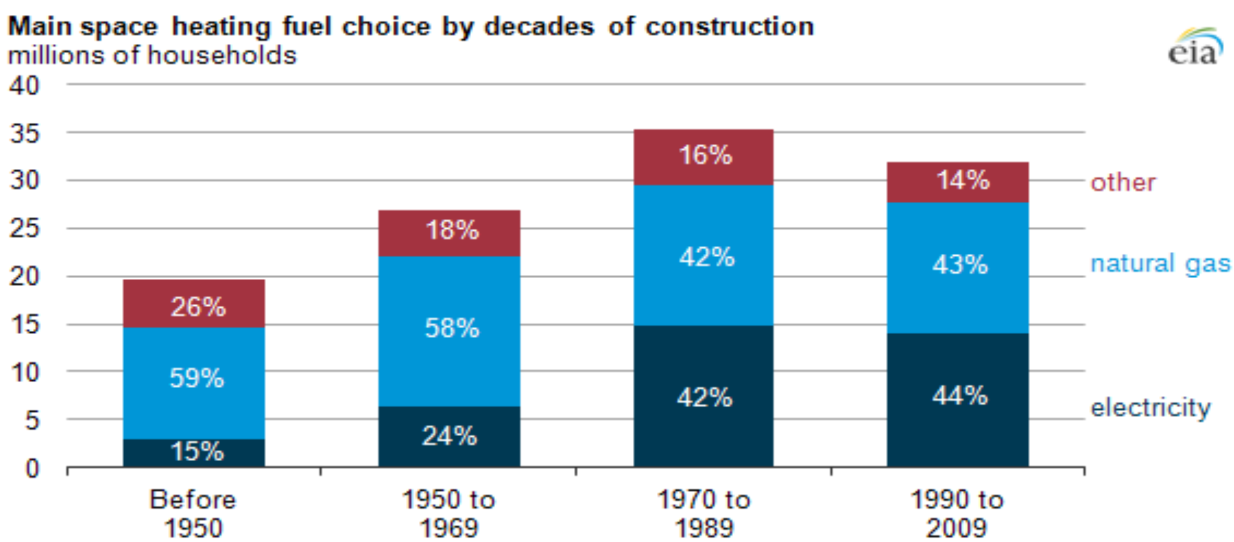
When looking at historical data, fuel choices have changed over time. Until the late 1800's, homes were primarily heated with wood. Then coal became the fuel of choice, especially in more urban areas of the United States. As energy grids and delivery systems developed in the early 1900's, more homes started to use fuel oil, natural gas, and electricity.



EIA "Today in Energy" (August 24, 2012)

https://www.eia.gov/todayinenergy/detail.php?id=7690

Heating fuel choice shows electricity and natural gas roughly equal in newer homes



Therefore, all of the data shown leads to the conclusion that using multiple baselines for an energy cost index would be reflective of the past history and current marketplace, where builders and owners have multiple choices of technologies and fuels.

Appendix B

Cost-based Index Concept

Table 10: Parameter Matrix

Element: Building Performance				
Parameter	CBI Context	nMEUL	TDV	Yes/No: Why?
Point of Use Annual Energy Reduction	JP: A fundamental aspect of a meaningful CBI. Must accommodate relative EEM energy consumption impacts at a minimum and should provide opportunity to execute rigorous cost effectiveness analysis. SR: Energy reductions are immediately translated to annual energy cost reduction. NL: Converts load reduction into energy reduction, then cost reduction.	SR: "modified" energy use and energy consumption are used. Fossil fuel energy use and reductions are multiplied by 0.4. Costs are not a factor. NL: Modifies load reduction using RESNET-derived algorithms. Does not directly correlate with annual energy reduction.	SR: Annual energy reductions are not a factor. Hourly energy reductions are used. NL: Converts load reduction into energy reduction, then time dependent value of cost reduction.	VM: Yes, because this is the fundamental principle of energy rating schemes CD: Yes, This is the most critical metric. PF- Yes JP- Yes, seems obvious NL- Yes SR: Yes, this is very important to determine costs.
Time of Use Annual Energy Reduction	SR: Used only where time of use energy rates (for any or all fuels) are used in the analysis. NL: May be insensitive to TOU if not included in methodology. If sensitive, converts TOU load reduction into TOU energy reduction, then cost reduction.	SR: Not a factor, as the rating is only based on annual "modified" energy use estimates. NL: May be insensitive to TOU if not included in algorithms. If sensitive, modifies load reduction using RESNET-derived algorithms. Does not directly correlate with TOU annual energy reduction.	SR: Hourly energy rates for electricity, and monthly energy rates for fossil fuels. NL: Converts TOU load reduction into TOU energy reduction, and then time dependent value of TOU cost reduction.	VM: Maybe considered but more discussion is needed. CD: No, Could be considered as an option for homes where this is an available tariff. Further research necessary PF- No, not yet JP- Yes, so far intuitively seems to provide a more meaningful result NL- No, not this cycle reconsider in the future SR: Maybe allow as an option in areas where the majority of residential customers are on TOU rates. Otherwise, use monthly, seasonal, or annual rates.
Life Cycle Energy Impacts	SR: Not applicable, as one year energy cost is typically used. NL: Could be done, but not contemplated for this initiative.	SR: Not applicable, as only one year of "modified" energy use is used. NL: Could not be done.	SR: Energy cost increases are estimated over 30 years, and then discounted to obtain NPV. NL: Could be done, but not contemplated for this initiative.	VM: May not be appropriate for an asset rating system. Will add complexity because construction and replacement costs will need to be considered. CD: No, too many variables to consider. PF- No, not in the rating JP- Hesitantly no NL- No SR: No, due to equipment replacement issues, fuel escalation issues, and discount rate issues.

Element: Building Characteristics				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Climate	SR: Only a factor for heating and cooling energy cost calculations. NL: Easily incorporated	SR: Only a factor for heating and cooling "modified" energy usage. NL: Easily incorporated	SR: Different climate zones have different TDV's, especially during peak times. NL: Easily incorporated	VM: Yes, because heating and cooling loads are a function of climate. CD: Yes, obvious parameter necessary in the calculation PF- Yes absolutely! JP- Yes NL- Yes SR: Yes, for heating and cooling energy costs.
Single baseline	SR: For energy costs, baseline is usually based on current energy code and current federal appliance standards. There are no requirements for specific fuels or types of equipment used (e.g., can have tankless water heater or storage tank, can have heat pump or furnace or boiler, etc.). NL: Easily incorporated. Most equitable approach if done with reasonable methodologies and values.	SR: Baseline based on IECC 2006 for envelope and DOE standards for equipment and appliances, but there is choice of fuels and equipment used. NL: Done for cooling, on site power generation. Easily incorporated for remainder of parameters of interest. Difficult to provide equitable approach due to normalizing factors for gas heating and water heating	SR: Baseline based on most recent version of Title 24(?). NL: Easily incorporated. Most equitable approach if done with reasonable methodologies and values.	VM: Desirable in concept but more discussion is needed to ensure equitable consideration. CD: Suggest NO, further discussion needed. May be a violation of NAECA. Need to devote a significant amount of time to this. PF- No JP- Yes NL- Yes SR: Not necessary, as some customers may not be able to use certain equipment that is required in a single baseline.
House size	SR: A factor in annual energy cost, only if proposed design is allowed to have a different size. NL: Impacts rating if not adjusted based on known issues with SF calculations.	SR: In previous versions, larger homes received better scores. NL: Impacts rating if not adjusted based on known issues with SF calculations.	SR: Possible impact with peak price days, with larger air conditioning equipment. NL: Impacts rating if not adjusted based on known issues with SF calculations.	VM: Yes, especially in light of recent efforts by RESNET to resolve the bias for larger homes. CD: Houses need to be compared to themselves. The bias must be addressed. PF- Yes JP- Yes NL- Yes SR: House size should be the same in the baseline case and proposed case to prevent any gaming.

Element: Building Characteristics (continued)				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Orientation	SR: A factor in annual energy cost, only if proposed design is allowed to have a different orientation. NL: Easily incorporated. Single baseline approach needed for reasonable compliance and equity.	SR: Orientation is fixed in baseline and proposed design (?) NL: Incorporated. Single baseline approach used for reasonable compliance and equity.	SR: Orientation is fixed in baseline and proposed design(?) NL: Easily incorporated. Single baseline approach needed for reasonable compliance and equity.	VM: Yes, because orientation can significantly impact heating and cooling load in the proposed case, even if the baseline is solar neutral. CD: Yes, the IECC/RESNET deals with this correctly. PF- Yes JP- Yes NL- Yes SR: Yes, if the overall house shape (wall and roof area) is the same in baseline and proposed cases
Out-structures	SR: A factor only if energy consumption associated with outstructures is included in energy cost simulation. NL: Can be included. Equitable treatment based on primary intent of rating.	SR: A factor only if "modified" energy consumption associated with outstructures is included in energy simulation. NL: Interpreted based on judgments.	SR: A factor only if energy consumption associated with outstructures is included in TDV energy cost simulation. NL: Can be included. Equitable treatment based on primary intent of rating.	VM: May be considered if these are included in the home's cost budget for the purpose of an "asset rating". CD: No, unless they contain bedrooms. PF- No JP- No NL- No, not this cycle SR: Only as an option, if there is reason to believe that the out-structure will use a significant amount of energy.
Other equipment on-site	SR: A factor only if energy consumption associated with "other site" equipment is included in energy cost simulation. NL: Can be included. Equitable treatment based on primary intent of rating.	SR: A factor only if "modified" energy consumption associated with "other site" equipment is included in energy simulation. NL: Interpreted based on judgments.	SR: A factor only if energy consumption associated with "other site" equipment is included in TDV energy cost simulation. NL: Can be included. Equitable treatment based on primary intent of rating.	VM: No CD: No, not this cycle PF- No not this cycle JP- No NL- No not this cycle SR: only if energy consumption associated with "other site" equipment is included in energy cost simulation.
IAQ (ventilation rate)	SR: Not a factor in energy costs unless a code has IAQ requirements (to prevent possible gaming). NL: Not energy cost, but constraint, could be handled similar to current RESNET methodologies.	SR: Not a factor(?) NL: Handled through reference ventilation rate.	SR: Not a factor in energy costs unless a Title 24 has IAQ requirements. NL: Not TDV, but constraint, could be handled similar to current RESNET methodologies.	VM: Yes CD: Yes PF- Yes JP- Yes NL- Yes not beyond what we are currently doing SR: No, IAQ is assumed to be met and codes are followed in baseline and proposed design.

Element: Energy Supply Characteristics				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Electricity	SR: Annual electric costs are used. Rates based on published data. NL: Easily handled. Choice of methodology and values is important.	SR: Annual electricity use is modeled with no modifications. NL: Cost not considered, EUL directly modified to electricity use without any normalization.	SR: Hourly electric usage is modeled. Hourly cost values are assigned. Avoided costs and external costs are included in the assigned value. NL: Easily handled. Choice of methodology and values is important.	VM: Yes, needs to be considered equitably with other fuels in methodology; well accepted prices need to be part of the cost calculation. CD: Yes, very different by methodology. CBI is the most easily understood. SR: Yes, using actual rates with no "adders" or "normalization" to penalize (or promote) its use. PF- yes NL- yes JP- yes MB- yes
Natural Gas	SR: If used at the building, annual natural gas costs are used. Rates based on published data. NL: Easily handled. Choice of methodology and values is important.	SR: Annual gas use is "modified" down by a factor of 2.5. NL: Cost not considered, EUL modified to gas use with normalization. Overvalues gas use reductions compared to electric use reductions.	SR: Hourly (monthly?) natural gas usage is modeled. Monthly cost values are assigned. Avoided costs? External costs? NL: Easily handled. Choice of methodology and values is important.	VM: Yes, needs to be considered equitably with other fuels in methodology; well accepted prices need to be part of the cost calculation CD: Yes, very different by methodology. CBI is the most easily understood. SR: Yes, using actual rates with no "adders" or "normalization" to promote (or penalize its use. PF- yes NL- yes JP- yes MB- yes
Other fossil	SR: If used at the building, annual fossil fuel costs are used. Rates based on published data. NL: Easily handled. Choice of methodology and values is important.	SR: Unclear. Annual fossil fuel use may be "modified" down by a factor of 2.5. NL: Not considered.	SR: Hourly (monthly?) fuel oil or propane usage is modeled. Monthly cost values are assigned. Avoided costs? External costs? NL: Ease of application depends on TDV of other fossil. Choice of methodology and values is important.	VM: Yes, needs to be considered equitably with other fuels in methodology; well accepted prices need to be part of the cost calculation. CD: Yes, very different by methodology. CBI is the most easily understood. SR: Yes, using actual rates with no "adders" or "normalization" to promote (or penalize its use. PF- yes NL- yes be careful how we do it JP- yes be careful how we do it MB-

Element: Energy Supply Characteristics (continued)				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Peak	SR: Only a factor if time-of –use rates and/or demand charges are used in the simulation. NL: Could be handled if desired. Choice of methodology and values is important.	SR: Only a factor if it affects annual modified energy usage (e.g., a house faces many hours of peak conditions). NL: Not considered.	SR: Peak hourly prices can have significant impact on electric TDV. No impact on fossil fuel TDV unless monthly peak values are assigned. NL: Could be handled if desired. Choice of methodology and values is important. May cause double counting.	VM: May need to be considered depending on the philosophy behind the methodology and the tariff structure used. CD: No, Not clear how it would be incorporated unless there is a KW type charge. SR: No. At this time, very few residential customers have peak kW demand charges. PF- no NL- no JP- no MB- no
Time dependence	SR: Only a factor if time-of –use rates and/or demand charges are used in the simulation. NL: Could be handled if desired. Choice of methodology and values is important.	SR: Not a factor. NL: May be insensitive to time dependence if not included in algorithms. If sensitive, modifies load reduction using RESNET-derived algorithms. Does not directly correlate with time-dependent annual energy reduction.	SR: Critical factor for electricity TDV only. Not a factor for fossil fuel TDV. NL: Considered in CA. hourly for electricity, monthly for natural gas.	VM: May need to be considered depending on the philosophy behind the methodology and the tariff structure used. CD: No, would be different for every utility, not an easy number to derive. SR: Only if it is in the rates used for the energy type in the residence. PF- not at this time NL- not at this time, a very worthy goal if it can be done soon JP- maybe but probably not MB- not at this time
Frequency	SR: Frequency of what? NL: Not sure what this is.	SR: Frequency of what?	SR: Frequency of what?	VM: national certified database CD: at this time single rate annually which should consider local tariff structure in the future SR: at this time annual or monthly or time of use depending on state PF- national certified database NL- monthly rates JP- annual or monthly for now with investigation of national certified database approach in the future MB- most granular level of cost that RESNET set that is not a user input

Element: Energy Supply Characteristics (continued)				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
History / Current / Forecast	SR: Energy price used in simulation is usually based on current prices (or sometimes current plus historical for "smoothing" purposes). NL: Evolving electricity grid mix poses challenges for determining methodology and values. Shale gas impacts also a challenge for forecasting.	SR: Energy prices are not a factor. NL: Insensitive by design. However, 0.40 on site power factor (which is not nMEUL but is part of the calculation) is of interest for determining equitable methodology and values.	SR: TDV hourly or monthly values are based on current prices, adders, and 30 year forecasts. NL: Evolving electricity grid mix poses challenges for determining methodology and values. Shale gas impacts also a challenge for forecasting.	VM: May not need to be considered if properly vetted current and future energy prices are used, depending on analysis period selected/agreed upon. CD: No, we know today, we are only guessing on tomorrow. Let's keep it to easily determined values. Ok with historical numbers SR: Current values are probably the most acceptable, but a multi-year average could work (e.g., past 3-5 years) for smoothing. PF- current national averages; most recent year from EIA NL- JP- in favor holistic forecast for utility costs MB- most comprehensive for lifetime of rating or building, look at 10 year historical average in spreadsheet to compare TDV and current year rating; also look at multiple years gas and electric cost as well Note- Philip will send updated data
Grid mix	SR: Only a factor as it affects current or historical prices. NL: See history/current/forecast.	SR: A factor used for "modification" of fossil fuel energy usage. The modification factor may change based on grid changes. NL: See history/current/forecast.	SR: TDV values for electricity are based on grid mix, and TDV projections may change significantly as the grid changes (e.g., 50% RPS by 2030). NL: See history/current/forecast.	VM: No should be an aspect of national regional state CD: No should be an aspect of national regional state SR: The grid mix will change (as do production processes for fossil fuels), but the impact on costs can be up, down, or neutral. PF- No should be an aspect of national regional state NL- JP- No should be an aspect of national regional state MB- don't need to worry about the grid mix separately since it is related to cost

Element: Energy Supply Characteristics (continued)				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Infrastructure	SR: Only a factor as it affects current or historical prices. NL: Policy decisions may impact cost, but unless there is a resilience or energy security question, this is not relevant.	SR: Not a factor. NL: Not considered.	SR: A possible factor that may have an impact on TDV (infrastructure costs as part of TDV). NL: Policy decisions may impact TDV, but unless there is a resilience or energy security question, this is not relevant.	VM: Not sure what this means from the perspective of the home-owner. May not be required if it is assumed that energy prices include these effects. CD: No, should not be considered. Too difficult and controversial to determine. SR: No. Infrastructure costs are already incorporated into current rates. PF, JP, MB- No should be an aspect of national regional state
National / Regional / State	SR: In terms of price, a key decision factor in terms of what energy price to use for analysis. NL: Easily handled. Choice of methodology and values is important.	SR: Not a factor, unless "modification" factor is changed to account for regional or state differences. NL: Not considered. 0.40 factor is a national factor, so regional or state could be easily handled.	SR: Only state factors (plus energy imports?) are used for the current TDV. NL: Need data to implement. Choice of methodology and values is important.	VM: National CD: National SR: Yes, a key decision factor for an energy cost index. PF- use national cost to construct index if you have a national rating; no option will match the bill JP- use national cost to construct index if you have a national rating; no option will match the bill. Accommodation for disclosing cost to consumer based on state or local price MB- use national cost to construct index if you have a national rating; no option will match the bill

Element: Emissions				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
GHG	SR: A factor where environmental remediation costs are included in energy rates (e.g., a charge per kWh or Therm) NL: Would need to be monetized. Choice of methodology and values is important.	SR: An optional output, with regional upstream values for electricity and site emission values for fossil fuels. NL: Not considered.	SR: Environmental (avoided, social) costs are included in TDV, which may overstate actual consumer savings. NL: Already attempted to include monetary impact, but in CA, it does not change annual answers. Choice of methodology and values is important.	VM: May be considered if it can lend itself to the energy cost metric easily. CD: No, this can be calculated as a byproduct of the above, but not inherent in the index calculation. SR: Environmental remediation costs are included in energy rates. No extra "costs adders" are needed. PF- No JP- No not currently in inherent in cost index calculation but this may change in the future MB- No energy index not a GHG index
Other Environment	SR: A factor where environmental remediation costs are included in energy rates (e.g., a charge per kWh or Therm) NL: Would need to be monetized. Choice of methodology and values is important.	SR: An optional output for certain emissions, with regional upstream values for electricity and site emission values for fossil fuels. NL: Not considered.	SR: Not clear if non-GHG emissions are included in TDV environmental costs. NL: Would need to be monetized. Choice of methodology and values is important.	VM: May be considered if it can lend itself to the energy cost metric easily. CD: No, unless there is a clear way to "monetize" the additional factors determined to be relevant for consumer cost of ownership. SR: Environmental remediation costs are included in energy rates. No extra "costs adders" are needed. PF- No JP- No not currently in inherent in cost index calculation but this may change in the future MB- No
Health / Safety	SR: All health and safety codes are assumed to be met. NL: Not energy cost, but constraint, could be handled similar to current RESNET methodologies.	SR: All health and safety codes are assumed to be met. NL: Handled through reference ventilation rate.	SR: All health and safety codes are assumed to be met. NL: Not TDV, but constraint, could be handled similar to current RESNET methodologies.	VM: May be considered if it can lend itself to the energy cost metric easily. CD: No, see above, we are wandering off subject. SR: No. All health/safety codes are assumed to be met. MB- No JP- No; no connection PF- No

Element: Onsite Renewables				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Photo-voltaic, wind, other (onsite generation)	SR: Credit for on-site solar if shown to reduce energy costs or "net" energy costs. Some programs may only focus energy costs before renewable energy credits. NL: Inherently in metered cost on site, so the only question would be net exports or other tariff issues. If PV is off site, grid electricity cost incorporates it already. SR: Credit for on-site solar if shown to reduce energy costs or "net" energy costs. Some programs may only focus on energy costs before renewable energy credits. SR: Credit for on-site wind if shown to reduce energy costs or "net" energy costs. Some programs may only focus on energy costs before renewable energy credits. NL: Usually off site, so grid electricity cost incorporates it already.	SR: Direct credit for on-site PV only. Indirect credit for non-PV that reduces heating, cooling, or water heating "modified" energy use. NL: PV included for on-site power production. Solar thermal open for interpretation. Indirect credit for reducing other "modified" energy usage. SR: No credit for on-site wind power production. NL: Off-site wind power not considered.	SR: On-site solar is not accounted for. Models assume no on-site energy production. NL: Inherently in metered cost, so the only question would be net exports or other tariff issues. If PV is off site, TOU grid electricity cost incorporates it already for TDV calculations. SR: Models assume no use of other on-site renewables. SR: Models assume no use of on-site wind turbines. NL: Usually off site, TOU grid electricity cost incorporates it already for TDV calculations.	VM: Yes because on-site renewables are on the rise. CD: Yes, we should care about the site impact on consumer energy cost. Should be considered. This will require significant discussion. SR: No. Energy production can reduce annual purchased energy costs from 3rd parties, but does not reduce equipment energy consumption. It depends on whether the goal is to reduce energy consumption and its associated costs, or to lower the "net" costs. PF- Yes JP- Yes however the index is based on the efficiency of the building an therefore there must be a distinction in the index between its connection to efficiency verses renewable generation MB- Yes solar thermal should be considered efficiency and not generation NL- Yes CD: Yes, we should care about the site impact on consumer energy cost. Should be considered. This will require significant discussion. SR: No. It depends on whether the goal is to reduce energy consumption and its associated costs, or to lower the "net" costs. Responses same as above VM: Not sure about the use of generally off-site generation in residential. Needs more discussion. CD: Yes, we should care about the site impact on consumer energy cost. Should be considered. This will require significant discussion. SR: No. Energy production (or energy capture) can reduce annual purchased energy costs from 3rd parties, but does not reduce equipment energy consumption. It depends on whether the goal is to reduce energy consumption and its associated costs, or to lower the "net" costs.
Solar Thermal Space and Water Heating Systems	SR: Credit if it reduces heating or water heating energy costs. NL: Credit if it reduces heating or water heating energy costs.	Indirect credit for reducing heating or water heating "modified" energy usage. NL: Typically requires an innovative design request for space heating. Water heating included	SR: Included subject to modeling limitations NL: Included subject to modeling limitations	VM: May be difficult to implement unless a simplified method is employed. Needs more discussion. CD: Yes, we should care about the site impact on consumer energy cost. Should be considered. This will require significant discussion. SR: No. Energy production (or energy capture) can reduce annual purchased energy costs from 3rd parties, but does not reduce equipment energy consumption. It depends on whether the goal is to reduce energy consumption and its associated costs, or to lower the "net" costs. PF- JP- MB- NL- Yes

Element: Onsite Renewables (continued)				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Weighting VS Conser-vation	SR: Energy cost reduction from on-site renewables depends on application (substitute for delivered energy or export). Value varies by state or region. Some programs may only focus on energy costs before renewable energy credits. NL: Would need adjustment factors after cost calculations.	SR: Full credit for PV, with no limit to score reduction. Score can be 130 before PV and 0 after PV. NL: On site PV is considered equivalent to conservation. Would need adjustment factor.	SR: Model assumes no on-site energy production, so no TDV value for on-site production. NL: Would need adjustment factors after TDV calculations.	CD: Needs to be included- potentially only including generation value (not T&D) for energy fed back into grid- depends on tariff. SR: No (or yes with some limits). Energy cost reduction from on-site renewables depends on application (substitute for delivered energy or export). Value varies by state or region. Some programs may only focus on energy costs before renewable energy credits.
Infrastruc-ture & Main-tenance	SR: Infrastructure and maintenance costs are typically not included in energy cost methodology. They would have to be assigned a $ / kWh or Therm value. NL: Off-site included in rates, but non-energy cost factors would need to be added to the equation.	SR: Infrastructure and maintenance costs are not included in PV credit calculation. NL: Not considered	SR: Model assumes no on-site energy production, so no calculation of infrastructure and maintenance costs are needed. NL: Off-site included in rates, but non-energy cost factors would need to be added to the equation.	VM: Depends on chosen fuel prices and whether they inherently account for these effects. CD: No, not clear how this would be applied. No apparent need. SR. Yes for programs looking at "net costs", if there is a way to assign a $ / kWh or Therm value to systems that are maintained by homeowners.
Off-site	SR: A factor where customer can choose their supplier and is allowed to use energy rates that are different from the standard rate (e.g., 14 cents/kWh for all wind power versus 12.5 cents/kWh for standard offer; $1.20 per Therm for biogas versus $1.00 per Therm for natural gas). NL: Question of equitable treatment compared to on site energy forms and uses.	SR: Not an issue or parameter. NL: Not considered	SR: Directly affects TDV going forward, as TDV for electricity changes as more renewables are added to the electric grid. "Super peak" TDV costs may be reduced significantly. NL: Question of equitable treatment compared to on site energy forms and uses.	VM: Depends on chosen fuel prices and whether they inherently account for these effects. CD: Possible, may want to put limits on application- e.g. not count hydro generation from 500 miles away. SR: Yes, where customer can choose their supplier and is allowed to use energy rates that are different from the standard rate (e.g., 14 cents/kWh for all wind power versus 12.5 cents/kWh for standard offer; $1.20 per Therm for biogas versus $1.00 per Therm for natural gas).
On-site	SR: Credit for on-site renewables if shown to reduce energy costs or "net" energy costs. Some programs may only focus energy costs before renewable energy credits. NL: Question of equitable treatment compared to other on site energy forms and uses.	SR: Direct credit for on-site PV only. Indirect credit for non-PV that reduces heating, cooling, or water heating "modified" energy use. NL: PV included for on-site power production. Solar thermal open for interpretation.	SR: On-site solar is not accounted for. Models assume no on-site energy production. NL: Question of equitable treatment compared to other on site energy forms and uses.	VM: Yes, because on-site generation is on the rise. CD: Yes, may want to incorporated local tariff structure. SR: No (or yes with some limits). Energy cost reduction from on-site renewables depends on application (substitute for delivered energy or export). Value varies by state or region. Some programs may only focus on energy costs before renewable energy credits.

Element: Non-energy Aspects				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Material Cost	SR: Not a factor for energy cost analysis. NL: Would need adjustment factors after energy cost calculations.	SR: Not a factor for analysis. NL: Not considered. Would need adjustment factors after calculations.	SR: Not a factor for analysis. NL: Would need adjustment factors after energy cost calculations.	VM: May need to be considered if an LCC approach is employed. Depends on the philosophy on the rating index. CD: No, let the designer/builder decide what is best to meet index. SR: No, not a factor for energy cost analysis. NL, PF, MB and JP- No
Installation Cost	SR: Not a factor for energy cost analysis. NL: Would need adjustment factors after energy cost calculations.	SR: Not a factor for analysis or methodology. NL: Not considered. Would need adjustment factors after calculations.	SR: May be a factor for life cycle cost analysis (?) NL: Would need adjustment factors after energy cost calculations.	VM: May need to be considered if an LCC approach is employed. Depends on the philosophy on the rating index. CD: No, let the designer/builder decide what is best to meet index SR: No, not a factor for energy cost analysis. NL, PF, MB and JP- No

Element: Non-energy Aspects (continued)				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
NPV/LCC	SR: Not used for programs that focus on annual energy costs. NL: Could be done, but not contemplated for this initiative.	SR: Not used, as the output score is based on one year "modified" energy use. NL: Not considered.	SR: NPV based on 30 year analysis period and specific fuel escalation rates and discount rates. NL: Could be done, but not contemplated for this initiative.	VM: Depends of the philosophy of the rating index. Will increase complexity of calculations and needs more discussion. CD: No, too many future assumptions. Today's energy cost is clear and provides value to consumer. SR: No, fuel escalation rates and discount rates have enormous impacts on eventual results. NL, PF, MB and JP- No
Maintenance Cost	SR: Maintenance costs are typically not included in energy cost methodology. They would have to be assigned a $ / kWh or Therm value. NL: Would need adjustment factors after energy cost calculations.	SR: Maintenance costs are not included in PV credit calculation. NL: Not considered. Would need adjustment factors after calculations.	SR: Model assumes no on-site energy production, so no calculation of maintenance costs is needed. NL: Would need adjustment factors after energy cost calculations.	VM: May need to be considered if an LCC approach is employed. Depends on the philosophy on the rating index. CD: No, too many future assumptions. Today's energy cost is clear and provides value to consumer. SR: No, unless there was a way to translate into $/kWh or $/Therm value and to differentiate baseline systems/ technologies and proposed technologies. NL, PF, MB and JP- No
Occupant Behavior	SR: Indirectly accounted for through modeling of heating/cooling/water heating thermostat settings and estimated hours of operation or number of uses per week for appliances. NL: Would need adjustment factors after energy cost calculations.	SR: Indirectly accounted for through modeling of heating/cooling/water heating thermostat settings and estimated hours of operation or number of uses per week for appliances. NL: Not considered. Would need adjustment factors after calculations.	SR: Indirectly accounted for through modeling of heating/cooling/water heating thermostat settings (and estimated hours of operation or number of uses per week for appliances?). NL: Would need adjustment factors after energy cost calculations.	VM: Very difficult to characterize in a broad manner. Besides, it is not an "asset" thing. CD: No, unless you want to have a post occupancy index. SR: No, it is indirectly accounted for through modeling of heating / cooling / water heating thermostat settings and estimated hours of operation or number of uses per week for appliances. Baseline and proposed behavior are the same. NL, PF, MB and JP- No

Element: Societal				
Parameter	**CBI Context**	**nMEUL**	**TDV**	**Yes/No: Why?**
Class / Luxuries	SR: Not a direct factor (only indirect, as larger homes tend to use more energy and have higher energy costs). Only luxuries with energy costs included in the model may be a factor. NL: Similar to house size question, could be done, but would need adjustment approach.	SR: In previous versions, larger homes received better scores. NL: Similar to house size question, could be done, but would need adjustment approach.	SR: Not a direct factor (only indirect, as larger homes use tends to use more energy and have higher energy costs). NL: Similar to house size question, could be done, but would need adjustment approach.	VM: Difficult to consider in a rating index except house size. CD: No, houses need to be compared to themselves. SR: No, agree with Craig. NL, PF, MB and JP- No
Energy Security	SR: A factor only where costs associated with energy security are included in energy rates (e.g., $ per gallon of imported fuel oil). Not a factor for electricity or natural gas costs. NL: Could be done, but would need adjustment approach.	SR: Not a factor, even for homes using fuel oil or propane. NL: Could be done, but would need adjustment approach.	SR: Not a factor, even for homes using fuel oil or propane. NL: Could be done, but would need adjustment approach.	VM: Needs more discussion. CD: No, not directly applicable to consumer. Difficult to derive and communicate. SR: No, as it is only a factor where costs associated with energy security are included in energy rates (e.g., $ per gallon of imported fuel oil). Not a factor for electricity or natural gas costs. NL, PF, MB and JP- No

Appendix C

Detailed EnergyGauge® USA Simulation Results

C1 Miami 2-story, 2,400 ft^2, 3-bedroom Homes

Miami - electric				Miami - gas			
normalized* End Use Loads (MBtu)				normalized* End Use Loads (MBtu)			
End Use	**Rated***	**Ref**	**e-Ratio**	**End Use**	**Rated***	**Ref**	**e-Ratio**
Heating*	0.15	1.28	0.12	Heating*	0.11	1.26	0.09
Cooling*	19.50	65.03	0.30	Cooling*	20.04	66.12	0.30
DHW*	1.77	5.25	0.34	DHW*	2.02	5.25	0.38
MVent	0.63	1.30	0.48	MVent	0.63	1.30	0.48
Lights	3.65	9.20	0.40	Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80	Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81	dWash	0.47	0.58	0.81
cFans	0.00	0.00		cFans	0.00	0.00	
cWash	0.13	0.23	0.57	cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63	cDryer	2.38	3.77	0.63
Cook	1.53	1.53	1.00	Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00	TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00	Misc	7.45	7.45	1.00
Total	**41.40**	**99.67**	**0.42**	**Total**	**44.06**	**102.81**	**0.43**

Energy Consumption (MBtu)				Energy Consumption (MBtu)			
End Use	**Rated**	**Ref**	**e-Ratio**	**End Use**	**Rated**	**Ref**	**e-Ratio**
Heating	0.06	0.54	0.11	Heating	0.21	2.23	0.09
Cooling	7.82	26.08	0.30	Cooling	8.01	26.44	0.30
DHW	2.08	6.16	0.34	DHW	6.08	11.10	0.55
MVent	0.63	1.30	0.48	MVent	0.63	1.30	0.48
Lights	3.65	9.20	0.40	Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80	Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81	dWash	0.47	0.58	0.81
cFans	0.00	0.00		cFans	0.00	0.00	
cWash	0.13	0.23	0.57	cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63	cDryer	2.38	3.77	0.63
Cook	1.53	1.53	1.00	Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00	TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00	Misc	7.45	7.45	1.00
Total	**29.94**	**60.89**	**0.49**	**Total**	**36.19**	**69.95**	**0.52**

Miami - electric			
Actual End Use Loads (MBtu)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heating	0.19	1.28	0.15
Cooling	35.74	65.03	0.55
DHW	4.64	5.25	0.88
MVent	0.63	1.30	0.48
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**60.55**	**99.67**	**0.61**

Miami - gas			
Actual End Use Loads (MBtu)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heating	0.18	1.26	0.15
Cooling	36.78	66.12	0.56
DHW	4.64	5.25	0.88
MVent	0.63	1.30	0.48
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**63.49**	**102.81**	**0.62**

End Use Energy (kWh/Thrm)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heat kWh	16	133	0.12
Heat Thrm			
fan kWh	2	26	0.08
Cooling	2292	7641	0.30
DHW kWh	609	1806	0.34
DHW Thrm			
MVent	185	380	0.49
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	36	69	0.52
cDry kWh	618	980	0.63
cDry Thrm			
Cook kWh	448	448	1.00
Cook Thrm			
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	29.92	60.90	0.49
Src MBtu	94.26	191.84	0.49
Cost $	$1,052	$2,141	0.49

End Use Energy (kWh/Thrm)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heat kWh			
Heat Thrm	2	22	0.09
fan kWh	1	21	0.05
Cooling	2347	7746	0.30
DHW kWh			
DHW Thrm	61	111	0.55
MVent	185	380	0.49
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	38	69	0.55
cDry kWh	49	77	0.64
cDry Thrm	22	35	0.63
Cook kWh	31	31	1.00
Cook Thrm	31	31	1.00
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	36.22	70.02	0.52
Src MBtu	90.19	179.57	0.50
Cost $	$979	$1,957	0.50

Source multipliers: electricity = 3.15; natural gas = 1.09
Prices: electricity = $0.12/kWh; natural gas = $0.98/Therm

C2 Houston 2-story, 2,400 ft^2, 3-bedroom Homes

Houston - electric

normalized* End Use Loads (MBtu)

End Use	Rated*	Ref	e-Ratio
Heating*	4.95	12.34	0.40
Cooling*	12.97	41.37	0.31
DHW*	2.39	6.79	0.35
MVent	0.63	1.26	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**40.29**	**88.57**	**0.45**

Energy Consumption (MBtu)

End Use	Rated	Ref	e-Ratio
Heating	2.94	7.33	0.40
Cooling	5.45	17.38	0.31
DHW	2.76	7.84	0.35
MVent	0.63	1.26	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**31.13**	**60.62**	**0.51**

Houston - gas

normalized* End Use Loads (MBtu)

End Use	Rated*	Ref	e-Ratio
Heating*	4.19	12.18	0.34
Cooling*	13.22	42.11	0.31
DHW*	2.76	6.79	0.41
MVent	0.64	1.26	0.51
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**42.07**	**91.22**	**0.46**

Energy Consumption (MBtu)

End Use	Rated	Ref	e-Ratio
Heating	8.14	21.48	0.38
Cooling	5.53	17.61	0.31
DHW	7.97	13.74	0.58
MVent	0.64	1.26	0.51
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**43.54**	**82.97**	**0.52**

Houston - electric			
Actual End Use Loads (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	7.14	12.34	0.58
Cooling	24.07	41.37	0.58
DHW	6.08	6.79	0.90
MVent	0.63	1.26	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	57.27	88.57	0.65
End Use Energy (kWh/Thrm)			
End Use	Rated	Ref	e-Ratio
Heat kWh	764	1853	0.41
Heat Thrm			
fan kWh	98	296	0.33
Cooling	1596	5091	0.31
DHW kWh	808	2299	0.35
DHW Thrm			
MVent	186	370	0.50
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	36	69	0.52
cDry kWh	618	980	0.63
cDry Thrm			
Cook kWh	448	448	1.00
Cook Thrm			
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	31.11	60.64	0.51
Src MBtu	98.00	191.01	0.51
Cost $	$1,094	$2,132	0.51

Houston - gas			
Actual End Use Loads (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	7.14	12.18	0.59
Cooling	24.71	42.11	0.59
DHW	6.08	6.79	0.90
MVent	0.64	1.26	0.51
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	59.83	91.22	0.66
End Use Energy (kWh/Thrm)			
End Use	Rated	Ref	e-Ratio
Heat kWh			
Heat Thrm	80	209	0.38
fan kWh	56	182	0.31
Cooling	1620	5160	0.31
DHW kWh			
DHW Thrm	80	137	0.58
MVent	187	370	0.51
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	38	69	0.55
cDry kWh	49	77	0.64
cDry Thrm	22	35	0.63
Cook kWh	31	31	1.00
Cook Thrm	31	31	1.00
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	43.63	83.01	0.53
Src MBtu	93.56	176.61	0.53
Cost $	$994	$1,874	0.53

Source multipliers: electricity = 3.15; natural gas = 1.09
Prices: electricity = $0.12/kWh; natural gas = $0.98/Therm

C3 Atlanta 2-story, 2,400 ft², 3-bedroom Homes

Atlanta - electric			
normalized* End Use Loads (MBtu)			
End Use	**Rated***	**Ref**	**e-Ratio**
Heating*	8.63	26.53	0.33
Cooling*	5.22	22.19	0.24
DHW*	3.13	8.16	0.38
MVent	0.86	1.74	0.49
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**37.19**	**85.43**	**0.44**

Atlanta - gas			
normalized* End Use Loads (MBtu)			
End Use	**Rated***	**Ref**	**e-Ratio**
Heating*	7.10	26.24	0.27
Cooling*	5.41	22.66	0.24
DHW*	3.43	8.16	0.42
MVent	0.87	1.73	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**38.07**	**87.67**	**0.43**

Energy Consumption (MBtu)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heating	5.43	16.70	0.33
Cooling	2.45	10.41	0.24
DHW	3.45	9.00	0.38
MVent	0.86	1.74	0.49
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**31.54**	**64.66**	**0.49**

Energy Consumption (MBtu)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heating	13.75	46.08	0.30
Cooling	2.52	10.55	0.24
DHW	9.64	16.10	0.60
MVent	0.87	1.73	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**48.04**	**103.34**	**0.46**

Atlanta - electric			
Actual End Use Loads (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	12.01	26.53	0.45
Cooling	9.80	22.19	0.44
DHW	7.36	8.16	0.90
MVent	0.86	1.74	0.49
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	49.38	85.43	0.58
End Use Energy (kWh/Thrm)			
End Use	Rated	Ref	e-Ratio
Heat kWh	1410	4205	0.34
Heat Thrm			
fan kWh	182	687	0.26
Cooling	718	3050	0.24
DHW kWh	1011	2637	0.38
DHW Thrm			
MVent	253	509	0.50
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	36	69	0.52
cDry kWh	618	980	0.63
cDry Thrm			
Cook kWh	448	448	1.00
Cook Thrm			
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	31.53	64.66	0.49
Src MBtu	99.32	203.69	0.49
Cost $	$1,109	$2,274	0.49

Atlanta - gas			
Actual End Use Loads (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	12.05	26.24	0.46
Cooling	10.21	22.66	0.45
DHW	7.36	8.16	0.90
MVent	0.87	1.73	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	51.75	87.67	0.59
End Use Energy (kWh/Thrm)			
End Use	Rated	Ref	e-Ratio
Heat kWh			
Heat Thrm	134	447	0.30
fan kWh	94	396	0.24
Cooling	738	3092	0.24
DHW kWh			
DHW Thrm	96	161	0.60
MVent	254	508	0.50
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	38	69	0.55
cDry kWh	49	77	0.64
cDry Thrm	22	35	0.63
Cook kWh	31	31	1.00
Cook Thrm	31	31	1.00
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	47.98	103.35	0.46
Src MBtu	92.84	186.72	0.50
Cost $	$969	$1,925	0.50

Source multipliers: electricity = 3.15; natural gas = 1.09
Prices: electricity = $0.12/kWh; natural gas = $0.98/Therm

C4 Albuquerque 2-story, 2,400 ft^2, 3-bedroom Homes

Albuquerque - electric			
normalized* End Use Loads (MBtu)			
End Use	Rated*	Ref	e-Ratio
Heating*	9.95	25.55	0.39
Cooling*	4.65	15.13	0.31
DHW*	3.65	9.30	0.39
MVent	0.73	1.45	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**38.33**	**78.24**	**0.49**

Albuquerque - gas			
normalized* End Use Loads (MBtu)			
End Use	Rated*	Ref	e-Ratio
Heating*	8.08	25.22	0.32
Cooling*	4.72	15.46	0.31
DHW*	4.00	9.30	0.43
MVent	0.72	1.44	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**38.78**	**80.30**	**0.48**

Energy Consumption (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	6.81	17.50	0.39
Cooling	2.04	6.63	0.31
DHW	4.01	10.20	0.39
MVent	0.73	1.45	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**32.94**	**62.59**	**0.53**

Energy Consumption (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	15.52	43.95	0.35
Cooling	2.06	6.75	0.31
DHW	11.02	17.99	0.61
MVent	0.72	1.44	0.50
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**50.58**	**99.01**	**0.51**

Albuquerque - electric				Albuquerque - gas			
Actual End Use Loads (MBtu)				Actual End Use Loads (MBtu)			
End Use	Rated	Ref	e-Ratio	End Use	Rated	Ref	e-Ratio
Heating	13.67	25.55	0.54	Heating	13.81	25.22	0.55
Cooling	7.15	15.13	0.47	Cooling	7.36	15.46	0.48
DHW	8.42	9.30	0.90	DHW	8.42	9.30	0.90
MVent	0.86	1.74	0.49	MVent	0.87	1.73	0.50
Lights	3.65	9.20	0.40	Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80	Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81	dWash	0.47	0.58	0.81
cFans	0.00	0.00		cFans	0.00	0.00	
cWash	0.13	0.23	0.57	cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63	cDryer	2.38	3.77	0.63
Cook	1.53	1.53	1.00	Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00	TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00	Misc	7.45	7.45	1.00
Total	49.44	78.53	0.63	Total	51.72	80.59	0.64
End Use Energy (kWh/Thrm)				End Use Energy (kWh/Thrm)			
End Use	Rated	Ref	e-Ratio	End Use	Rated	Ref	e-Ratio
Heat kWh	1773	4415	0.40	Heat kWh			
Heat Thrm				Heat Thrm	152	427	0.36
fan kWh	223	711	0.31	fan kWh	108	380	0.28
Cooling	577	1943	0.30	Cooling	604	1977	0.31
DHW kWh	1174	2988	0.39	DHW kWh			
DHW Thrm				DHW Thrm	110	180	0.61
MVent	213	424	0.50	MVent	212	423	0.50
Lights	1069	2695	0.40	Lights	1069	2695	0.40
Refrig	553	691	0.80	Refrig	553	691	0.80
dWash	136	171	0.80	dWash	136	171	0.80
cFans	0	0		cFans	0	0	
cWash	36	69	0.52	cWash	38	69	0.55
cDry kWh	618	980	0.63	cDry kWh	49	77	0.64
cDry Thrm				cDry Thrm	22	35	0.63
Cook kWh	448	448	1.00	Cook kWh	31	31	1.00
Cook Thrm				Cook Thrm	31	31	1.00
TV	620	620	1.00	TV	620	620	1.00
Misc	2184	2184	1.00	Misc	2184	2184	1.00
Site MBtu	32.85	62.59	0.52	Site MBtu	50.63	99.10	0.51
Src MBtu	103.47	197.16	0.52	Src MBtu	94.58	173.53	0.55
Cost $	$1,155	$2,201	0.52	Cost $	$981	$1,778	0.55

Source multipliers: electricity = 3.15; natural gas = 1.09
Prices: electricity = $0.12/kWh; natural gas = $0.98/Therm

C5 Chicago 2-story, 2,400 ft², 3-bedroom Homes

Chicago - electric

normalized* End Use Loads (MBtu)			
End Use	**Rated***	**Ref**	**e-Ratio**
Heating*	22.89	56.04	0.41
Cooling*	2.00	8.28	0.24
DHW*	4.55	10.67	0.43
MVent	0.44	1.51	0.29
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**49.23**	**103.31**	**0.48**

Chicago - gas

normalized* End Use Loads (MBtu)			
End Use	**Rated***	**Ref**	**e-Ratio**
Heating*	19.22	53.55	0.36
Cooling*	2.13	8.94	0.24
DHW*	5.00	10.67	0.47
MVent	0.45	1.52	0.30
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**48.06**	**103.56**	**0.46**

Chicago - electric

Energy Consumption (MBtu)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heating	16.83	41.21	0.41
Cooling	0.98	4.07	0.24
DHW	4.86	11.41	0.43
MVent	0.44	1.51	0.29
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**42.46**	**85.01**	**0.50**

Chicago - gas

Energy Consumption (MBtu)			
End Use	**Rated**	**Ref**	**e-Ratio**
Heating	37.00	93.53	0.40
Cooling	1.11	4.68	0.24
DHW	12.48	18.68	0.67
MVent	0.45	1.52	0.30
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	**72.30**	**147.29**	**0.49**

Chicago - electric			
Actual End Use Loads (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	31.84	56.04	0.57
Cooling	3.19	8.28	0.39
DHW	9.61	10.67	0.90
MVent	0.44	1.51	0.29
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.11	3.34	0.63
Cook	1.53	1.53	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	64.42	103.31	0.62
End Use Energy (kWh/Thrm)			
End Use	Rated	Ref	e-Ratio
Heat kWh	4350	10458	0.42
Heat Thrm			
fan kWh	581	1649	0.35
Cooling	288	1198	0.24
DHW kWh	1426	3343	0.43
DHW Thrm			
MVent	130	443	0.29
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	36	69	0.52
cDry kWh	618	980	0.63
cDry Thrm			
Cook kWh	448	448	1.00
Cook Thrm			
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	42.45	85.15	0.50
Src MBtu	133.73	268.22	0.50
Cost $	$1,493	$2,994	0.50

Chicago - gas			
Actual End Use Loads (MBtu)			
End Use	Rated	Ref	e-Ratio
Heating	32.82	53.55	0.61
Cooling	3.77	8.94	0.42
DHW	9.61	10.67	0.90
MVent	0.44	1.52	0.29
Lights	3.65	9.20	0.40
Refrig	1.89	2.36	0.80
dWash	0.47	0.58	0.81
cFans	0.00	0.00	
cWash	0.13	0.23	0.57
cDryer	2.38	3.77	0.63
Cook	3.17	3.17	1.00
TV	2.12	2.12	1.00
Misc	7.45	7.45	1.00
Total	67.89	103.56	0.66
End Use Energy (kWh/Thrm)			
End Use	Rated	Ref	e-Ratio
Heat kWh			
Heat Thrm	361	911	0.40
fan kWh	256	780	0.33
Cooling	326	1374	0.24
DHW kWh			
DHW Thrm	125	187	0.67
MVent	133	446	0.30
Lights	1069	2695	0.40
Refrig	553	691	0.80
dWash	136	171	0.80
cFans	0	0	
cWash	38	69	0.55
cDry kWh	49	77	0.64
cDry Thrm	22	35	0.63
Cook kWh	31	31	1.00
Cook Thrm	31	31	1.00
TV	620	620	1.00
Misc	2184	2184	1.00
Site MBtu	72.31	147.59	0.49
Src MBtu	116.75	225.12	0.52
Cost $	$1,176	$2,237	0.53

Source multipliers: electricity = 3.15; natural gas = 1.09
Prices: electricity = $0.12/kWh; natural gas = $0.98/Therm