A Modest Approach to the (Equipment) Standards Conundrums: Separate Compliance from Installed Performance Descriptors

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ABSTRACT

For complex equipment the current approach used to develop rating methods and standards is obsolete. Federal compliance is based on a single metric measured by a stipulated test method. Better performance is judged by the scalar positive difference on the same test, such as a seasonal energy efficiency ratio (SEER) of 15 against a national minimum of 13. Test methods evaluate core mechanical performance such as the combustion efficiency of a furnace. They do not see the performance contributions of so-called intelligent machines, they cannot always duplicate field operation, and they cannot reflect regional needs for key secondary performance features, such as humidity control where needed.

We propose an alternative: retain the simple mechanical model for minimum energy performance (MEP) compliance, and develop software that allows manufacturers to make demonstrable claims for better performance of a specific model in a specific application, along with a process to verify these claims. This extends current reliance on alternative efficiency determination methods (AEDMs) from simulating specific variants of a basic model. It is analogous to current application ratings that estimate performance under conditions different from those tested for compliance, but extends it beyond mechanical features.

The following are the advantages of this approach:

- Thermodynamics limit mechanical-system performance in terms of delivered energy savings; the possibilities when other characteristics are included are much higher.
- This can unleash innovation by allowing manufacturers to show savings that cannot be revealed by the test method.
- For designers and contractors this can lead to much more accurate performance estimates for specific buildings, enabling better choices—and improving system integration.

Disadvantages include the difficulty of transitions, as shown by recent experience with a new rating method for water heaters.

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Introduction

Goals of This Paper

Progress achieved from increasing standards stringency is slowing, at least for more-complicated products. This results from the current methods of certifying and rating products and from technical and economic factors. We summarize the arguments below, then consider several routes that might avoid the approaching plateau and save much more energy in the future. From these alternatives we develop a promising path, one based on separating testing for compliance with minimum energy performance standards (MEPS) from rating performance in field applications. Because current limits tend to discourage manufacturers from investing in innovations that would save energy in ways not directly addressed by the standards, separating compliance from verifiable performance would reveal the true value of advanced equipment, which in turn would cause manufacturers and their downstream customers and trade allies to encourage incorporating efficiency innovations into their products.

Today's federal rating or test methods are based on simplified models of how products perform. During the early days of equipment ratings, in an era of electromechanical instruments, stopwatches and clipboards were used, not automated equipment.[1] To rate products in a reasonable amount of time this required simple tests, such as steady-state combustion efficiency under stipulated conditions. Such tests were likely to offer reasonable relative performance indices. There was no pretension to accurate seasonal energy consumption for all applications in all regions, and little effort in this direction until federal standards were being developed. As an example, first-round efficiency standards for central air conditioners estimated seasonal energy efficiency ratio (SEER) from a steady-state measurement under part-load conditions (82°F).

The National Appliance Energy Conservation Act (NAECA) of 1987 mandated the first federal appliance standards. Since then patches have been added to rating methods to try to accommodate advanced technologies or incorporate other parameters such as electricity used in standby and off mode (EISA 2007). Arguably today many of the current rating methods are obsolete (Amann and Sachs 2010) and should be replaced. Our goal is to introduce an alternative approach: separating the test methods required to ensure minimum energy performance (i.e., compliance) from the methods required to describe premium performance, through a more accurate representation of the expected annual energy consumption for a specific application.

Background

Serious public interest in energy conservation in the United States arose from the Arab oil embargo of 1973–74 (Office of the Historian 2013) and led to California's first state appliance efficiency standards in 1974. This led to initial national legislation, the Energy Policy and Conservation Act (EPCA), enacted in 1975 and amended in 1979. That law directed the US Department of Energy (DOE) to establish energy-conservation standards for consumer products. NAECA (NAECA 1987) established minimum efficiency standards for many consumer appliances. This was followed by the Energy Policy Act (EPAct) of 1992, which addressed lighting, plumbing, and many commercial products—and authorized DOE to extend its jurisdiction to other products. EPAct 2005 and the Energy Independence and Security Act (EISA) 2007 followed. Under these laws DOE has adopted processes for adopting and modifying its standards, which now cover more than 60 products (DOE undated).

Introduction to Ratings and Test Methods

Equipment and appliances of the 1970s were relatively simple compared with what is available, expected, or required four decades later. Consider the water heater: the residential test was developed exclusively for tank (storage) water heaters, whether atmospheric gas or resistance electric. During the development of the original test over 40 years ago, no one envisioned today's tankless water heater's prevalence in the US market, so the rating method

[1] The founders of energy efficiency remember an era before calculators, spreadsheets, and data-acquisition systems, when they did their physics problems with slide rules.

was not designed to compare the two technologies. As another example, older furnaces were low- to medium-efficiency, with atmospheric or induced draft. By contrast many of today's furnaces utilize condensing heat exchangers and modulating burners, constant-torque or constant-airflow motors, as well as various control technologies. Similarly almost all central air conditioners originally used a one-stage compressor (i.e., no modulation); however modern-day air conditioners are in the process of moving to two-speed and variable-speed compressors, and moving from less-efficient permanent split capacitor (PSC) motors in air handlers to more-efficient constant-torque or constant-airflow permanent magnet AC (PMAC) motors. Successive generations of foam-in-place insulation have replaced fiberglass batts in refrigerators and water heaters. All in all designers have reinvented the technologies and underlying manufacturing processes of many products, sometimes simultaneously improving efficiency and reducing prices (deLaski and Nadel 2013).

Is Efficiency Plateauing? If So, Why?

Consider a gas furnace. As a pure combustion appliance it cannot produce output energy (warm air) greater than the heat value of the input fuel.[2] In other words its efficiency cannot be greater than 100%. The federal metric, annual fuel utilization efficiency (AFUE), is roughly comparable to steady-state efficiency. Of the roughly 4,500 discrete models of non-weatherized (indoor) furnaces listed in the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) directory (AHRI 2016), increasing AFUE is strongly associated with a decline in the number of models listed, as table 1 shows.

Table 1. Number of non-weatherized natural gas furnace models per standard achieved

Rating range	# models	Standard achieved
80 ≤ AFUE < 90	2,450	US legal, non-condensing
90 ≤ AFUE < 95	476	ENERGY STAR® South States
95 ≤ AFUE < 97	1,392	ENERGY STAR North States
97 ≤ AFUE ≤ 100	220	ENERGY STAR Most Efficient

Almost half (46%) of today's product offerings (number of models) are at or above 90 AFUE (i.e., wasting 10% of input energy). Of the available product offerings 35% achieve an efficiency rating of 95 AFUE, meaning that they waste no more than 5% of the input fuel. Furnaces are asymptotically approaching maximum efficiency, in which units would capture all of the chemical energy of the fuel. In its regulatory analyses DOE designates the maximum technologically feasible (i.e., best) products *max-tech* (DOE 2015a). Even though many projected equipment prices are lower in the market than what DOE projects during the rulemaking cycle (deLaski and Nadel 2013), the trend is unmistakable: higher-efficiency

[2] For simplicity we ignored the electrical energy of the furnace fan and the controls. We also excluded the gas heat pump, which scavenges and concentrates energy from the ambient air.

products cost more to install.[3] For example, incremental costs for manufacturing and shipping are three times higher to move from SEER 21 to SEER 22 than to move from SEER 14 to SEER 15 (DOE 2006).[4] Based on SEER, expected energy savings from SEER 15 are 4.8%, but decrease to 2.2% for SEER 22 versus SEER 21. Thus three times the incremental cost to the consumer yields less than half the savings for this extreme example.

The same trends are observed for common air-conditioning products such as residential central air conditioners and heat pumps (DOE 2015a). As efficiency levels increase equipment cost reaches levels at which it would take longer to recoup the incremental purchase price from the anticipated savings than the expected product life, regardless of future electricity prices.[5]

Regardless of how an organization represents the metrics derived from these relatively simple model tests (i.e., current rating methods), these ratings will reach practical limits, as determined through engineering economics and shown in DOE's Technical Support Documents (TSDs) for each product rulemaking. Additionally, the Federal Trade Commission (FTC) forbids representations of product efficiency except by reference to performance on the federal rating method. With this constraint, as standards approach practical limits the market becomes increasingly compressed, and manufacturers struggle to differentiate the energy- and cost-saving benefits of premium products from the base-efficiency stock. A 97% AFUE gas furnace in a typical house in a cold climate will save only about $12 more per year than a 95% furnace (ENERGY STAR 2016), and hardly justifies the extra cost of better components such as substantially larger heat-exchanger surfaces.

What if there are ways to save substantial amounts of energy that are not reflected in the test? What if, for example, a dry-climate air conditioner could be tested with higher air flow (i.e., less ability to reduce humidity), so that it gave the same cooling effect with less energy? What if there are many other innovations that could also save energy but are excluded from the testing, and thus cannot be advertised as energy savings? Without effective marketing hooks, who would invest in such features? Our goal, stated differently, is to explore alternative rating methods that will cut this Gordian knot: the knot of regulations will ultimately stifle energy-saving innovation by commodifying the industry.

Alternatives for Saving More Energy

For thermodynamic and/or energy-economic reasons many products soon will approach practical limits for minimum energy efficiency standards. This leads to commodification, wherein minimum standards are so close to demonstrable maximum performance that customers are unwilling to pay even more for higher efficiency. This also discourages manufacturers from investing in innovations that would save energy. No matter how rich the opportunities to actually save energy, if these technologies *cannot* be reflected in marketing and sales, they are worthless

[3] See for example the record of the negotiated rulemaking for residential air conditioner and heat pump standards for these products (DOE 2015b). For furnaces see table 8.2.10 on pages 8–15 of the Furnace Technical Support Document (DOE 2015c).

[4] Data for blower coil units, comparing the respective cost differences between SEER 15 and SEER 14 ($41) and between SEER 22 and SEER 21 ($120), based on DOE TSD LCC chapter "Manufacturer Selling Price" (table 8.2.4) and "Transportation Cost" (table 8.2.9; $-0.30 versus $2.45). Following DOE we assumed that markups and installation costs do not vary with SEER.

[5] In this case the fuel cost can be extended to include maintenance, embodied energy, and externalities without changing the conceptual result.

to the manufacturer and its downstream customers and trade allies. In the United States the FTC limits efficiency claims to those that can be substantiated by the DOE testing methods, which limits paths to recognizing better products.

The US government has provided varied responses to this conundrum. In one example DOE sets different minimum efficiency standards in kilowatt-hours per year (kWh/yr) for 19 different classes of automatic-defrost refrigerator-freezers, depending on configuration (e.g., side-by-side, top-freezer, and so forth) and other features (e.g., ice-makers, automatic defrost, and so on), with a separate maximum annual energy consumption estimated by the test procedure for each (DOE 2011). For furnaces DOE now sets standards for gas consumption (AFUE), standby and off-mode power (i.e., kWh/yr), and furnace-fan efficiency, set to take effect in 2019 (DOE 2014a). Residential air conditioners have regional minimum energy efficiency standards and subclasses for some niche products (e.g., small-diameter, high-velocity ducted, smaller space-constrained units, and so on). In the case of air conditioners reduced fan power also contributes to higher SEER values. Measures like these increase testing burdens and save energy but rarely improve marketability.

It has not been possible to adapt the uniform national test procedure for optimal regional parameters, such as hot-dry performance. Air conditioners for the southwestern United States would work more efficiently with higher air flow and a warmer evaporator, as dehumidification is not important there. Conversely it would be technically challenging to develop a simple but representative test for higher latent-heat recovery, for use in hot-humid climates like the southeastern part of the country. It is not surprising that international perspectives on ratings, standards, and appliance labels vary (e.g., the Collaborative Labeling and Appliance Standards Program, or CLASP, of 2011). Some of these warrant consideration as alternatives to our proposal, but we will not consider them further in this study.

In the United States there has been movement toward rating *extended products*, which can be defined as systems whose components are usually provided by separate actors and generally have separate standards, but are typically installed as assemblies. Examples include fan systems and pump systems, which might include the fan or pump, the motor, and the motor drive (if applicable). For residential equipment an interesting parallel opportunity exists: the use of Quality Installation (ACCA 2015) and Quality Installation Verification (ACCA 2011). It is widely recognized that common installation practices degrade central air conditioner performance. Domanski et al. (2014) carried out a comprehensive simulation study. The calculated effects depend on climate, duct type, and fault type severity. Single duct sizing and leakage or refrigerant charge faults can increase energy consumption by more than 20%; reduced air flow by itself can increase energy use by >10%. It may be possible to define, utilize, and verify an equivalent SEER+ for equipment whose installation meets high performance standards.

Decoupling Compliance from Performance Claims

As established above, today compliance with MEPS (making a product legal to sell) and predicted field performance are based on the same laboratory rating method, which limits any significant technological advancement. At present AFUE 80 is the legal minimum rating for furnaces; a “premium-performance” AFUE 90 furnace performs 12.5% more efficiently than an

80% furnace.[6] It also uses 89% as much fuel.[7] However its premium performance is determined by the same test method as the minimum compliance rating, which cannot include any features outside the scope of the testing methodology no matter how much energy these features might save.[8] Limited testing protocols do not provide manufacturers with the ability to incorporate technologies to differentiate these higher-performance products, thus stifling innovation.

We propose an alternative that would decouple compliance (minimum energy performance) from verifiable field performance, which we will call *performance rating*. In every case compliance is traceable to a laboratory test, which is often augmented by simulations used to certify that products in the same basic model group also qualify for sale, as discussed below under "How to Test for Superior Performance." Ideally a single measurement would suffice, but more are required in many cases as we discuss below.

In contrast we would expect that performance ratings would almost always be based on simulations, which could be, for example, tied to regional climate conditions (very much like application ratings) and/or even specific building types.[9] In the simple case above available software (e.g., TANK, WATSIM, and WHAM; Lutz et al. 1998) might be acceptable to extrapolate for higher-efficiency products. Rating superior performance at various ambient or supply temperatures (application ratings) could be completed by simulations. We expect many challenges in attempting to transition to a new testing and rating system; however, if we continue down the current path, we will miss a significant opportunity to increase energy savings, encourage innovation in the energy industry, and more accurately estimate potential energy savings.

How to Test for Minimum Compliance

The minimum compliance rating would use steady-state testing to determine whether a product can legally be sold in the United States.[10] In the simplest case a single measure would suffice. This might be the case for a dehumidifier. Under given test conditions (i.e., specified temperature and humidity), we are interested only in the minimum weight (volume) of water that drains out per unit of electric energy dissipated, in grams (liters) per kWh. Many appliances require more than one parameter, each with its own test. For example, a gas-fired commercial water heater is rated with a minimum combustion efficiency and a minimum insulation quality (i.e., thermal decay).

In some cases the underlying technology paths differ enough that there are multiple approaches that yield the same energy consumption in the same application. We believe that very different designs may actually need different metrics.

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[6] (Premium-performance AFUE 90 / Legal minimum AFUE 80) - 1 = 12.5%.

[7] Legal minimum AFUE 80 / premium-performance AFUE 90 = 89%.

[8] We are describing an older rating method. Today we also certify stand-by and off-mode power (EISA 2007).

[9] Used today for large chillers.

[10] This may include regional variations depending on requirements by DOE.

How to Test for Superior Performance (Application Ratings)

Unlike the minimum compliance rating, application ratings rate equipment performance under conditions more relevant to the customer's use than standard ratings. Application ratings broadly speaking can provide more-realistic efficiency estimates for parameters that could include building type, climate zone, and usage patterns. These ratings account for energy-saving equipment features not captured by the steady-state minimum compliance tests, such as advanced controls functions in a central air-conditioning unit. These application ratings could be regional. In the end energy simulations of specific buildings as located and utilized would be possible.[11]

Through verifiable computer-simulation models, original equipment manufacturers (OEMs), third-party firms, or potentially heating, ventilation, and air-conditioning (HVAC) contractors could compute application ratings. DOE could be responsible for maintaining a library of base models, which the user would be able to adjust to meet the exact specifications for the installation of the equipment. Additionally, DOE or DOE-approved third-party certification bodies would be responsible for post hoc testing and validating simulation models, as an extension of the current AEDMs and alternative rating method (ARM) processes. At present DOE and voluntary industry certification programs could challenge any rating with appropriate penalties for noncompliance.[12]

Application ratings should not be expressed in terms of the MEP metric, as that implies standard test conditions. Instead the rating would indicate that the equipment performs a certain percentage better than a minimally compliant version. The language on the label and marketing materials might take the following form: "When properly installed in [location, climate zone, or any other relevant claim by OEM], this unit will use X% less energy than the legal minimum in a normal year." Alternatively it could express the claim as X% greater efficiency.

One example would be an air conditioner in a hot-dry climate, perhaps rated at 450 or 500 cfm/ton. The increased air flow over the evaporator would still provide sensible cooling, without cooling the evaporator enough to needlessly condense the low amounts of humidity in the air stream. Incremental fan power uses less energy than incremental compressor power, so the rating would most likely be higher.[13]

By rewarding creative solutions for equipment that minimizes wasted energy, this rating system encourages equipment designers to innovate. One possible example would be cold-climate heat pump water heaters (HPWHs) with additional features not accounted for in the compliance test. Such features might include a kind of dummy ductwork for exhausting chilled evaporator air, which could offer greater performance than the MEP test. Similarly certain models of HPWHs would likely display a higher application rating when a situation requires an

[11] In this case we are effectively using application ratings as inputs to a building energy model.

[12] "…if a manufacturer chooses to use an AEDM, it must make information available to DOE upon request for verification of the AEDM, including but not limited to: The mathematical model, complete test data, and the calculations used to determine efficiency. Additionally, if requested by DOE, a manufacturer must perform simulations, analysis, or unit testing to verify the AEDM." (DOE 2014b)

[13] Conversely an air conditioner in a hot-humid climate that was rated at a lower sensible heat ratio (more-humid air) would use more energy than in standard conditions, raising the issue of legal sales of air conditioners whose customer-facing application ratings would be lower than the MEP for the same product on the MEP test.

extended compressor operating range or other climate-sensitive features. The need has been recognized in the multitier northern-climate HPWH specification (NEEA 2013).

Given the freedom to factor in characteristics besides thermodynamics, equipment designers would have the opportunity to greatly improve equipment energy savings. Through (computed) application ratings, a sales representative can more easily differentiate (and help justify the cost of) the highest-performing equipment for a particular application, which will help better inform consumers and increase the sale of premium products.

Examples from Recent Experience

Residential Central Air Conditioners (CACs)

Residential CAC standards, set to take effect in January 2023, were developed through a negotiated rulemaking that addressed both rating methods and standards (ASRAC 2016). This recent action provides sufficient time to consider prior to the next rulemaking a new approach to ratings and standards, such as we propose. As noted previously, today central air conditioners are rated (and marketed) by SEER, the seasonal energy efficiency ratio. Heat pumps are rated by HSPF, the heating seasonal performance factor. Both are augmented by other mandatory performance metrics such as off-mode and standby power consumption. The seasonal metrics SEER and HSPF were chosen instead of the simpler steady-state alternatives, energy efficiency ratio (EER) and coefficient of performance (COP), respectively. SEER is a fairly effective descriptor of efficiency for conventional systems with fixed-capacity or two-speed compressors; high values require some combination of very good compressors, feedback controllers (e.g., thermostatic expansion valves or TXVs), and large (i.e., effective) heat exchangers.

SEER and HSPF both give reasonable relative rankings in average climates for fixed-capacity and two-speed equipment. In effect both emphasize performance at moderate temperatures, while EER focuses on a more extreme condition. Over the past decade or so the introduction of variable-capacity equipment has raised issues about the adequacy of these peak indicators and the seasonal metrics largely derived from them. So-called inverter air conditioners with variable-speed compressors have very high turndown ratios (perhaps a 4:1 capacity ratio). The inverter drive inherently dissipates some energy, slightly reducing the EER. However almost all operating hours are at less than full load. Because efficiency can increase for large heat exchangers under reduced loads, inverter air conditioners can deliver very high efficiency with smaller heat exchangers than the single-stage and two-speed designs. There have been additional complications with the rating method for inverter heat pumps, as the test procedure requires fixing the compressor speed artificially to run the test, which is a large deviation from field conditions.

In this case a level playing field might best be served by using a dual-path approach, such as that used for water-chilling packages (i.e., larger commercial products) in ASHRAE 90.1 (2013, table 6.8.1–3). This approach allows certification either with a higher full-load (FL) and slightly lower part-load (IPLV) value[14] or vice versa.[15] The former certification can be more

[14] Note that IPLV itself requires multiple measurements; it is the weighted average steady-state performance at four AHRI Standard 550/590 rating points.

[15] Take for instance the dual-path options for chillers from ASHRAE 2013. A 200-ton water-cooled centrifugal chiller can meet either 0.610 FL/0.550 IPLV (integrated part-load value) ratings or 0.635 FL/0.400 IPLV ratings.

easily met by variable-speed equipment, which performs better under part-load than a fixed-speed system, while the latter is appropriate for fixed-capacity equipment such as what is frequently employed in multi-chiller applications.

As important is the fact that climates vary enormously across the United States, and thus performance requirements vary also. The fixed rating conditions for SEER and HSPF, such as defined hours of operation in a given temperature bin and air flow by capacity (cfm/ton), do not allow climate-sensitive ratings. These could use higher flow rates in dry climates (reducing the ability to dehumidify, which is not needed) and lower flow rates in hot-humid climates. The workarounds used in the current regional standards mostly address this by requiring a specified EER for four hot-dry states in the Southwest.[16] Next-generation ratings could address these issues. However, in the form we present, adaptations to regional conditions may require separate regional product classes to be included in the MEP approach.

Commercial Air Conditioner and Heat Pump Rooftop Units (RTUs)

Historically the efficiency of rooftop units (RTUs), the dominant air conditioners and heat pumps for light to medium commercial buildings, was measured by peak efficiency through EER. With the increased market penetration of multi-compressor and variable-speed equipment, and recognition of the importance of part-load efficiency, AHRI changed its basic performance metric to IEER, or integrated energy efficiency ratio (AHRI 2007). In turn use of this measure has been incorporated into ASHRAE 90.1 (2013). Subsequently a DOE negotiated rulemaking determined revised minimum performance standards using IEER, which will go into effect in two phases, in 2018 and 2023 (ASRAC 2015). This two-step change is estimated to cumulatively save nearly 15 quadrillion Btus (quads) of energy (ASAP 2015).

Although this was the largest savings potential ever for a DOE rulemaking, it was still restricted to the metrics of the IEER test method, leaving out opportunities for further innovation and energy saving. Other opportunities to incorporate features not tested with the new rating method include regional approaches such as using the Cromer cycle (Cromer 2000), which contains enhanced dehumidification capabilities, or application ratings for dedicated outdoor air systems (DOAS).

In addition to missed opportunities to incorporate energy-saving advancements into products, the negotiation process can be a burden to manufacturers, who have incurred substantial costs to evaluate the effects on their product lines of the rating-method change and the coming rules.

Residential and Light-Commercial Water Heaters

Residential water heaters suffered for decades with a rating method that worked as intended only for tank (storage) water heaters larger than 20 gallons. The emergence of alternative technologies such as tankless or instantaneous water heaters required change, which stakeholders widely supported in concept. In practice developing the new rating method required completely changing the definition of capacity from volume to the amount of hot water that could be supplied in the first hour, to give a basis for comparison of alternative technologies. The

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Chiller efficiency is expressed in kW/ton, so lower numerical values represent an increase in efficiency (Trane 2015).

[16] California, Nevada, Arizona, and New Mexico (EERE 2016).

old draw pattern, containing 6 water uses of 10.3 gallons each at 3 gallons per minute (gpm), was replaced with four different capacity-based draw patterns. The rating condition was changed from average tank temperature to supply water temperature, with large effects on the test procedure.

DOE was well disposed to adopt the new method. Unfortunately the regulatory timetable required simultaneous consideration of the new test method and the new standards. This required adopting standards based on the old rating method, with the promise of a crosswalk to convert from the old standard to the new one in order to minimize retesting. Geometric and other factors slowed development of the crosswalk, leaving manufacturers uncertain about future design and testing burdens, a huge challenge for industry. The implication is that conversion to a new approach, such as our recommended decoupled method, requires choosing one or more products that have just adopted new standards so that they have a large enough time window to develop both new rating methods (if required) and new standards for MEP, verification of simulations for premium performance, and so forth.

We expect the new test method to be much more useful. However it still lacks a path to rating integrated appliances that provide both water and space heating.

Discussion

We have proposed the skeleton of an alternative to the present minimum-performance and equipment-rating system that would decouple the former from the latter and allow manufacturers to describe the savings attributable to features not included in minimum compliance testing. We urge serious consideration by all parties, as the current system is rapidly becoming obsolete—in ways that can harm the industry and depress innovation. Clearly other alternatives could achieve the same goals.

One obvious concern is how to address the verification of actual field performance, and existing (and future) technologies may be able to offer potential solutions. One proposal, from J. D. Lutz (2015), would use the Internet of Things (IoT) to require appliances to report the work they accomplish at site conditions, such as gas consumed per unit of energy supplied to the hot water drawn at the outlet from a water heater. This would be a field-verified energy-use system and could be coupled with enforcement. Of course, verification of performance requires verification of distributed software, which can be subject to gaming or illegal subterfuge.

Another possibility would be to provide a more data-rich environment, that is, a performance map for each piece of covered equipment. At first glance this may appear to be a huge increase in testing burden, but some variant (such as partial-audit testing) is likely to be needed for modeling the performance of component systems. This is the thrust of ASHRAE SPC 205 (ASHRAE 2012).

Achieving large changes to today's standards philosophy has many challenges. Attitudes characterized by fear, uncertainty, and inertia would have to give way to positive feelings about the potential benefits unleashed by change. Costs are uncertain, as are the effects on today's premium lines. There are fears around keeping the competitive market fair, as simulations can be uncertain and verification difficult.

There are also regulatory and legal issues, which may require legislation. Can the FTC recognize the energy-savings potential of premium features that achieve energy savings by measures not included in the test procedure? For example, will the minimum compliance level ratchet up and make for more-complex testing that will threaten to bring commodification? Or could some states, such as California, undertake enforcement themselves? Present law would preclude states from requiring premium features by legislation or building codes, but public benefits programs such as utility incentives could require specific levels (as they do now) or feature sets without change from present practice. Specifiers could benefit by providing products tailored for specific applications, with ways to show the premium performance to justify premium prices as well.

We recommend that this approach be evaluated for a product with a long lead time before the next standards rulemaking must be developed. Residential air conditioners and heat pumps would be obvious candidates, as the next standards are not to take effect until 2023. This allows enough time for the test procedure to be modified as needed, before the actual rulemaking begins.[17] It allows time to identify and work on possible critical paths, such as the development and validation of simulation packages for advanced features, and time for the equally important acceptance of these methods for marketing—an FTC responsibility. The available time also allows this conceptual proposal to be fleshed out and tested with simulations of the potential benefits of possible features added but not included in certification. This proposed evaluation would explore costs (including administrative costs), mechanisms, and benefits, in greater product differentiation to meet regional and other specific needs for various housing types.

Summary and Conclusions

We have established that the decades-old approach to appliance and equipment standards is obsolete. Because it relies on relatively simple and testable models of field performance, and because FTC regulations prohibit performance claims except as substantiated by ratings based on the federal metrics, there is little incentive for manufacturers to develop and market products that save energy in the field in ways that will not lead to better performance on the test. This inhibits innovation and leaves unrealized substantial savings potential through better equipment.

To circumvent these problems we propose to separate test methods for minimum legal performance from ways to rate premium products with advanced features, in order to stimulate innovation and achieve greater savings. Advanced features would be evaluated by verified simulation regimes. Because available software codes are satisfactory for equipment design and are used for certifying the performance of similar products offered by a manufacturer, we believe that there is no technical obstacle to this approach.

The work required to evaluate and move to such a bifurcated architecture is substantial. It should therefore be undertaken first for products that have recently finalized their next standards and thus have the largest time window before the next rulemakings commence. One such product class is residential central air conditioners and heat pumps.

If nothing else, at least once every quarter century it is worthwhile to go back to first principles and consider whether our rating methods are going to work as well as is feasible over the next decades, or whether change would potentially be beneficial enough to warrant the investigation of alternatives such as we propose.

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