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IMPACT OF ASHRAE STANDARD 169-2013 ON BUILDING ENERGY CODES AND ENERGY EFFICIENCY

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ABSTRACT

A more recent period of weather data published in the ASHRAE 2009 Handbook of Fundamentals was used in developing ASHRAE Standard 169-2013. The new Standard remapped counties to climate zones based on the new weather data. More than 400 counties out of a total of over 3,000 in the U.S. were reassigned to different climate zones and most of the counties were reassigned to warmer climate zones. Many code requirements, such as for wall insulation, are less stringent in warmer climate zones. Thus, when a county is reassigned to a warmer climate zone, new buildings built in that county are likely to be less energy efficient than before. The new county-to-climate zone mapping in ASHRAE Standard 169-2013 has been adopted by Standard 90.1 and may be adopted by other codes and standards as well. In this paper, we present the impact of changing the county-climate zone mapping on energy codes and building energy efficiency in the country. The analysis shows that adopting the new county-to-climate zone mapping in ASHRAE Standard 169-2013 results in an overall weakening of ASHRAE Standard 90.1-2013 at the national level while the impacts at the state level can be dramatic, as there are several states where large population centers are reassigned to a warmer climate zone.

INTRODUCTION

Geographically-based climate zones in codes

Building energy codes have been predominantly based on geographically defined climate zones since about 2004. Prior to that time, the national model energy codes—the International Energy Conservation Code for low-rise residential buildings and ASHRAE Standard 90.1 for commercial and high-rise residential buildings—had energy efficiency provisions that varied directly with climate parameters such as heating and cooling degree-days (HDD and CDD). The most recent versions of both those model codes can be found in ICC 2014. As part of an effort to simplify the codes, the U.S. Department of Energy (DOE) led a process to transform the continuously variable code provisions into requirements that follow geographic zones with boundaries defined along state and county lines (Briggs et al 2003, 2003b). As of the 2006 IECC (and the 2004 Supplement to the 2003 IECC before that) and ASHRAE Standard 90.1-2004, the two model codes have shared essentially the same set of mappings between county and climate zone.

Geographically based climate zones have several advantages over continuously variable climate parameters as a basis for code requirements, usability being a primary one. Because many if not most code jurisdictions are county based, enforcement is considerably easier when all buildings in a jurisdiction are subject to the same requirements. Builders and developers likewise find complying less burdensome when the requirements are consistent within easily defined geographic boundaries. In addition to being logistically simpler, geographical zones can be defined to recognize multiple climate parameters without imposing additional complexity on builders and code officials. Prior to the introduction of these zones, the codes were mostly limited to accounting for degree-days because accommodating other climate nuances would have introduced far more complexity into the codes.

Development of the original zones

The original climate zones and corresponding county-to-zone mappings were developed based on a rigorous analysis of climate data from numerous locations along with a strong consideration of numerous usability factors (Briggs et al 2003, 2003b). The number of U.S. zones was limited to eight temperature regions crossed with three moisture regimes for a theoretical maximum of 24 zones, although only 15 of those exist in the U.S.[1] Practical considerations exerted substantial influence on the various zone boundaries. First and foremost, boundaries were limited to county lines. Other considerations included keeping metropolitan areas together even if they crossed county or state lines, avoiding the "checkerboarding" of zones wherein adjacent counties alternately flip between two zone numbers, and accommodating historical precedents. A key example of the latter is that the boundary between climate zones two and three was based almost exclusively on the desire to mimic the prior codes' cutoff point for requiring glazing with a low solar heat gain coefficient (SHGC).

Against the usability advantages, however, geographically-based codes also have some disadvantages, most notably those related to large climate differences within county boundaries. For example, there exist counties with elevations ranging from near sea level to over 7000 feet, with corresponding HDDs ranging from about 1000 to nearly 7000.[2] Such cases are somewhat rare, and population centers are usually clustered at the lower elevations, but this climate "accuracy" issue remains nonetheless.

Why a new set of climate zones?

ASHRAE Standard 169 is focused on developing and maintaining a set of code-appropriate climate zones, and recently released a modification to the original zone scheme (ASHRAE 2013). The new scheme largely retains the overall format of the previous zones but has remapped a number of counties based on new climate information. Since the original zones were developed, the overall U.S. climate has warmed a bit and a much larger set of climate files is available for analysis. The original zones were developed using the National Oceanic and Atmospheric Administration's (NOAA) 1961-1990 period of record and a set of 239 Typical Meteorological Year 2 (TMY2) datasets (Marion 1995). The developers of the new zones had access to data from NOAA's 1981-2010 period of record as well as the greatly expanded TMY3 database, which comprises 1020 stations embodying a 1991-2005 record (Wilcox et al 2008). NOAA has estimated that the 1981-2010 record represents a nationwide warming of about 0.5 °F (0.28 °C) relative to the 1971-2000 record (NOAA 2011), so the new climate zones are likely based on a similar or slightly larger difference.

It is worth noting, however, that the changes in county assignments may not be entirely attributable to changes in the climate information. As discussed above, the original zone assignments were made in the context of numerous non-climatic concerns, so it is possible, and even likely, that the new assignments result, to some degree, from a change in focus rather than just a change in climate--the ASHRAE 169 committee being more focused on the climatic details than the orignal developers.

The importance of analyzing the zone changes

Although the change in county zone assignments is a relatively small correction accounting for a relatively small climate effect, the difference it makes on code provisions is important. As the 90.1 Standing Standards Project Committee (SSPC) fields proposals to update the standard, it is necessary to keep track of the net impact changes have on the energy use of buildings constructed to the standard. Pacific Northwest National Laboratory (PNNL) has developed a methodology for calculating and tracking those changes (Thornton et al. 2011) to create what are known as "Progress Indicator" (PI) for the standard. The methodology includes a suite of 16 prototype building models representing about 80% of the U.S. commercial building stock, a set of cities representing the climate of all the climate zone/moisture regime combinations, and a set of weighting factors based on recent building type-specific data on newly constructed floor space (Jarnagin and Bandyopadhyay 2010).

The PI process is impacted by the change in climate zones in several major ways. First, whenever a county is reclassified into a new climate zone, new construction in that county will suddenly be subject to different energy efficiency requirements. Because most of the reclassifications move counties to warmer zones, those requirements will be less stringent for envelope components than before. Climate zone dependent requirements for HVAC systems get more, or less stringent when moving to a warmer climate zone. Second, because the reclassifications change the population of buildings in each climate zone, the construction starts-based weighting factors need revision. Finally, for each climate zone, the PI process uses a representative city to perform energy simulations. The change in geography included in each climate zone may necessitate a change to some of those representative climate. This paper discusses only the first of these impacts.

[1] An additional extremely hot designation was subsequently added to ASHRAE Standard 169-2013.

[2] San Bernardino County, California, is one example.

NEW COUNTY-CLIMATE ZONE MAP

Changes made by ASHRAE 169-2013

ANSI/ASHRAE Standard 169-2013 (ASHRAE 2013) used the newly available weather data to remap counties to climate zones. More than 400 counties out of a total of more than 3,000 counties in the U.S. were reclassified into new climate zones. Most of the reclassified counties moved to warmer zones. In addition to the new mapping, ASHRAE Standard 169-2013 also introduced a new climate zone, climate zone 0, which represents extremely hot regions. Climate zone 1, which previously encompassed both extremely hot and very hot regions, now represents only very hot regions (Hogan 2014). There are no US locations that fall under climate zone 0; therefore, it has no impact on the construction weights and analysis reported here.

Figure 1 shows the original county-to-zone mapping of counties in the continental U.S. Figure 2 contains a similar map showing counties that were reclassified into new climate zones. Counties moving to warmer climate zones are colored red, while counties moving to colder zones are green.

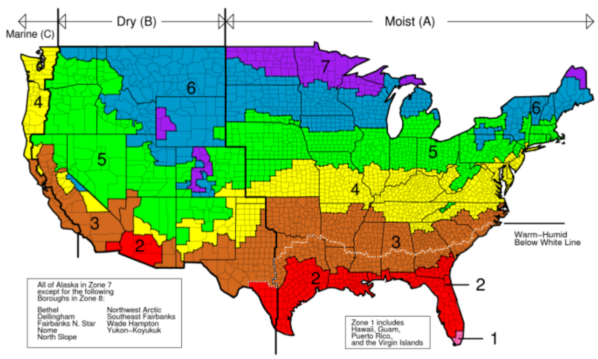

Figure 1. U.S. map showing original county-to-zone mappings

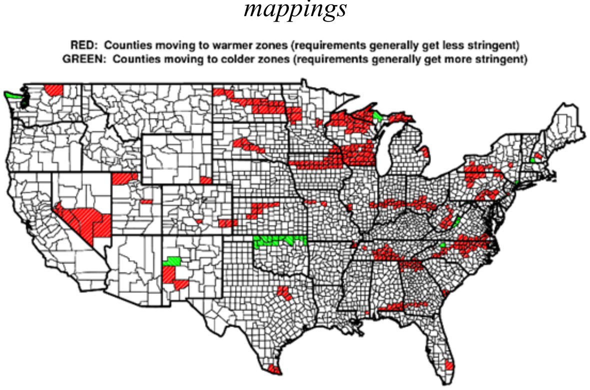

Figure 2. Counties in the continental U.S. reclassified into new climate zones

Because many (though not all) energy code requirements become less stringent in warmer zones (see table 3 below for an example), one clear implication of these changes is that energy efficiency in new buildings will be reduced in many locations. The magnitude of those changes is discussed later.

Because population, and hence the bulk of new construction, tends to be focused in relatively small areas in many states, the implications of the zone changes is not readily apparent from Figure 2. To assess the magnitude of the impacts, construction weights were collected from the McGraw-Hill Construction (MHC) Project Starts Database (Jarnagin and Bandyopadhyay 2010). The total square footage of new floor area in each county was summed and the fraction of that floor area involved in a reassignment to a new climate zone—and hence subject to different code requirements than before—was calculated. In most states, the percentage of new floor space subject to changed requirements is relatively small, but the number can be quite large in some states. Table 1 shows the percentage of new floor space that has been shifted to a new climate zone for the top 10 states.

The zone changes will clearly have substantial impact on energy code requirements in a number of states.

Table 2 further illustrates the magnitude of the changes at the county level. Shown are the top 10 counties based on the absolute magnitude of new construction floor area involved in a zone change.

Table 1 Top ten states with the largest fraction of new floor space reclassified into new climate zones

State	Fraction of New Floor Area in State Reclassified to a New Climate Zone (percent)
Wisconsin	82.68
North Carolina	42.35
North Dakota	41.18
Tennessee	40.89
Indiana	33.48
Ohio	31.83
Texas	27.20
Wyoming	23.30
Pennsylvania	19.14
Virginia	18.82

Table 2 Top ten counties with the most floor space (ft^2) reclassified into new climate zones

County, State	Shift in Climate Zone	Floor Area, ft^2 ('000s)	Fraction of Floor Space in State from County (percent)
Dallas, TX	Down (3A to 2A)	109769	14.12
Palm Beach, FL	Down (2A to 1A)	69206	7.77
Tarrant, TX	Down (3A to 2A)	65159	8.38
Franklin, OH	Down (5A to 4A)	47549	18.01
Marion, IN	Down (5A to 4A)	34518	17.51
Wake, NC	Down (4A to 3A)	33504	14.03
Davidson, TN	Down (4A to 3A)	28054	15.93
Milwaukee, WI	Down (6A to 5A)	27292	21.26
Dane, WI	Down (6A to 5A)	24081	18.76
Hidalgo, TX	Down (2A to 1A)	19596	2.52

ENERGY IMPACT OF NEW COUNTY-CLIMATE ZONE MAP

Goal of the Simulation Analysis

When the climate zone assigned to a county changes, the requirements associated with a code for buildings within that county may also change. Code requirements, such as wall, roof, and floor insulation, window U-factor, reduced stringency of economizer trade-off, and so on, are generally less stringent in warmer climate zones. For example, a county reclassified from climate zone 3A to 2A requires less insulation for steel-framed walls according to ASHRAE Standard 90.1-2013. One such highly populated county is Dallas County, TX, where the climate zone will change from 3A to 2A. Table 3 shows a sampling of requirements in ASHRAE 90.1-2013 that will change because Dallas County moved from climate zone 3A to 2A.

The goal of the simulation analysis was to capture the impact of climate zone reassignments on individual climate zones. For example, what is the impact of reassignments from climate zone 3A on the "old" climate zone 3A?

Table 3 Sampling of ASHRAE 90.1-2013 requirements that would change for Dallas County

90.1-2013 REQUIREMENTS, NON-RESIDENTIAL		
SECTION	**CLIMATE ZONE 3A**	**CLIMATE ZONE 2A**
5.4.3.4: Vestibules	Required for buildings > 4 stories and > 10,000 ft^2	Not required
5.5.3.2: Steel-framed Walls	U-0.077	U-0.084
5.5.4.3: Windows, metal fixed	U-0.50	U-0.57
5.5.4.4: Skylights	U-0.55	U-0.65
6.5.2.2.3: Water loop HP	Additional requirements when fluid coolers are used	Not required
6.5.5.2: Fan speed control (heat rejection equipment)	Required	Not required
6.5.6.1: Heat Recovery	Required	Heating energy recovery exempted

Simulation Setup

To capture the impact of county reassignments from a climate zone, prototype building models were simulated in the same climate zone as well as the new climate zone but with the old climate zone requirements.

Table 4 shows the fraction of construction area that is reassigned from one climate zone to another as a percentage of the old climate zone. For example, 8.1% construction area is reassigned from climate zone 2A down to 1A. This impact will be reflected back on 2A, whereas the impact on 1A is considered to be zero (we account all changes in terms of the original zones for this analysis). The impact of the 8.1% of area reassigned is calculated by simulating prototypes with climate zone 2A weather (because the affected buildings have not moved) but with climate zone 1A requirements (because the buildings' climate zone assignment has changed). As an example, the total impact for the Medium Office prototype on climate zone 2A is calculated as follows:

Table 4 Impact on Construction Area from reassignment of Climate Zones

Climate Zone	Shift in Climate Zone	Fraction of New Construction Area (%)
1A	No Change	100.0
2A	Down (2A to 1A)	8.1
2A	No Change	91.9
2B	No Change	100.0
3A	Down (3A to 2A)	16.0
3A	No Change	83.5
3A	Up (3A to 4A)	0.5
3B	No Change	100.0
3C	No Change	100.0
4A	Down (4A to 3A)	15.1
4A	No Change	83.9
4A	Up (4A to 5A)	1.0
4B	Down (4B to 3B)	0.4
4B	No Change	98.3
4B	Up (4B to 5B)	1.3
4C	No Change	98.0
4C	Up (4C to 5C)	2.0
5A	Down (5A to 4A)	13.5
5A	No Change	86.5
5A	Up (5A to 6A)	0.1
5B	Down (5B to 4B)	1.3
5B	No Change	98.7
6A	Down (6A to 5A)	35.1
6A	No Change	64.7
6A	Up (6A to 7)	0.2
6B	Down (6B to 5B)	14.1
6B	No Change	85.9
7	Down (7 to 5C)	0.5
7	Down (7 to 6A)	29.4
7	No Change	70.1
8	Down (8 to 7)	10.5
8	No Change	89.5

- Old climate zone 2A consumption = (energy consumption of Medium Office simulated in 2A with 2A code requirements) x 100.0%
- New climate zone 2A consumption = [(energy consumption of Medium Office simulated in 2A with 2A code requirements) x 91.9%] + [(energy consumption of Medium Office simulated in 2A with 1A code requirements) x 8.1%]
- Impact on climate zone 2A = New climate zone 2A consumption – Old climate zone 2A consumption.

Table 5 shows the same calculation in a tabular format. Note that the energy use intensities (EUI) are for illustration purposes only; the actual EUIs for Medium Office prototype are different.

In the same manner, all 16 prototype buildings were simulated for all original climate zones as well as reassignments in climate zones and with the appropriate code requirements for each case. Finally, the prototypes were weighted with construction weights (Jarnagin and Bandyopadhyay 2010) by prototype and climate zone to calculate the national weighted impact.

Impact from change in climate zone map

Table 6 shows the aggregate national impact from the climate zone reassignments for each prototype. The impact for each of the 17 climate zones is weighted at the prototype level to develop the national impact by prototype. The table also shows that the national weighted impact across all prototypes is 0.18%. The largest impacts at the prototype level are for Retail Strip Mall (0.31%), Warehouse (0.29%), Medium Office (0.25%), and High-rise Apartment (0.25%).

Table 7 shows the aggregate impact of climate zone reassignments by climate zone. As explained earlier, the reassignment from an old climate zone are accounted against the same climate zone. The national weighted impact is the same as that shown in Table 6. Looking at Table 4, the largest changes can be seen in climate zones 6A, 7 and 8. Table 7 shows that the largest energy impacts are on climate zone 6B (0.92%), 7 (0.73%), 4A (0.52%) and 2A (0.20%). The reason climate zone 6B shows a larger impact than 6A, despite the latter's larger proportion of construction area being reassigned to a new zone, is that the code requirements change less between 6A and 5A than between 6B and 5B. Another factor is that certain thresholds for HVAC equipment may have been triggered in one reassignment but not in the other. A prototype's equipment sizing and corresponding required efficiencies are updated during each simulation run. Also, economizer and energy recovery thresholds are evaluated for each run and the systems are modified accordingly. This can result in significant changes in energy consumption if a climate zone reclassification triggers any of these thresholds.

Although the impact at the national level appears to be small, the impact on individual prototypes in a given

Table 5 Sample calculation showing new weighted EUI

Old Zone/ Regime	Zone/Regime Shift	Old Area Fraction (%)	New Area Fraction (%)	Example Medium Office EUI (kBtu/sf)	Old Weighted EUI		New Weighted EUI	
1A	No Change	100.0	100.0	50.00	50.00	50.00	50.00	50.00
2A	Down (2A to 1A)	0.0	8.1	52.00	0.00	50.00	3.37	50.13
2A	No Change	100.0	91.9	50.00	50.00		46.76	

Table 6 Impact of climate zone reassignments on prototype buildings

Prototype	90.1-2013 EUI (kBtu/sf-yr)	90.1-2013 EUI After CZ Changes (kBtu/sf-yr)	EUI Change (%)
Large Office	70.84	70.94	0.14%
Medium Office	34.05	34.14	0.25%
Small Office	29.38	29.41	0.10%
Standalone Retail	45.92	46.00	0.18%
Strip mall Retail	55.09	55.26	0.31%
Primary School	53.71	53.76	0.10%
Secondary School	41.69	41.79	0.24%
Hospital	123.67	123.74	0.06%
Outpatient Health Care	115.77	115.95	0.15%
Sit-down Restaurant	372.55	372.84	0.08%
Fast-food Restaurant	576.43	576.93	0.09%
Large Hotel	89.03	89.25	0.24%
Small Hotel	59.99	60.04	0.07%
Warehouse	17.14	17.19	0.29%
High-rise Apartment	46.91	47.03	0.25%
Mid-rise Apartment	43.86	43.94	0.20%
National Weighted EUI Change	**54.08**	**54.18**	**0.18%**

Table 7 Impact of climate zone reassignments on U.S. climate zones

Old Climate Zone	90.1-2013 EUI (kBtu/sf-yr)	90.1-2013 EUI After CZ Changes (kBtu/sf-yr)	EUI Change (%)
1A	47.75	47.75	0.00%
2A	51.18	51.28	0.20%
2B	52.34	52.34	0.00%
3A	52.66	52.75	0.16%
3B	47.47	47.47	0.00%
3C	45.40	45.40	0.00%
4A	54.88	55.17	0.52%
4B	56.18	56.18	0.00%
4C	51.45	51.45	0.00%
5A	59.25	59.28	0.06%
5B	55.59	55.59	0.01%
6A	64.38	64.42	0.07%
6B	60.21	60.77	0.92%
7	70.24	70.76	0.73%
8	71.44	71.56	0.16%

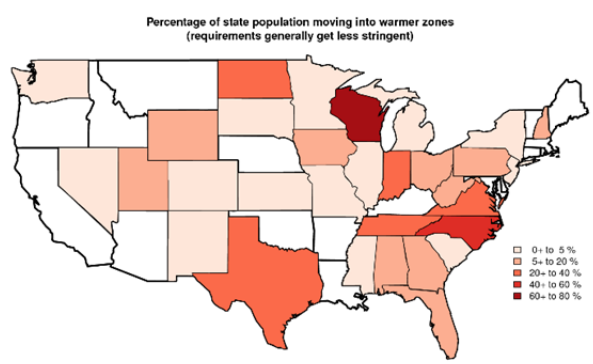

Figure 3 Percent of construction area within states reassigned to warmer climate zones (requirements generally get less stringent)

climate zone can be large. For example, the Medium Office prototype sees an almost 8% increase in consumption in climate zone 7, and the Secondary School sees a 5.5% increase in consumption in climate zone 6B.

Finally, the impact at the state level, where energy codes are usually adopted, can be even higher. Figure 3 shows a map of the U.S. with states that have climate zone reassignments. Darker colors indicate larger reassignment of construction floor area to a different climate zone. It can be seen that Wisconsin (>60%), North Carolina (>40%) and Texas (>20%) have large reassingnments in construction area, and most of these are to warmer climate zones meaning that requirements will generally get less stringent.

OTHER POTENTIAL IMPACTS OF CHANGING COUNTY-CLIMATE ZONE MAP

Impacts on state adoption.

Beyond the direct impact on county code jurisdictions and the overall reduction in commercial building energy efficiency owing to the climate reclassifications, several additional impacts are relevant. DOE is required by statute to issue a "determination" as to whether each new revision to the IECC, for low-rise residential buildings, and ASHRAE Standard 90.1, for commercial buildings, will save energy compared to its predecessor. An affirmative determination triggers a requirement for states to update their commercial codes to meet or exceed the efficiency requirements of the latest 90.1 and to evaluate whether it is appropriate to update their residential requirements to meet or exceed the latest IECC. DOE's determinations are made for the U.S. as a whole, not for individual states or code jurisdictions.

Were the climate reclassification to lower overall efficiency of either code, DOE could issue a non-affirmative determination. However, if the reclassification, combined with other changes to the IECC and/or 90.1, resulted in overall energy savings, DOE's affirmative determination would trigger state actions. Because some counties and some states will see very large fractions of new construction subject to code requirements from warmer climate zones, it is conceivable that those states or counties would experience an overall reduction in new building efficiency if they were to adopt the latest code(s). Such adoption would not be a requirement, but the situation could result in a policy quandary for some states.

Impacts on residential codes.

As of this writing, the new climate classifications have not been incorporated into the IECC. If they are adopted into the 2018 revision, the same efficiency issues discussed herein for commercial buildings would arise. If they are not adopted into the 2018 IECC, some states may face the uncomfortable situation of having different county-to-zone mappings for low-rise residential than for commercial buildings, especially for states adopting IECC for residential buildings and Standard 90.1 for commercial buildings.

Impacts on other codes.

The IECC and ASHRAE Standard 90.1 affect more than just building construction regulations in code jurisdictions. A number of advanced (voluntary) codes and beyond-code programs either rely directly on the two model codes as a baseline or are indirectly influenced by those model codes. The IECC has commercial building efficiency provisions, for example, which are often similar to those of Standard 90.1, but not always. A difference in climate zone definitions between Standard 90.1 and the IECC would be logistically difficult for many states. ASHRAE also publishes an advanced code, Standard 189.1 (ASHRAE 2014), which uses Standard 90.1 as a prerequisite. Finally residential beyond-code programs such as Energy Star are often compared to a minimum code baseline and to some extent are designed to push home efficiency beyond that baseline, so the issues discussed here for commercial construction may eventually need to be addressed for homes as well.

Administrative Impacts

Beyond the specific energy impacts discussed here, changing county climate zone assignments can have substantial impacts on jurisdictional staff and infrastructures. Builders and code officials will have to learn the new code requirements, and new training materials or compliance materials may have to be developed. Like the pragmatic considerations that framed the original zone assignments, these considerations may be more important in some ways than the climatological correctness of the zone assignments. Although not the subject of this paper, there may be legitimate questions whether apparent climate “misassignments” might be better mitigated by changing the weather reference files used in energy analyses or even changing the zone’s code requirements in some cases.

CONCLUSIONS

Building energy codes, such as Standard 90.1, the IECC as well as advanced codes such as Standard 189.1 and beyond code programs, such as LEED, rely on geographically defined climate zones and requirements classified according to these climate zones. Standard 169-2013 reassigned the climate zones to about 400 U.S. counties. Standard 90.1 has adopted the new climate zone map. The reassignment of climate zones results in an overall reduction in stringency of Standard 90.1 because most of the reassignments are to warmer climate zones, which have generally less stringent requirements. The national weighted impact on the energy consumption of commercial buildings is 0.18%, measured using the Progress Indicator process. While this impact may appear small, some highly populous counties have been reassigned to milder climate zones and in such counties, the decrease in stringency will be quite high. The reduction in stringency could also be higher for residential buildings and poses difficult questions for future adoption of codes.

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