Appliance Standards Awareness Project
American Council for an Energy-Efficient Economy
Natural Resources Defense Council

January 14, 2019

Mr. Daniel Simmons
Assistant Secretary
Energy Efficiency and Renewable Energy
U.S. Department of Energy
1000 Independence Ave. SW
Washington DC 20585-0121

Re: Test Procedure for Consumer Warm Air Furnaces Petition
Docket No. EERE-2018-BT-PET-0017

Dear Assistant Secretary Simmons:

This letter constitutes comments of the Appliance Standards Awareness Project, American Council for an Energy-Efficient Economy and Natural Resources Defense Council regarding AHRI's petition for rulemaking related to furnace and furnace fan test procedures and energy conservation standards published in the Federal Register on November 14, 2018.

We strongly oppose the petition and urge the Department to promptly reject it. We also urge the agency to immediately rescind the furnace fan enforcement policy statement published on November 2, 2018. We oppose the petition because the approach proposed would, if implemented:

- Increase consumers' costs and national energy waste:
  - Annual electricity bills for a large portion of furnace purchasers would go up by about $70 and total furnace lifecycle costs would be about $670 higher.
  - Total consumer costs nationally would go up by at least $3.9 to $11.4 billion;
  - National energy use would increase by at least 1.6 quads.
- Create product ratings that mislead consumers about the cost to operate furnaces.
- Undermine regulatory predictability.
- Violate federal law.

The approach proposed in AHRI's petition would cause these consumer cost and energy use increases because, for a large portion of the furnace market, it would effectively eliminate the duly-promulgated furnace fan standard issued nearly five years ago. Merging separate standards that save electricity and

gas into a single standard, as proposed, would cause further harm to consumers. These energy sources have very different costs, yet under the proposed approach improvements to either could yield equivalent efficiency ratings. Consumers would no longer be able to rely on the product ratings to predict relative operating costs.

In addition, the proposal undermines a hallmark of the national efficiency standards program: regulatory predictability. Furnace manufacturers and furnace fan component manufacturers that have made substantial investments to bring their product offerings into compliance would be unfairly undercut.

Not surprisingly, this proposal that harms consumers and undermines regulatory predictability would, if implemented, violate federal law in multiple ways. Furthermore, each of the rationales offered by AHRI in support of the petition are either grossly overstated or inaccurate.

We understand manufacturer concerns about having multiple rulemakings affecting furnaces on different schedules. However, DOE can align the rulemaking schedules and address test procedures and standards for furnace fuel efficiency, furnace fan efficiency and standby/off mode as part of consolidated future rulemakings. Alignment of the legally-required reviews of furnace-related test procedures and standards would reduce regulatory burden without harming consumers.

In the sections below, we provide greater detail on each of these points.

1. The proposal would increase consumer costs and national energy waste.

DOE's analysis conducted for the furnace fan rule completed in 2014 and the information provided in the AHRI petition show that the proposal in the petition would increase costs for many consumers and increase national energy waste. Under the furnace fan standard required by Congress and completed by DOE in 2014 after an extensive notice-and-comment rulemaking, all furnaces must meet minimum air movement efficiency standards, as measured by fan energy rating, FER. The furnace market is split roughly evenly between condensing and non-condensing products. All equipment, condensing or not, manufactured after July 3, 2019 must comply with the furnace fan standards. In the analysis for the furnace fans final rule, DOE estimated that absent a new standard, the furnace fans in 14% of non-condensing gas furnaces sold and 34% of condensing gas furnaces sold would meet the 2019 FER efficiency levels.[1] The majority of the remaining furnace fans would need to switch from permanent split capacitor (PSC) motors to brushless permanent magnet (BPM) motors (and also likely incorporate multi-stage controls) in order to meet the 2019 standards.

With AHRI's proposed AFUE2 metric, **all condensing furnaces could meet the new AFUE2 standard without making any improvement in furnace fan efficiency (or any other efficiency improvement)**. As shown in Figure 1, the example calculations submitted by AHRI for 140 furnace models[2] show that the AFUE2 metric provides a significant separation between non-condensing and condensing furnaces. (We show below that this separation in many cases does not reflect either full-fuel-cycle energy use or consumer energy costs.) The most-efficient non-condensing furnace as rated by the AFUE2 metric has

[1] https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111. pp. 8-31, 8-34. The 2019 FER levels are equivalent to CSL 4.

[2] https://www.regulations.gov/document?D=EERE-2018-BT-PET-0017-0002. "AHRI AFUE2 Petition Exhibit 2 (Example Calculations) _101218."

an AFUE2 rating of 80%, while the least-efficient condensing furnace (which is single-stage and has a PSC motor) has an AFUE2 rating of 87%. Presumably a "crosswalk" to AFUE2 as AHRI has proposed would result in a minimum AFUE2 standard of no greater than 80%. With an AFUE2 standard of 80%, all condensing furnaces would easily meet the standard, including those with inefficient furnace fans with PSC motors.

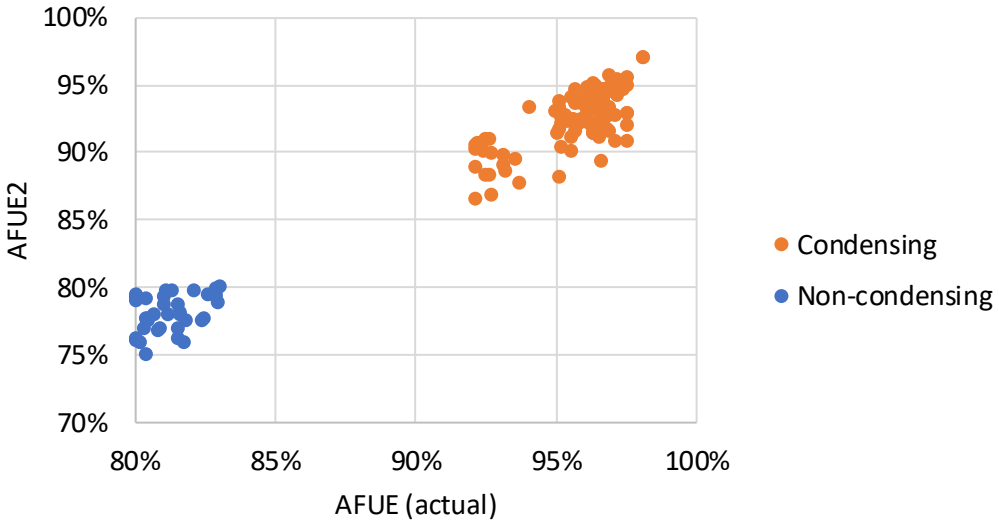

Figure 1. AFUE2 values for non-condensing and condensing gas furnaces. *Source*: Exhibit 2 of the AHRI petition.

The proposed crosswalk would harm individual consumers. DOE estimated that condensing furnaces with fans compliant with the FER standards would cut electricity use by about 50%, yielding 532 kWh per year in savings.[3] At national average electricity prices, those savings are worth about $70 per year. Considering the additional upfront cost of the more-efficient fan and the time value of money, condensing furnace buyers would save about $670 over the life of their furnace relative to a product with a baseline fan.[4] Consumers would lose all these savings with AHRI's proposal since it would effectively eliminate the furnace fan standard for condensing furnaces.

On a national level, DOE estimated that the furnace fan standard for condensing furnaces will save 1.6 quads of energy with net present value savings to consumers of $3.9 to $11.4 billion.[5] All these savings would be lost with AHRI's proposal.

[3] https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111. p. 7-25.
[4] DOE's final rule summary reported average lifecycle savings of $341 for condensing furnace buyers (79 Fed Reg 38131), but that estimate averages in zero savings for consumers who DOE predicts would buy furnaces with efficient fans even absent the standard. Average lifetime savings for consumers relative to the baseline efficiency level is shown elsewhere in the final rule. Table V.3 shows a baseline lifecycle cost of $2,478 and lifecycle cost at the selected standards level of TSL 4 of $1,812 (79 Fed Reg 38185).
[5] 79 Fed. Reg. 38192-94. Tables V.19, V.21. The 2019 FER levels are equivalent to TSL 4.

2. The proposal would create misleading ratings.

The Federal Trade Commission (FTC) uses the existing AFUE metric on the Energy Guide label to show the fuel efficiency for a given furnace, and manufacturers must use the metric in making representations regarding fuel use. Electricity consumption and costs are not reported on the Energy Guide label today, but manufacturers must use the FER metric in making any representations of electricity use for air circulation. These metrics provide clear information on the fuel efficiency and electrical efficiency of furnaces, respectively, enabling fair comparisons among products. In contrast, **combining gas and electricity use into a single metric, AFUE2, would make it impossible for consumers to understand the relative operating costs of different furnaces**, and total primary energy use would also be obscured. Two furnaces with the same AFUE2 rating, one with a higher combustion efficiency and the other with a higher electrical efficiency, could consume significantly different amounts of energy on a primary energy basis and have significantly different energy costs for consumers. As we show below, a unit with a higher (better) AFUE2 than another could cost **more** to operate.

These problems occur because the AFUE2 metric combines direct fuel use (gas or oil) with electricity use based on site energy. For gas and oil, primary energy use (or full-fuel-cycle energy use) is similar in magnitude to site energy use, while for electricity, primary energy use is roughly two to three times greater than site energy use due to losses in generation, transmission and distribution. Furthermore, on a per MMBtu basis, electricity is significantly more expensive than gas and oil. The AFUE2 metric thus significantly undervalues both the primary energy savings and the consumer cost savings from reducing electricity use. AFUE2 would incentivize manufacturers to optimize their designs to reduce site energy use, rather than consumer operating costs or total primary energy use.

Figures 2-4 show the breakdown of total site energy use, total full-fuel-cycle energy use,[6] and total energy cost,[7] respectively, for eight representative gas furnace models. The eight models represent combinations of four different AFUE levels (80%, 92%, 95% and 98%) and two furnace fan technologies (a baseline PSC motor, and a constant-torque BPM motor with multi-stage controls). The total energy use and energy cost include contributions from direct fuel use, standby electricity use, furnace fan electricity use, and additional fuel use for models with BPM motors (which give off less waste heat) based on DOE analysis for the 2016 furnaces SNOPR and the 2014 furnace fans final rule.[8]

As shown in Figure 2, on a site energy basis, furnace fan electricity represents between 4% and 10% of total energy use for a gas furnace. However, on a full-fuel-cycle basis, as shown in Figure 3, furnace fan electricity represents between 9% and 21% of total energy use. As shown in Figure 4, furnace fan electricity represents up to 27% of total consumer energy costs. Importantly, Figures 2-4 also show that site energy use does not provide an accurate relative ranking of furnace models when looking at either full-fuel-cycle energy use or consumer energy costs. On a site energy basis, as shown in Figure 2, energy use decreases monotonically going from Unit #1 to Unit #8. The AFUE2 metric, as a measure of site

[6] Full-fuel-cycle energy use includes energy consumed in extracting, processing, and transporting or distributing primary fuels. We use full-fuel-cycle multipliers of 1.045 and 1.123 for electricity and gas, respectively. We assume a heat rate of 9,000 Btu/h to convert site electricity to primary energy.
[7] We use 2017 national average electricity and gas prices of $0.1289/kWh and $10.52/MMBtu, respectively.
[8] https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217, pp. 7-12, 7-13; https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111, p. 7-25. We assume a standby power of 8.5 W.

energy use, would show the same relationship among models, with AFUE2 increasing going from Unit #1 to Unit #8 as site energy use decreases. (Figure A1 in the Appendix shows this relationship between site energy use and AFUE2.) However, the relative rankings change significantly when looking at either full-fuel-cycle energy use or energy cost as shown in Figures 3 and 4.

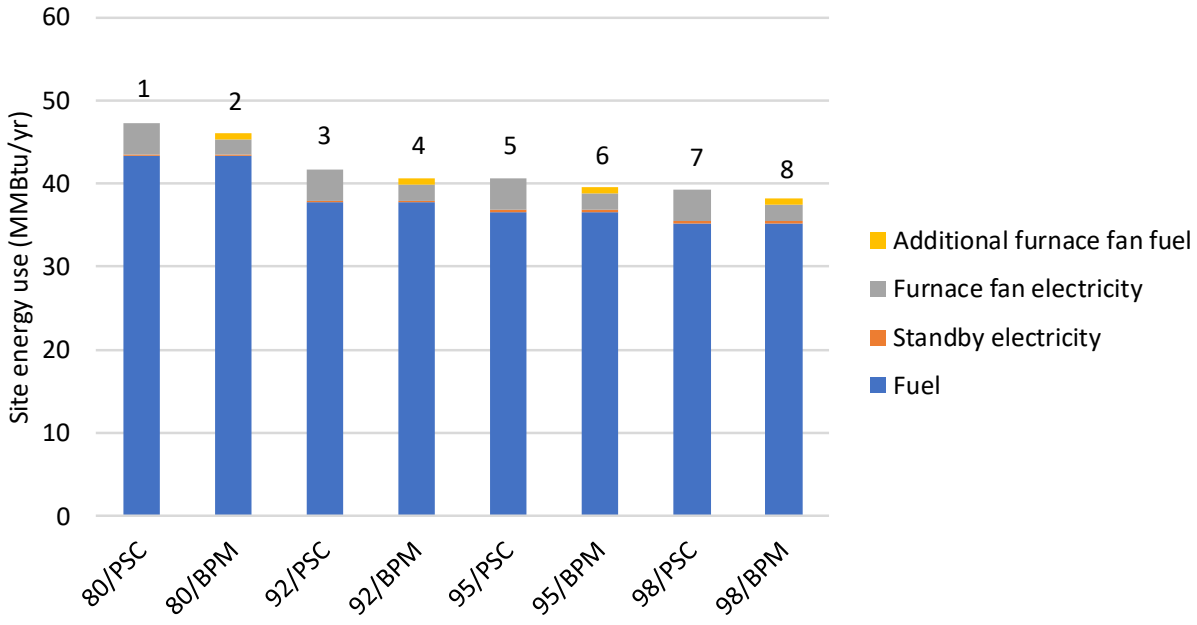

Figure 2. Breakdown of total site energy use

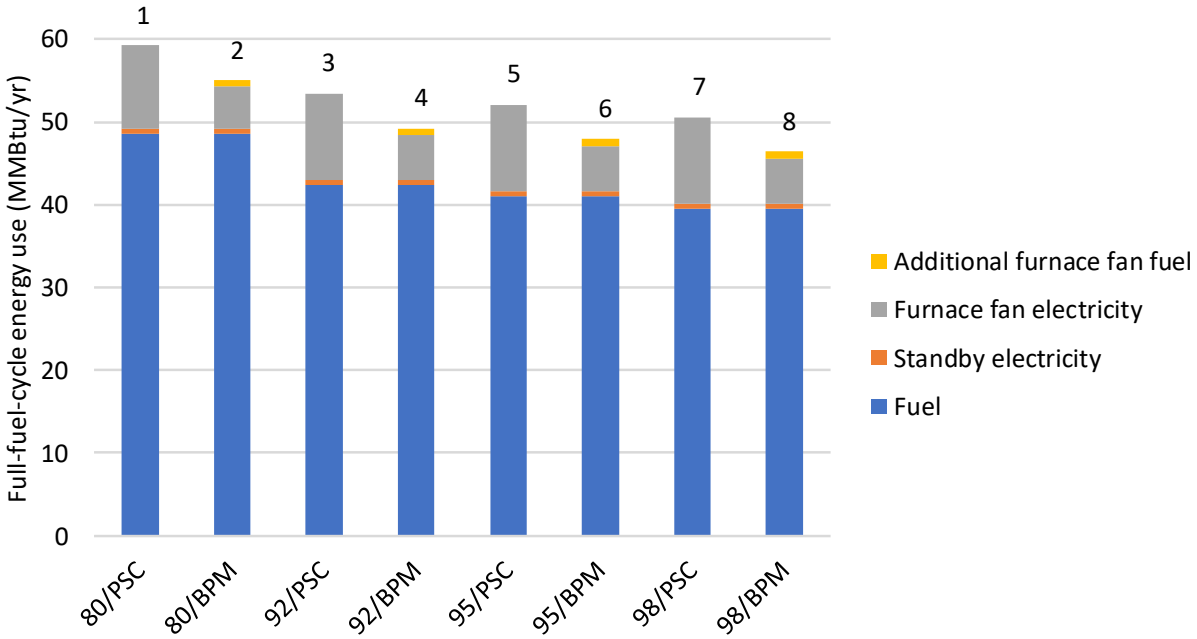

Figure 3. Breakdown of total full-fuel-cycle energy use

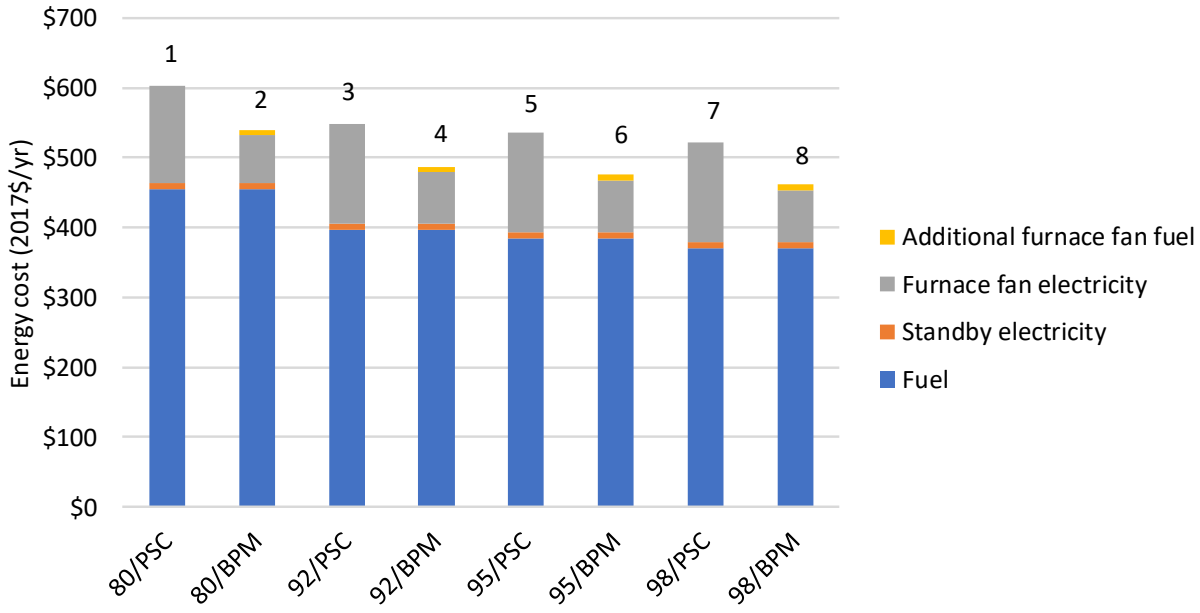

Figure 4. Breakdown of total consumer energy costs

A metric based on site energy use, such as AFUE2, will thus provide misleading information about both full-fuel-cycle energy use and consumer energy costs. For example, Unit #4 consumes essentially the same amount of total site energy as Unit #5, so the two units would have essentially the same AFUE2 ratings. However, on a full-fuel-cycle basis, Unit #5 consumes 6% more energy, and total consumer energy costs are 10% greater for Unit #5. These differences in consumer operating costs and total energy use would be masked by the AFUE2 ratings. Unit #5 would cost about $50 more per year to operate yet have the same AFUE2 rating as Unit #4.

As another example, Unit #3 uses 9% less energy on a site basis than Unit #2, so Unit #3 would have a significantly better AFUE2 rating. However, on a full-fuel-cycle basis Unit #3 uses just 3% less energy than Unit #2, and the energy cost to operate Unit #3 is *greater* than the cost to operate Unit #2. Unit #3, which would have a significantly higher AFUE2 rating, would cost about $10 more per year to operate. In this example, the AFUE2 ratings would suggest that Unit #3 would save a consumer a significant amount of money in energy costs, while in fact the consumer would end up paying more. (The Appendix provides details on our calculations for these comparisons.)

3. **The proposal undermines regulatory predictability.**

Regulatory predictability is a fundamental feature of the national appliance standards law. The law provides for rules that are developed through a thorough regulatory process subject to judicial review and followed by multi-year periods between rule issuance and compliance dates. In general, state standards are preempted. Manufacturers of regulated equipment and the components used in that equipment are the primary beneficiaries of this predictability: they can plan investments over time with full knowledge of the future regulatory landscape.

DOE's decision to grant AHRI's request for non-enforcement of the furnace fan standard and the AHRI petition, if implemented, both undermine this regulatory predictability. With the non-enforcement policy, DOE has abdicated its legal obligation to enforce the furnace fan standard, duly promulgated in 2014 with compliance required as of July 3, 2019, for all furnaces. As shown above, eventual implementation of the AFUE2 proposal would be equivalent to removal of the furnace fan standards for about half of furnace sales.

The non-enforcement policy, if continued, and the AFUE2 metric, if adopted, would strand the investments that furnace fan component manufacturers and furnace manufacturers have already made towards FER compliance. Furnace fan component manufacturers have invested in designs, plants and equipment to provide efficient components for compliant furnace fans. In addition, with the FER compliance date just a few months away, we expect that most, if not all, furnace manufacturers have already made much of the investments needed to comply with the FER standard. Manufacturers that have relied on the predictability of the national appliance standards program should not have the rug pulled out from under them at the last hour. Doing so would harm those manufacturers who have planned and invested and advantage those that have not.

More broadly, if the non-enforcement policy remains in place it conveys to all manufacturers and component makers that they can longer have confidence in the applicability of appliance standards contained in the US Code of Federal Regulations. If DOE can simply decree non-enforcement of the full breadth of a duly-promulgated standard, then manufacturers will be forced to wait and see if DOE actually applies existing standards. Some might choose to bet on persuading the agency to forgo enforcement, while others plan to comply. With this policy, DOE has created regulatory uncertainty where there was none. Regulatory uncertainty increases manufacturer costs, which ultimately are borne, at least in part, by consumers.

4. The proposal violates the law.

Not surprisingly, an enforcement policy and a proposal that would cause the substantial harms described above violates federal law. Separate comments filed by Earthjustice and National Consumer Law Center and Consumer Federation of America ("Consumer Groups") in this docket detail the multiple ways in which implementing the actions proposed by AHRI's petition would violate the law. Specifically, the AFUE2 proposal, if implemented would:

- Violate the law's specific directive for DOE to set air circulation efficiency standards for furnaces, as properly carried out by DOE in the process that culminated in the 2014 final rule;
- Illegally combine that required standard with another for fuel use;
- Violate the law's anti-backsliding provision;
- Improperly use the statutory provision for adjusting a particular standard due to a test method change for merging existing standards; and
- Adopt an approach for standby and off mode that the Department has found, based on a notice and comment rulemaking, is not technically feasible.

The agency's non-enforcement policy, already adopted without any public process whatsoever, violates the anti-backsliding provision of the appliance standards law, among other legal deficiencies.

We support and join in the detailed comments filed by Earthjustice and the Consumer Groups.

5. AHRI's rationales for AFUE2 are inaccurate and over-stated.

AHRI claims in the petition that the merged metric will be easier for consumers to understand, increase innovation and reduce manufacturer costs. Each of these arguments is either incorrect or grossly over-stated.

Section 2 in these comments shows how a merged metric would make furnace ratings unreliable for predicting operating costs. AFUE2 may appear simpler because it is just one number, but it would be a single number that masks operating cost differences. An "easy-to-understand" metric that yields inaccurate operating cost comparisons harms consumers.

AHRI's claim of substantial manufacturer cost savings is grossly overstated. The largest component of the cost savings claim appears to assume that no future merged metric standard will ever result in improvements to furnace fans or standby and off mode. Since future standards, even for a merged metric, must maximize technologically feasible and economically justified efficiency improvements, an assumption of no further improvements to fan or standby and off mode efficiency is not realistic. But, AHRI appears to assume that, absent a merged metric, there would be five improvements to the furnace fan standards and six to the standby and off mode standards over the next thirty years and each would incur the same conversion costs as the initial standards adopted. In other words, with a merged standard, AHRI assumes no further improvements and no costs: with separate metrics they assume substantial costs. AHRI does not explain why none of the improvements they assume would be justified with separate metrics would be justified with a combined metric.

Furthermore, the assumption that all future standards will have the same conversion costs as the first is unrealistic. Any future improvement to the furnace fan standard cannot be as far-reaching as the first because the initial standard cut baseline furnace fan electricity use by about half. Similarly-sized absolute savings cannot be achieved again. More modest savings from potential future standards most likely imply lower investment costs for manufacturers. Furthermore, under the law, the benefits of any improved standard must outweigh the costs. If not, DOE must leave the standard unchanged.[9]

AHRI claims further cost savings due to reduced testing burden. The petition does not clearly explain why testing time, and therefore testing costs, would be reduced with AFUE2. The petition claims savings from "conducting one test," but also states that three tests would need to be conducted that separately measure fuel consumption, standby/off mode electricity use and ventilation (furnace fan) electricity use. It appears that AHRI's cost savings assumption derives from doing the three tests at the same time. This same outcome can be achieved by aligning rulemaking schedules and compliance dates without merging the metrics. To the extent that some of the cost savings derive from changes to how the individual tests are conducted, these savings are unrelated to merging the metrics.

[9] AHRI's assumption of a new standard every six years is also incorrect. Federal law requires DOE to review each standard every six years and either issue a proposed change or a determination not to change the standard. If DOE proposes a change, a revised standard is due two years later.

Similarly, AHRI claims substantial savings from cutting the number of DOE regulatory proceedings over thirty years in which manufacturers would need to participate. Some rulemakings are already combined (e.g. the gas furnace and standby/off mode are being considering in a single rulemaking). As we describe below, DOE could consolidate future rulemakings. Adopting AFUE2 is not necessary to achieve that regulatory efficiency.

AHRI's third rationale for AFUE2 is a claim that the proposal will increase innovation. Yet AHRI offers no supporting evidence. Rather, the petition merely asserts that allowing for trade-offs between gas and electrical efficiency is inherently helpful for innovation. As we have shown above, an effect of the proposed AFUE2 approach would be to allow manufacturers to *avoid* using innovative air movement efficiency designs in a large portion of their offerings. No innovation would be sparked simply by combining the metrics.

On the other hand, the FER standard issued in 2014 did spark significant innovations, not just in furnace fan efficiency, but in other product features. Motor manufacturers have invested substantially in new designs that will save consumers money and improve performance. Some improvements go beyond those needed to meet the standards. A major manufacturer, Regal Beloit Corporation, described how the FER standard created an "innovation window." According to the manufacturer, prior to the FER rule, furnace fans and motors were effectively "closed to much innovation" largely due to the challenge of retrofitting existing HVAC designs. The FER standard "kick-started innovative thinking," not just for efficiency, but comprehensively.

> By evaluating the complete line against the FER requirements, our engineers realized they were in an unusual situation: they had the "hood up" on every motor they build. They were already designing for the next generation. As long as they were innovating across the board, they had another opportunity to design for the future, engineering for the Internet of Things (IoT).[10]

In other words, the FER standard has sparked product innovations that not only save consumers money on their electricity bills, but also innovations that can lead to "substantial increases in reliability and productivity, reduce the need for hands-on maintenance, and expand automated command and control."[11] Regal is not the first manufacturer to acknowledge that new standards create such an innovation window. Rigorous academic work has shown that when manufacturers make investments to comply with new standards, they seize the opportunity to make other improvements to their production processes and products.[12]

In sum, each of the rationales offered by AHRI in support of the petition are either overstated or inaccurate: the proposal would harm consumers, manufacturer cost reductions are grossly overstated, and the proposal would reduce innovations that improve furnace fan efficiency.

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[10] Dey, Deep. "The Innovation Window: How FER Compliance Connected Fan Motors to the Internet of Things: New government regulation can be a kick-starter for comprehensive innovations." Appliance Design. October 8, 2018. https://www.appliancedesign.com/articles/96010-the-innovation-window-how-fer-compliance-connected-fan-motors-to-the-internet-of-things.

[11] Ibid.

[12] See for example A. Brucal and M. Roberts, "Do Energy-Efficiency Standards Hurt Consumers? Evidence from Household Appliance Sales." March 2017. London School of Economics. Also see M. Taylor, C.A. Spurlock and H.C. Yang. "Confronting Regulatory Cost and Quality Expectations: AN Exploration of Technical Change in Minimum Efficiency Performance Standards." October 2015. Resources for the Future.

6. DOE can align rulemaking schedules without merging metrics.

We agree that concurrent review of all furnace-related standards and, separately, all furnace-related test procedures would make sense. Concurrent reviews, conducted as part of consolidated regulatory proceedings, would reduce time spent on DOE rulemakings. Any changes to furnace-related metrics or standards would be made at the same time, allowing manufacturers to make design, manufacturing and marketing changes once in response to a set of regulatory changes. We believe rulemakings can be consolidated without sacrificing consumer benefits or falling further out of compliance with statutory deadlines. Importantly, doing the reviews at the same time in a single proceeding does not require merging the three metrics into a single value.

Currently, the standards rulemakings for two of the three metrics are already combined. For non-weatherized gas furnaces, DOE is evaluating revised AFUE standards and initial standards for standby and off mode as part of the ongoing furnace rulemaking (81 Fed Reg 65720).[13] The next review for furnace fans is due in 2020. DOE could consolidate that review with the ongoing rulemaking covering fuel efficiency and standby/off mode.

The same approach could be taken for the test procedures: the next AFUE review is due in 2023, the next FER review is due in 2021 and the standby/off mode review in 2020. These reviews could be consolidated by DOE into a single review completed in 2020.

DOE has previously combined multiple products into a single rulemaking to reduce the time and cost needed to participate in DOE rulemakings.[14] A rulemaking that evaluates all three metrics at the same time may offer an opportunity to consider approaches that allow tradeoffs without the negative effects on consumers and energy use that AFUE2 would cause. Evaluating the standards together would enable DOE to focus resources on the largest economic and energy savings opportunities, consider the total impact on manufacturers and consumers, and select standards that best meet the statutory criteria. Once consolidated into a single proceeding, future test procedure and standards reviews will come due at the same time.

Summary

AFUE2, if implemented, would increase costs for many consumers, add to energy waste and create product ratings that prevent consumers from making accurate operating cost comparisons among

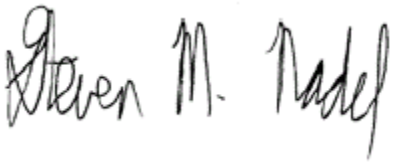
[13] AHRI incorrectly asserts in their petition that "Each of the six applicable regulations follows a different schedule" (83 Fed Reg 56749). To support this claim, they refer to a 2013 final rule for standby/off mode but do not provide a citation. The CFR does not currently contain any standby/off mode standards for non-weatherized gas furnaces. Oil-fired and electric furnaces do have standby/off mode standards, established by rule in 2011. (That rule also established revised standards for non-weatherized gas furnaces, but that part of the rule was vacated in a court decision.) Presumably, DOE will review the standby/off mode standards for oil-fired and electric furnaces when it next reviews AFUE requirements for those products. That review appears to be overdue.

[14] For example, DOE combined work on standards for clothes dryers and room air-conditioners in a single rulemaking (76 Fed Reg 22454) and addressed updates for several standards affecting lighting manufacturers in two consecutive rulemaking (74 Fed Reg 34080 and 80 Fed Reg 4042).

their furnace choices. DOE's non-enforcement policy and the AFUE2 proposal both create substantial regulatory uncertainty, harming businesses that have already invested with the expectation that DOE will maintain and enforce duly-promulgated standards. Any regulatory efficiencies that can be achieved by combining reviews of existing standards and test procedures into consolidated rulemakings do not require merging of the metrics. Finally, failure to enforce existing standards and/or implementation of the AFUE2 metric would violate federal law. For these reasons, we urge DOE to promptly reject AHRI's petition and rescind its non-enforcement policy.

Sincerely,

Andrew deLaski
Executive Director
Appliance Standards Awareness Project



Steve Nadel
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Contact: Please direct any questions regarding these comments to Andrew deLaski at adelaski@standardsASAP.org or 617-390-5334

About the signatories:

The Appliance Standards Awareness Project (ASAP) is a coalition with representation from energy and water efficiency, environmental and consumer advocacy groups, utilities and state government that works to advance cost-effective appliance, equipment and lighting standards that deliver large energy and water, monetary and environmental benefits. www.standardsASAP.org

The American Council for an Energy-Efficient Economy (ACEEE), a nonprofit, 501(c)(3) organization, acts as a catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviors. www.aceee.org

The Natural Resources Defense Council (NRDC) is a not-for-profit advocacy organization that works to safeguard the earth—its people, its plants and animals, and the natural systems on which all life depends. www.nrdc.org

Appendix

Table A1 shows the eight representative furnace models we analyzed to compare site energy use to full-fuel-cycle energy use and consumer energy costs. Table A2 shows our assumptions for calculating site energy use for each representative unit, and Tables A3 and A4 show the full-fuel-cycle energy use and energy costs, respectively, for each unit.

Table A1. Representative furnace models

Unit number	Furnace efficiency (AFUE)	Furnace fan technology
1	80	Baseline PSC
2		Constant-torque BPM motor + multi-stage
3	92	Baseline PSC
4		Constant-torque BPM motor + multi-stage
5	95	Baseline PSC
6		Constant-torque BPM motor + multi-stage
7	98	Baseline PSC
8		Constant-torque BPM motor + multi-stage

Table A2. Site energy use for each representative furnace model

Unit number	Annual fuel use (MMBtu/yr)	Annual standby electricity use		Annual furnace fan electricity use		Annual furnace fan additional fuel use (MMBtu/yr)	Total energy use (MMBtu/yr)
		kWh/yr	MMBtu/yr	kWh/yr	MMBtu/yr		
1	43.3	63	0.2	1,080	3.7	--	47.2
2	43.3	63	0.2	537	1.8	0.7	46.0
3	37.7	63	0.2	1,110	3.8	--	41.7
4	37.7	63	0.2	578	2.0	0.8	40.7
5	36.6	63	0.2	1,110	3.8	--	40.6
6	36.6	63	0.2	578	2.0	0.8	39.6
7	35.2	63	0.2	1,110	3.8	--	39.2
8	35.2	63	0.2	578	2.0	0.8	38.2

Sources: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217, pp. 7-12, 7-13; https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111, p. 7-25.
Note: We assume a standby power of 8.5 W.

Table A3. Full-fuel-cycle energy use for each representative furnace model

Unit number	Annual fuel use (MMBtu/yr)	Annual standby electricity use (MMBtu/yr)	Annual furnace fan electricity use (MMBtu/yr)	Annual furnace fan additional fuel use (MMBtu/yr)	Total energy use (MMBtu/yr)
1	48.6	0.6	10.2	--	59.4
2	48.6	0.6	5.1	0.7	55.0
3	42.3	0.6	10.4	--	53.4
4	42.3	0.6	5.4	0.9	49.2
5	41.1	0.6	10.4	--	52.1
6	41.1	0.6	5.4	0.9	48.0
7	39.5	0.6	10.4	--	50.6
8	39.5	0.6	5.4	0.9	46.4

Notes: We use full-fuel-cycle energy multipliers of 1.045 and 1.123 for electricity and gas, respectively, based on DOE's analysis for the 2016 furnaces SNOPR. We assume a heat rate of 9,000 Btu/h to convert site electricity to primary energy.

Table A4. Energy cost for each representative furnace model

Unit number	Fuel cost (2017$)	Standby electricity cost (2017$)	Furnace fan electricity cost (2017$)	Furnace fan additional fuel cost (2017$)	Total cost (2017$)
1	$456	$8	$139	--	$603
2	$456	$8	$69	$7	$540
3	$397	$8	$143	--	$548
4	$397	$8	$75	$8	$487
5	$385	$8	$143	--	$536
6	$385	$8	$75	$8	$476
7	$370	$8	$143	--	$522
8	$370	$8	$75	$8	$461

Note: We use 2017 national average electricity and gas prices of $0.1289/kWh and $10.52/MMBtu, respectively.

Figure A1 shows the relationship between site energy use and AFUE2 for the eight representative furnace models. The values for AFUE2 are based on the example calculations provided by AHRI.[15]

[15] AFUE2 for Unit #1 is the average AFUE2 of the non-condensing models with PSC motors. AFUE2 for Unit #2 is the average AFUE2 of the non-condensing models with constant-torque BPM motors. For Units #3, #5, and #7, the AFUE2 values are based on a linear regression of the condensing models with PSC motors. Finally, the AFUE2 values for Units #4, #6, and #8 are based on a linear regression of the condensing models with constant-torque BPM motors.

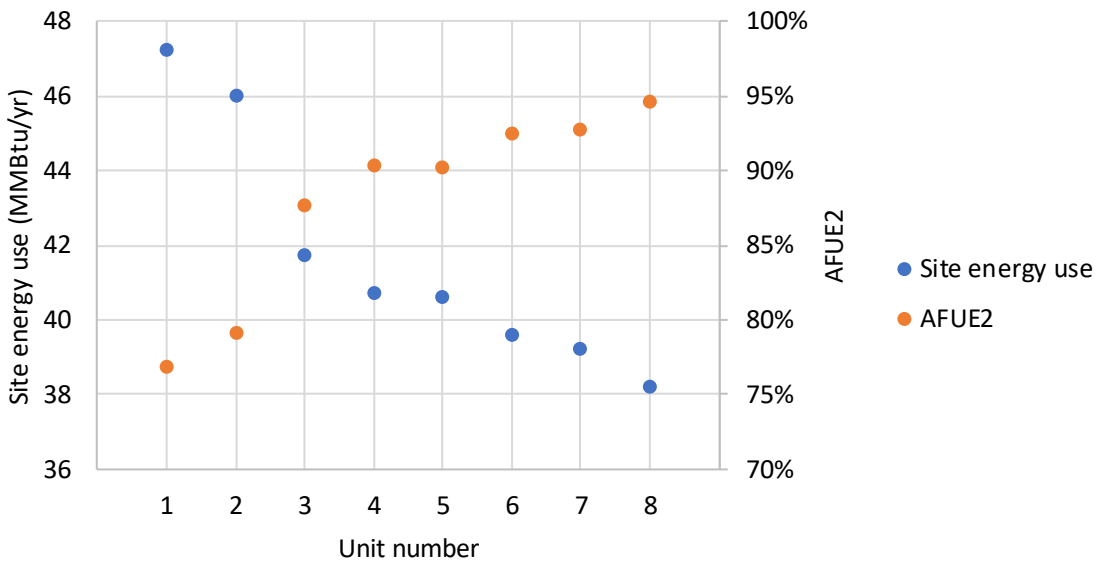

Figure A1. Relationship between site energy use and AFUE2