# Review and Analysis of Equipment Trade-offs in Residential Energy Codes

## Executive Summary

This report examines the homeowner energy cost impacts of reinstating equipment trade-offs, as proposed by the National Association of Homebuilders (NAHB) in RE166-13 for the residential energy chapter of the 2015 IECC. Such trade-offs would allow the installation of less-efficient windows, reduced insulation levels, or increased infiltration in exchange for installing more efficient heating, cooling, or water heating systems. The ICC's Governmental Member Voting Representatives removed these trade-offs from the 2009 IECC, and reaffirmed their removal in 2012. Since that time, most states have adopted the 2009 or 2012 editions of the IECC and rejected efforts to reinstate equipment trade-offs. The elimination of these trade-offs was based on the recognition that they weaken the energy efficiency of new buildings, both initially and over the life of the home.

### Including Equipment Trade-Offs Would Significantly Weaken the IECC

This analysis shows that the equipment trade-offs proposed in RE166-13 would increase homeowner energy bills significantly. They would reduce the energy savings the IECC is intended to produce in two ways (both of which were identified by the U.S. Department of Energy (DOE) in its statutorily-mandated determination[1] on the 2009 IECC):

1. **Free ridership effect:** Because high-efficiency equipment is already widely used in the residential construction market,[2] there is substantial free ridership[3] potential from permitting equipment trade-offs. Adding equipment trade-offs in the 2015 IECC would allow the weakening of building envelopes based on unwarranted trade-off credit for equipment *that is being installed anyway*.

2. **Balance of lifecycle energy waste:** The IECC's stated intent is to save energy "over the useful life of the building" (see 2012 IECC Section R101.3). A lifecycle analysis of equipment trade-offs therefore requires that the differential lifetimes of equipment vs. envelope technologies be taken into account. But the performance compliance trade-off method in the IECC only considers energy use for the first year of operation. Heating, cooling or water heating equipment typically lasts between 10 and 20 years while envelope measures typically last 30-50 years or more. When the original equipment is replaced, homeowners would be expected to install new equipment at the efficiency levels prevailing at that time, but the "trade-off" home would have a weaker envelope than the 2012 IECC-compliant home. So while a home using equipment trade-offs might show equivalent first-year energy costs, its weaker envelope will increase energy bills over the life of the building.

### The IECC Without Equipment Trade-offs is Critical to Long-Term Energy Savings

The effects of energy wasted by free ridership and lifecycle impacts would be substantial over the long lives of today's homes, and would significantly erode the energy efficiency gains that the IECC process has achieved since 2006. This analysis shows that trading off the commonly installed 90+ AFUE furnace for weaker envelope efficiency, in the high proportion of homes where such furnaces are installed anyway, would by itself increase national-average homeowner energy costs by 6% to 9% for gas heated homes, depending on the furnace efficiency selected.[4] On a national level, the table below shows that the 30-year present value of

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[1] See Appendix K for language from DOE determination of the 2009 IECC.
[2] 90+ AFUE gas furnaces account for half of all units sold in recent years, and a higher percentage in colder states.
[3] Free ridership is defined as giving policy or program credit for actions that would have occurred without the policy or program.
[4] See Appendix J for impacts for each equipment type and efficiency level.

higher homeowner energy bills from trading-off a 90 AFUE furnace for a weaker envelope would be about $400 million.

**Energy Cost Impacts of Permitting AFUE 90 Furnace Trade-offs**

| | Years 1-20 Free Ridership | Years 21-30 Balance-of-Lifecycle | 30 Year Total |
|---|---|---|---|
| Energy Cost Impact ($) | $335,285,848 | $167,642,924 | $502,928,772 |
| Energy Cost Impact - Present Value ($) | $292,431,744 | $102,818,134 | **$395,249,878** |
| Carbon Impact (MTCO2e) | 1,642,497 | 821,248 | 2,463,745 |
| Natural Gas Impact (Therms) | 308,691,672 | 154,345,836 | 463,037,508 |

While $400 million in higher energy bills sounds like a lot of money, it represents the impacts for only a single average year of housing starts. If such trade-offs continued for just one 3-year code cycle, homeowners could be saddled with more than $1.1 billion in needlessly-high energy bills.

Beyond the commonly installed 90 AFUE gas furnace, if builders used a wider range of trade-offs for higher efficiency heating equipment, air conditioners, and water heaters, this could increase individual homeowner energy costs by a national average 11% to 22% for gas heated homes and 3% to 18% for electric heated homes and the increase in homeowner energy bills would roughly increase accordingly. Simply upgrading water heaters, for example, would increase energy use by an average of 9% for a tankless gas water heater or 10% for an electric heat pump water heater, as builders would be able to permanently reduce building envelope efficiency for short-life equipment. Home builders are free to upgrade equipment already, and many do, for any number of reasons. But to give code compliance credit for such actions would weaken the IECC's intended energy efficiency goals, now and over the long term.

## The IECC Without Equipment Trade-offs is Current National Policy

The 2009 American Recovery and Reinvestment Act (ARRA) made state adoption of and compliance with the 2009 IECC a condition for receiving State Energy Program ARRA grants. Accordingly, all fifty states submitted letters committing to adopt residential codes that meet or exceed the 2009 IECC, and many states used grant funds to implement and improve compliance with it. The DOE has issued its statutory-required determinations on the 2009 and 2012 IECC, finding they would improve energy efficiency over previous versions, thereby requiring states to review these codes for potential adoption. Two-thirds of the states and numerous localities have enacted the 2009 or 2012 IECC residential energy code without equipment trade-off provisions.

**In summary, the IECC has not allowed equipment trade-offs since 2006, and their removal has been a key element of the IECC's 30% improvement in energy efficiency. The proponents of RE166-13 claim that this code change is 'energy neutral', and one hearing witness stated that 'a BTU is a BTU.' This analysis shows those statements to be factually incorrect. Reintroducing equipment trade-offs in the 2015 IECC would increase new homes' energy use substantially, imposing needless homeowner energy bill increases for the life of the home.**

**Beyond the effects quantified in this analysis, trade-offs have other effects not measured in the IECC performance calculation procedure. They would: (1) increase initial construction and later replacement costs for the larger equipment sizes that weaker envelopes create, (2) raise future electricity bills from increased peak demand, and (3) increase energy costs as homeowners adjust thermostats to compensate for reduced comfort levels.**

## House A vs. House B - Basis for Comparing Trade-off Scenarios

This example of the national average long-term energy usage and cost impact of equipment trade-offs, as shown in Exhibit 2-1, is based on two identically-sized homes, with identical location, operation, occupancy and ownership. The only differences are: (1) House A is built to the 2012 IECC prescriptive envelope criteria, with federal minimum-standard equipment, and (2) House B is built using efficient-equipment trade-offs to reduce thermal envelope component efficiencies below IECC prescriptive criteria. Under the RE166-13 proposal, both would be code compliant. The advanced-efficiency HVAC equipment in House B is described in further in Appendix F and includes a 96 AFUE furnace and 19 SEER split-system AC, and a 0.80 EF gas water heater.

**Exhibit 2-1. House A (2012 IECC) vs. House B (Advanced equipment with weaker envelope)**


| | House A | House B |
|---|---|---|
| Year 1 Energy Cost | $767 | $767 |
| A/C Size | 3.5 tons | 5 tons |
| Year 21 Energy Cost | $668 | $767 |
| Year 21 Electricity kWh | 5,330 kWh | 6,058 kWh |
| Year 21 Electricity kW | 1.4 kW | 1.8 kW |
| Year 21 Gas Therms | 532 Therms | 583 Therms |
| Year 21 CO2e | 16,686 lbs CO2e | 18,734 lbs CO2e |

In the first year, House A and House B in theory use the same amount of energy, however, as heating, cooling, and water heating equipment is replaced every 10 to 20 years, House A will outperform House B because it will benefit from both the stronger thermal envelope and the improvements in equipment efficiency that history shows are likely to occur within its first replacement cycle. In the last 20 years, NAECA standards for residential heating, cooling, and hot water equipment have increased, making it likely that by the time equipment used for trade-offs is replaced, federal standards will have increased further. In any event, a homeowner can be expected to install the same efficiency of replacement equipment regardless of whether the home used the equipment trade-off or a better envelope. For the purposes of calculating energy savings impacts over the life of the building, this means that the savings claimed from equipment trade-offs should only be counted for the first equipment lifecycle, while the losses from longer-term envelope features should be accounted for over the longer term.

In addition, owners of House B will need to pay the added costs for larger equipment both at construction and upon replacement. This equipment oversizing also adds to risk of peak shortages on electricity grids and to the likelihood of higher electric rates to pay for increased system peak capacity. In addition, homeowners with weaker envelopes will be saddled with homes that will not remain as comfortable, and that can increase energy bills further by causing occupants to adjust thermostat settings to compensate for this loss of comfort.

## House A vs. House B - Examples of Weakened Envelope Efficiencies

To flesh out the phrase "weakened envelope" into more concrete terms, this section examines a typical home in Climate Zone 3, to illustrate the envelope measures that can be traded off for high efficiency heating, cooling, and water heating equipment. In this example, a 90 AFUE gas furnace, 19 SEER air conditioner, and a 0.80 EF water heater were installed in the house in Climate Zone 3.

**Exhibit 2-3. Climate Zone 3 Example of House A vs. House B – Advanced Equipment**

| | House A (2012 IECC) | House B (Equipment Trade-off) |
|---|---|---|
| Natural Gas Furnace | 80 AFUE | 96 AFUE |
| Air Conditioner | 14 SEER | 19 SEER |
| Water Heater | 0.62 EF Gas DHW | 0.80 EF Gas DHW |
| Wall R-Value | 20 | 11 |
| Ceiling R-Value | 38 | 38 |
| Floor R-Value | 19 | 19 |
| Window U-Factor | 0.35 | 0.75 |
| Window SHGC | 0.25 | 0.50 |
| Infiltration ACH50 | 3 | 7 |
| Duct Leakage to Outdoors (CFM/100 sq.ft.) | 4 | 10 |
| **Energy Code Compliance with Trade-off:** Deemed "energy neutral" | | |
| **Equipment Trade-off:** Shifts $66 of annual costs from equipment to envelope | | |

If RE166-13 were to be approved and assuming no mandatory measures are in place to prevent these trade-offs, using this set of equipment in a trade-off would permit significant weakening a number of building components, including each of the following measures in a single home:

- **Wall insulation – from R-20 to R-11**. This could mean weakening a 6-inch wall with cavity and sheathing insulation to a 4-inch wall with low-density insulation and no insulated sheathing.
- **Window U-factor – from 0.35 to 0.75**. This would more than double the energy losses through windows, increase condensation and moisture problems, and reduce occupant comfort, potentially inducing increased energy use through thermostat adjustments.
- **Window SHGC – from 0.25 to 0.50.** By doubling solar heat gain, this weakening would increase peak cooling loads, and reduce occupant comfort, potentially inducing increased energy use through thermostat adjustments.
- **Infiltration – from 3 ACH50 to 7 ACH50**. This would more than double air filtration, making the home significantly draftier and less comfortable, potentially inducing increased energy use through thermostat adjustments.
- **Duct leakage to outdoors – from 4 CFM/100 SF to 10 CFM/100 SF**. Increased duct leakage can lead to oversized equipment, reduction of delivered air to designated spaces, and reduced comfort, potentially inducing increased energy use through thermostat adjustments.

The effects of weakened envelopes can have significant impacts on actual energy consumption in ways not measured by the IECC performance path calculation methods. While the proposed trade-offs claimed in this example could claim to be energy cost neutral under the modified IECC in the first year, the trade-offs would result in larger equipment capacities (63% larger furnace and 80% larger air conditioner), higher peak electricity demand (22% increase), and significant comfort reduction due to having a leakier home, with leakier ducts and with more extreme temperature near the exterior walls and windows.

The larger equipment sizes will increase the cost of future equipment. Higher peak demand will increase the risk of power shortages during peak times and can increase future electric rates. The occupant comfort losses will likely lead to higher energy bills than estimated in the IECC calculation procedure, as occupants adjust thermostats higher in winter and lower in summer to adjust for poorer comfort performance from windows and walls. None of these negative effects are accounted for in the IECC performance path trade-off calculation provision.